



# **Calibration ISO/IEC 17025 Application Document**

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# Calibration ISO/IEC 17025 Application Document

This document provides interpretative criteria and recommendations for the application of ISO/IEC 17025 in the field of Calibration for both applicant and accredited facilities.

Applicant and accredited facilities must also comply with the ISO/IEC 17025 Standard Application Document and any field annexes, policies and/or technical circulars (refer to *NATA Procedures for Accreditation*).

The clause numbers in this document follow those of ISO/IEC 17025. However since not all clauses require interpretation, the numbering may not be consecutive.

The terms facility and laboratory are interchangeable in this document.

Any new interpretative criteria included in this Application Document (as identified in the Amendment Table), are applicable from the effective date included on the cover page.

## 4 Management requirements

### 4.1 Organisation

#### 4.1.3 In-situ calibration

Facilities can be accredited for carrying out in-situ, at the customer's site and/or mobile calibration of equipment. Where such activities are accredited, ranges and least uncertainties of measurement applicable to in-situ work and/or mobile facility will be included in the facility's Scope of Accreditation. Furthermore, if the calculated uncertainties and/or limits of ranges are different to work carried out at the main laboratory separate Calibration and Measurement Capability (CMC) shall be defined.

When accredited for conducting in-situ calibrations, the facility bears the responsibility for ensuring that conditions at each location are suitable for ensuring the validity of the work to be carried out there.

Where necessary precautions shall be adopted and documented. Issues to consider may include, but are not limited to:

- the handling and transport of reference equipment to prevent vibration, shock and temperature excursions;
- reduced calibration intervals on reference equipment and regular cross-checking to prove that it is not being adversely affected;
- separation of the activity from other activities that could adversely affect the integrity of the work;
- ensuring that the environment is suitable and meets all of the requirements specified in the test method, including that the temperature is monitored and recorded during both stabilisation and calibration work conducted in-situ;
- ensuring that reference equipment has reached thermal equilibrium;

- other factors outside of the control of the facility staff (e.g. the electromagnetic environment, stability of the available power supply) when setting up and conducting calibrations.

#### **4.4 Review of requests, tenders and contracts**

When reporting compliance to a published standard, the review phase should address the following:

- if the customer has indicated that testing is to be performed for multiple markets and regulatory frameworks, that their requirements are clearly understood, including whether the tests are to be conducted and reported to multiple standards;
- the version and amendment status of the standards to which the tests are to be conducted is explicit.

Where appropriate, the facility shall confirm with their customer whether the equipment undergoing calibration is to be adjusted and if so, measurements taken both before and after adjustment, if available, are to be reported.

The calibration laboratory's least uncertainty of measurement as stated on the Scope of Accreditation must be appropriate for the level of accuracy the device under test may achieve or to the customer's needs. When a facility's best calibration uncertainty (CMC) is known to be larger than what is necessary to ensure optimal performance from the item being calibrated, for example, one quarter of manufacturer's specification or one quarter of the customer's criteria, then evidence that the customer has accepted and approved this calibration must be retained.

#### **4.13 Control of records**

##### **4.13.2.1 Information on the sources of uncertainty**

Calibration certificates on reference equipment shall be kept for longer periods than just their validity in order to determine the equipment's stability. Any evidence of drift will be a component to be considered in the uncertainty estimation.

## **5 Technical requirements**

### **5.2 Personnel**

Facilities must document a policy or procedure for the approval of appropriate staff authorised to perform critical tasks, which includes the issuing of reports and/or assuming technical control of a facility's calibration and measurement capability. Approval is to be based on academic qualifications, practical experience and demonstration of technical competence.

Records of staff authorisation by management and the information on which it has been made must be maintained.

## 5.2.5

### **Persons who have overall technical control of the calibrations**

For calibration activities, the facility shall have one or more key personnel who assume overall technical control of each set of calibrations as recorded in the Calibration and Measurement Capability (CMC) in the Scope of Accreditation. These staff must have demonstrated technical competence to work to the level (measurement range and uncertainty of measurement) provided in the CMC, through their demonstrated application of acknowledge and/or via suitable measurement comparisons with higher level laboratories (see clause 5.9 of this document).

The facility's management must formally authorise these personnel to assume this responsibility, linking the authorisation to the CMC/s listed in the Scope of Accreditation. These personnel may or may not be the same individuals as those authorised to release results and/or issue reports. When a new individual is authorised to assume this responsibility, a series of proficiency tests or measurement audits (to the best CMCs) that supports the technical competency of the application of knowledge is required. Where such are not available, then other means of demonstrating competency must be established which will be reviewed by NATA at assessment. This is particularly critical where the facility's CMC in the Scope of Accreditation is listed at a level better than which has been supported or demonstrated through suitable proficiency testing or measurement audits.

Where a facility's approval process for authorising staff to perform critical tasks, (including the release of results or assuming overall technical control of the calibrations) is found to not satisfy the requirements for accreditation, the facility will be required to review all results issued since the time it was determined not to comply and, if necessary, withdraw and/or issue replacement reports. The accreditation status of the facility may also be reviewed.

### **Persons issuing results**

NATA will no longer formally recognise facility staff as approved signatories (however named) in the field of Calibration unless a requirement exists under a regulatory framework such as for Legal Metrology or is covered in a Deed of Agreement, Memorandum of Understanding or other binding agreement with a third party. NATA will continue to provide signatory approval for Legal Metrology Authorities. For these Authorities, the facility must nominate individuals who are authorised to release calibration results and NATA will formally acknowledge these individuals as Approved Signatories in the report on assessment.

Any individuals issuing results assumes responsibility for the technical validity and accuracy of all the information that they approve to be released, irrespective of whether the results are contained in a report. Accordingly, they must have and demonstrate a sound knowledge of:

- the principles of the calibrations, measurements and/or tests they perform or supervise;
- the standards or specifications for which accreditation is sought or held;
- the facility's management system;



- ISO/IEC 17025, NATA Rules, this document and other pertinent NATA Policy and Technical Circulars;
- measurement ranges and the estimation of the uncertainties of measurement associated with the test or calibration results for which the facility is accredited or seeking accreditation.

Facility staff who release results shall hold a position within the organisation which provides authority over the calibration and/or testing activities and, where necessary, results are to be rejected when they consider them to be inadequate.

### **5.3 Accommodation and environmental conditions**

The facility shall specify limits on the environmental conditions to be achieved in the laboratory, in-situ and in mobile facilities. The conditions shall be appropriate to the level of accuracy required for the calibration, or as specified in a relevant measurement specification.

### **5.4 Test and calibration methods and method validation**

#### **5.4.1 General**

In the field of Calibration, the accreditation covers calibration activities only and the Scope of Accreditation encompasses all calibrations associated with the items listed in the scope.

#### **5.4.2 Selection of methods**

Recommended reference literature and standard methods that are acceptable may be found in the appendices of this document, which cover measurement activities for several different metrology disciplines.

#### **5.4.6 Estimation of uncertainty of measurement**

The Scope of Accreditation is to be expressed in terms of a Calibration and Measurement Capability (CMC), which includes the facility's estimate of their least uncertainty of measurement for each measurement range. Any associated measurand parameters that are required to fully define ranges must also be stated, e.g. frequency for AC voltage or temperature for relative humidity. Facilities are required to maintain detailed records for their least uncertainty estimates and to review them periodically for currency.

There shall be no ambiguity on the expression of the CMC on the scopes of accreditation and, consequently, on the least uncertainty of measurement that can be expected to be achieved by a facility during a calibration or a measurement. Particular care should be taken when the measurand covers a range of values. One or more of the following methods are generally employed for the expression of the facility's best achievable uncertainty:

- a single value, that is valid throughout the measurement range;
- a range. In this case a calibration facility should have proper assumption for the interpolation to find the uncertainty at intermediate values, e.g. the uncertainty increases linearly with range;

- an explicit function of the measurand or a parameter;
- a matrix of measurement points.

Open intervals (e.g. “ $U < x$ ”) are not allowed in the specification of uncertainties and an expression cannot imply zero uncertainty of measurement.

The least uncertainty covered by the CMC shall be expressed as the expanded uncertainty having a specific coverage probability of 95%. The unit of the uncertainty shall always be the same as that of the measurand or in a term relative to the measurand, e.g. percentage of the reading or full scale. Usually the inclusion of the relevant unit gives the necessary explanation. The uncertainty in the CMC shall be stated to no more than two significant figures.

Laboratories shall provide evidence that they can provide calibrations to customers with measurement uncertainties equal to those covered by the CMC. In the formulation of a CMC for an activity, a laboratory shall take notice of the performance of the “best existing device” which is available for a specific category of calibrations. At a minimum, all of the uncertainty contributions that are applicable to the “best existing device” are to be included in the CMC calculation.

A reasonable amount of contribution to uncertainty from repeatability shall be included and contributions due to reproducibility are to be included in the CMC uncertainty component, when available. Conversely there should be no significant contribution to the CMC uncertainty component attributable to physical effects that can be ascribed to imperfections of even the “best existing device” under calibration or measurement.

It is recognised that for some calibrations a “best existing device” does not exist such as is the case with high level time measurement. In these cases the Scope of Accreditation shall clearly identify that the contributions to the uncertainty from the device are not included and each of these CMCs as stated in a scope is to be approved by the Accreditation Advisory Committee.

**Note:** The term “best existing device” is understood as a device to be calibrated that is commercially or otherwise available for customers, even if it has a special performance (stability) or has a long history of calibration.

Where laboratories provide services such as reference value provision, the uncertainty covered by the CMC should generally include factors related to the measurement procedure as it will be carried out on a sample, i.e. typical matrix effects, interferences, etc. shall be considered. The uncertainty covered by the CMC will not generally include contributions arising from the instability or inhomogeneity of the material. The CMC should be based on an analysis of the inherent performance of the method for typical stable and homogeneous samples.

**Note:** The uncertainty covered by the CMC for the reference value measurement is not identical with the uncertainty associated with a reference material provided by a reference materials producer. The expanded uncertainty of a certified reference material will in general be higher than the uncertainty covered by the CMC of the reference measurement on the reference material.

An accredited facility is not permitted to issue an endorsed report stating an uncertainty of measurement which is less than that stated in their CMCs. The facility’s ability to achieve their stated CMC giving consideration to the extremes

of measurement range and smallest uncertainty is evaluated by the assessment team during on-site assessments and by review of proficiency testing results.

Uncertainty calculations must include components for contributions from the customer's device under test including the resolution of the device, repeatability and observed drift.

Appropriate methods of uncertainty of measurement analysis are described in the following:

- ISO/IEC Guide 98-3 *Uncertainty of measurement Part 3: Guide to the expression of uncertainty in measurement (GUM: 1995)*;
- certain test or calibration specifications which specify the method for the estimation of uncertainty.

Facilities shall have a system for reviewing and, where necessary, updating their uncertainty calculations following recalibration of reference equipment or other changes that would significantly affect the magnitude of relevant uncertainty components. This review would cover both the uncertainty of the latest calibration results reported for the reference equipment and a review of the stability of the equipment by comparing the latest results with at least two previous results, where available. In the absence of an established calibration history, an uncertainty contribution for drift from reference equipment may be obtained from sources such as manufacturer's specification.

#### **5.4.7 Control of data**

Whenever possible, a second staff member should check all calculations and data transfers. Worksheets must have a place dedicated, or other means available for the identifying the individual checking the results.

Problems may arise when computer files such as spreadsheets, word processor worksheets and/or report files are reused by overwriting previous results. Accordingly, only blank templates should be used.

Where measurements are highly automated and/or routine, or where information is processed electronically, the emphasis may be moved to checking for errors created by the system (e.g. by audit checks) and to automatic highlighting of results falling outside the expected range.

Validation of spreadsheets must be carried out initially and after significant changes. It must include examination of cell formulae as well as comparison against data sets that have been manually checked. Validation records must be kept.

### **5.6 Measurement traceability**

#### **5.6.2 Specific requirements**

##### **In-house calibrations**

A facility performing calibrations of its own equipment will also be subject to technical assessment of these in-house calibrations. The assessment team will determine if the in-house calibrations are fit for the purpose for which they are being used and that a reasonable estimate of the associated measurement uncertainty has been made. Where possible, the review of in-house calibrations

will be covered as part of the traceability and calibration aspects during reassessments. Where significant additional assessment time or additional assessors are required, there will be an additional and ongoing cost associated with this activity. Additional specialist assessors will only be used when either the calibration is outside the area of expertise of the Technical Assessors who would normally conduct the assessment or it will be more time or cost effective.

**Note:** Refer to *NATA Policy Circular 12* for additional information.

### **5.6.2.1 Calibration**

Reference standards and equipment shall be calibrated over the range for which accreditation is held and to an appropriate level of accuracy. Nominally accreditation cannot be given for extremes of the measurement range based on extrapolation beyond the maximum and minimum calibration points.

**Note:** Interpolation is permitted, provided a suitable contribution for doing so has been included within the facility's uncertainty estimation.

## **5.8 Handling of test and calibration items**

**5.8.1** Where the equipment to be calibrated or tested may need to be dismantled, the facility must provide appropriate means of identifying and storing the various components. Similarly, when equipment is provided with accessories, these must be appropriately identified and stored.

Where type testing or product development testing is performed, facilities must take steps to ensure the issues covered by Clause 5.8.1 of ISO/IEC 17025,, including 'visual' security of the equipment under test, are adequately addressed.

**5.8.2** As many instruments are identified by a manufacturer's model type or number as well as a unique serial number, additional labelling of equipment under test may not be necessary provided the instrument's identification and the customer's details are recorded immediately upon receipt.

## **5.9 Assuring the quality of test and calibration results**

NATA requires calibration activities to be supported by appropriate proficiency testing (PT), or measurement audits on an ongoing basis and that PT performance records are submitted to support requests for variations to scopes of accreditation (and signatory approvals where applicable).

On occasions, facilities are offered the opportunity to participate in proficiency testing programs (round robins) organised by members of the Asia Pacific Laboratory Accreditation Cooperation (APLAC) and facilities will be expected to participate in these programs when available.

### **PT participation**

The onus is on each facility to ensure participation in suitable quality assurance activities with regard to their Scope of Accreditation and to ensure that their best Calibration and Measurement Capability (CMC) as reported in their Scope of Accreditation is being tested. This can be done by:

- participating in the identified round robins when they become available;

- arranging individual measurement audits with other accredited facilities of an equal or better capability; or
- performing PT available through commercial PT scheme providers.

Records of proficiency testing activities that support the CMCs are to be made available prior to requests for variations to scope, initial assessment or prior to scheduled reassessments.

Compliance with this criterion will be assessed during NATA assessments with continuation of accreditation being subject to the adequacy/suitability of the activity.

In some circumstances in which it is difficult to arrange an appropriate measurement comparison, the assessment team will consider other records in support of the claimed CMC, including:

- comparisons conducted with non-accredited facilities;
- validation of the facility's measurement methodology;
- suitability of reference equipment;
- evaluation of measurement uncertainty calculations;
- ongoing intra-laboratory checks.

However the facility must be aware that when supporting records of a measurement comparison with an accredited facility to the best claimed CMC is not available, the CMC as stated in the Scope of Accreditation may need to be revised to a lesser capability during the accreditation decision process.

All staff authorised as having overall technical control of the calibrations as listed in the scope (see clause 5.2 above) are expected to have participated in an inter or intra-laboratory measurement comparison.

Frequency of participation will be based on measurement type or a group of similar measurements as per the table below. For example, calibration of thermometers and thermocouples will be considered one measurement group. Similarly, all measurements related to electrical low-frequency calibration, voltage, current and resistance are combined into one measurement group. However, mass calibration and voltage standards are considered to belong to two different measurement groups. This grouping of measurements has been modeled on measurement disciplines and the assessment effort for each accreditation.

Accredited facilities are required to participate in proficiency testing in at least one measurement group once per year. Each year, PT must be performed in a different measurement group until all accredited activities are covered. However where a facility's scope covers only one or two measurement groups, participation is required once every 2 years.

For facilities with an extensive Scope of Accreditation, a higher frequency of PT may be necessary. This will be determined at assessments.

The following table provides a listing of the common measurement groups for which ongoing PT is required.

Acoustic Equipment	Mass, density and Balances	Low Frequency calibration (Electrical)	Thermocouple calibration
--------------------	----------------------------	--	--------------------------

Force calibration	Metering - electrical	Pressure calibration	Thermometer - calibration
Humidity calibration	Metering - gas	Pyrometer calibration	Time and Frequency calibration
Ionising Radiation	Metering - liquid	RF and microwave calibration	Torque calibration
Irradiance instrument calibration	Optical systems	Spectrophotometry	Vibration equipment calibration
Length metrology	Photometry	Speed measuring devices	Volume and Flow
Ultrasonic calibration	LIDAR/RADAR calibration	Survey equipment calibration	Gas analysis

When a facility initiates and conducts its own inter- or intra-laboratory comparison, it must be able to demonstrate that each of the personnel involved are not aware of the reference values. The appropriateness of the facility's quality assurance activity will be assessed during assessment.

Proficiency testing may take the form of a program involving a number of participants where the results are intercompared or, particularly in the calibration and measurement areas, a measurement audit on an artefact where an individual facility's results are compared with those of a higher level reference facility (a facility with a lower uncertainty of measurement). The facility's best capability as described in the Scope of Accreditation (CMC) is to be tested.

For measurement audits, results will be evaluated by  $E_n$  ratios. This ratio is used to evaluate each individual result from a facility.  $E_n$  stands for 'Error normalised' and the ratio is defined as:

$$E_n = \frac{LAB - REF}{\sqrt{U_{LAB}^2 + U_{REF}^2}}$$

Where:

LAB is the participating laboratory's result

REF is the Reference Laboratory's result

$U_{LAB}$  is the participating laboratory's reported uncertainty

$U_{REF}$  is the Reference Laboratory's reported uncertainty combined with a component for artefact stability where appropriate.

For the result to be acceptable absolute values of  $E_n$  less than or equal to unity should be obtained, i.e.:

$$|E_n| \leq 1 = \text{satisfactory}$$

$$|E_n| > 1 = \text{unsatisfactory}$$

Generally, the desired outcome is for the value to be as close to zero as possible.

**Note:** For  $E_n$  ratios to be statistically useful as a PT activity it is necessary that  $U_{REF} \leq U_{LAB}$ .

## 5.10 Reporting the results

### 5.10.2 Test reports and calibration certificates

Units and unit symbols shall be in the form specified in AS 1000 unless the device being calibrated reads in other units or where contractual arrangements demand otherwise.

### 5.10.3 and 5.10.4

#### Sampling

When a batch or consignment is sampled in accordance with a method included in the Scope of Accreditation, test results for samples may be extended to the batches or consignments from which they are drawn.

#### Reporting the uncertainty of measurement

Calibration reports must include both numerical measurement result and the associated uncertainty of measurement even when compliance with a specification is stated.

By exception, and where it has been established during contract review that only a statement of compliance with a specification is required, then the measured value and measurement uncertainty may be omitted on the calibration certificate, given the following also applies:

- the calibration certificate is not intended to be used in support of the further dissemination of metrological traceability (for example, to calibrate another device);
- as specified in Clause 5.10.4.2 of ISO/IEC 17025, the facility shall determine the uncertainty and take that uncertainty into account when issuing the statement of compliance; and
- the facility shall retain documentary evidence of the measured quantity value and the uncertainty of measurement, as specified in Clauses 5.10.4.2 and 4.13 of ISO/IEC 17025, and shall provide such evidence upon request.

Contributions to the uncertainty stated on the calibration certificate shall include relevant short-term contributions during calibration and contributions that can reasonably be attributed to the customer's device. Where applicable the uncertainty shall cover the same contributions to uncertainty that were included in evaluation of the CMC uncertainty component, except that uncertainty components evaluated for the best existing device shall be replaced with those of the customer's device.

Therefore, reported uncertainties tend to be larger than the uncertainty covered by the CMC as stated in the scope. Random contributions that cannot be known by the facility, such as transport uncertainties, should normally be excluded in the uncertainty statement. If, however, a facility anticipates that such contributions will have significant impact on the uncertainties attributed by the

facility, the customer should be notified according to the general clauses regarding tenders and reviews of contracts in ISO/IEC 17025.

Pre-calculated (typical) uncertainties may only be reported where there is adequate and documented justification. If uncertainties are derived using a pre-characterised standard deviation, for the facility's measurement system, then an appropriate acceptance limit shall be set for the spread of results.

Unless otherwise required by a calibration specification, uncertainties shall be reported as an expanded uncertainty at a 95% coverage probability. The coverage probability and coverage factor 'k' shall be reported.

The estimated uncertainty shall be reported using a maximum of two significant figures.

The numerical value of the measurement result shall in the final statement be rounded to the least significant figure in the value of the expanded uncertainty assigned to the measurement result to avoid the reporting of over-precise measurement results beyond that presented by the estimated uncertainty of measurement.

For the process of rounding the reported uncertainty of measurement, the usual rules for rounding of numbers shall be used, subject to the guidance on rounding provided for example, in Section 7 of ISO/IEC Guide 98-3 (ISO GUM).

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. To aid in clarity of expression where percentage is applied it should be expressed as % of full scale or % of reading or % of property.



# Calibration Appendix A: Acoustic, Ultrasonic and Vibration Measurement

This appendix is divided into two sections; the first provides additional guidance and recognition of the general requirements that are applicable to all types of measurements in this discipline, while the latter provides additional guidance and recognition of the requirements that are specific to individual types of measuring equipment. For ease of use and to avoid fragmentation of the guidance, the clauses of ISO/IEC 17025 have not been applied.

## General Requirements

Facilities are to ensure a suitable CMC is stated in the Scope of Accreditation for the main measurement parameters for each instrument type. For activities such as the calibration of Sound Level Meters a separate CMC may be stated for acoustic measurements and 'electrical signal input' measurements as applies to the calibration test standard. Where an applicable standard incorporates maximum test uncertainties the facility must demonstrate that for each test the uncertainties do not exceed the maxima.

### Accommodation and environmental conditions

As many instruments are sensitive to temperature, pressure and humidity variations, all instruments must be allowed to come to equilibrium with the ambient environment before a calibration commences.

**Note:** Instruments with larger masses and specialist materials (such as artificial mastoids) may need many hours to equilibrate before reliable measurements can be made.

### Anechoic and reverberant rooms

Records of the evaluation of rooms must be kept and must include a description of room size, volume and construction, ambient noise and vibration levels, environmental conditions, microphone placements and measurement techniques and must also provide a statement of uncertainty of measurement and the frequency range over which measurements can be performed satisfactorily. The low frequency cut-off frequency must be stated together with the deviation from anechoicity at each working frequency.

**Note:** Refer to ISO 3741 and ISO 3745 for additional information.

### Field sites

Sites used for measurement of sound and vibration levels must be adequately described, preferably with an attached map of the site location. Measurement sites must be identified, the period of measurement reported and temperature, humidity and weather conditions recorded.

### Calibration method

The recommended calibration interval for a measurement system is the shortest interval of each of the components of the system. For example, a system consisting of a reference accelerometer (3-year interval), a charge amplifier (1-year interval), a reference capacitor (5-year interval), and a voltmeter (1-year interval), would have a recommended re-calibration interval of 1 year. Alternatively each component may be calibrated individually according to the

NATA-recommended guidelines: for example, a measurement system comprising a reference accelerometer and a conditioning amplifier may be calibrated either (i) as a system (in  $V/(m.s^{-2})$ ) every year, or (ii) as individual instruments with the accelerometer calibrated in  $C/(m.s^{-2})$  every three years, and the conditioning amplifier calibrated every year in  $V/C$ .

The facility should minimise the frequency of use of any internal reference artefacts to avoid compromising the stability. Where necessary a working standard artefact should be used for more frequent use and an internal calibration procedure established. Calibration records of working or reference artefacts should be recorded to establish a history of stability. A calibration check should be made of the working standard before use.

## **Specific requirements for types of measurement equipment**

### **Sound level meters**

Due to regulatory and industry requirements, NATA will continue to accredit facilities calibrating Sound Level Meters to the superseded and/or withdrawn standards IEC 60651, AS 1259.1, IEC 60804 and AS 1259.2 following the minimum requirements of Test of Periodic Verification published in Annex A of OIML R 88. Annex A OIML R 88 tabulates the clauses of IEC 60651 and IEC 60804 required for periodic verification, which can also be applied to the equivalent clauses given in AS 1259 parts 1 and 2.

Sound Level Meters that have been type-approved to Part 2 Pattern Evaluation Tests of IEC 61672 *Electroacoustics - Sound Level Meters* are to be normally calibrated following IEC 61672 *Electroacoustics - Sound level meters - Part 3: Periodic tests*, unless the calibration facility can demonstrate a customer need for reporting to the superseded and/or withdrawn standards IEC 60651, AS 1259.1, IEC 60804 and AS 1259.2 due to regulatory or industry requirements as indicated above.

Continuation of accreditation to the superseded standards will be subject to evaluation of the industry requirements by the Calibration Accreditation Advisory Committee.

New facilities wishing to gain accreditation for the calibration of sound level meters must first show competence in testing to IEC 61672-3 before gaining accreditation to the superseded standards.

### **Personal sound exposure meters**

Annex B of AS/NZS 2399, *Acoustics - Specifications for personal sound exposure meters* should be used as a guide for the periodic testing of sound exposure meters. For periodic testing some concession to reduced integration times is acceptable in order to have the activity cost-effective. Periodic testing of sound exposure meters must include a range linearity test at least as low as 85 dB. For devices which do not display a sound pressure level, sufficient integration time must be allowed to determine a resolution of  $0.1 Pa^2hrs$  or equivalent  $Leq$  (with a minimum of  $0.3 Pa^2hrs$  being recorded in each individual measurement). An acoustic frequency response in octaves from 63 Hz to 8 kHz must be conducted.

Using the instructions given in clauses 6 to 11 of AS/NZS 2399 periodic testing of sound exposure meters shall include:

- indication at reference conditions before and after any adjustments, Annex B1.5 of AS/NZS 2399;
- acoustic frequency weighting as outlined in Annex B3 of AS/NZS 2399;
- linearity of response to steady signals over the full stated dynamic range as outlined in Annex B2 of AS/NZS 2399, preferably at 63 Hz, 1 kHz and 8 kHz but as a minimum a test of linearity at 4 kHz;
- response to short duration signals as outlined in Annex B4 of AS/NZS 2399;
- response to unipolar pulses as outlined Annex B5 of AS/NZS 2399;
- latching over load indicator as outlined in B6 of AS/NZS 2399.

Additionally, if the sound exposure meter includes a facility to measure C-weighted Peak levels as required in Australian noise standard NOHSC1007 2000, the applicable test from IEC 61672-3 may be used to demonstrate correct operation.

### **Acoustic filters**

Modern sound level meters often incorporate constant percentage octave-band or fractional-octave-band filters used for the analysis of complex noise signals. Some filter sets may be dedicated stand-alone units.

Facilities performing verification of filter performance must use AS/NZS 4476 Octave-band and fractional-octave-band filters Appendix C as a guide to testing taking into account the situation described in a) or b) below.

- a) Where the filter equipment comprises analogue components, all filters in the set must be tested as required by AS/NZS 4476 clauses 4.4 and 5.3 and Appendix C.
- b) Where the filter function is implemented in a digital algorithm within host equipment such as a sound level meter, some concession to the breadth of testing is acceptable to avoid unnecessary testing. Once initially tested, unless the firmware version changes in a manner likely to cause a change in the function, the filter set does not require periodic re-testing.

In the case of b) for a digital filter the minimum tests to be performed on the set are:

- relative attenuation (insertion loss) at the centre frequency of all filters in the set;
- level linearity of filter response according to clauses 4.6 and 5.5 of AS/NZS 4476 at the centre frequency of a selection of 3 filters, the lowest filter below but closest to 31.5 Hz, the highest filter above but closest to 16 kHz and a filter chosen in the middle of the frequency range of the set;
- relative attenuation according to clauses 4.4 and 5.3 of AS/NZS 4476 of the same three filters chosen above.

### **Statistical noise level analysers**

Modern sound level meters often incorporate a statistical analyser to give information about the statistics of a time varying noise signal. Some analysers may be dedicated stand-alone units.

Facilities performing verification of statistical analyser performance must use DIN 45657 as a guide to testing taking into account the situation described in a) or b) below.

- a) Where the analyser equipment comprises a stand-alone unit built of analogue components, the complete tests described in DIN 45657 must be carried out to include three ramped down/up amplitude cycles with one cycle centered on the dynamic range limits and the two other cycles at displaced levels either side of the main cycle. The ramped amplitude must comprise steps no greater than the resolution of the analyser and be over the dynamic range of the instrument with no less than 1 second between step changes.
- b) Where the analyser is implemented in a digital algorithm within host equipment such as a sound level meter, some concession to the breadth of testing is acceptable to avoid unnecessary testing. Once initially tested, unless the firmware version changes in a manner likely to cause a change in the function, the statistical analyser function does not require periodic re-testing.

In the case b) for a digital implementation the minimum test to be performed on the function is:

- Ln performance using a single down/up ramped amplitude cycle using steps no greater than the least count of the host instrument and with at least 1 second between step changes and between limits no more than 10 dB from the under-range and overload levels.

### **Audiometers**

All facilities performing verification of audiological equipment must test to AS IEC 60645.1-2002 *Electroacoustics – Audiological equipment*. The Scope of Accreditation must indicate the 'type' of audiometer within its capability.

### **Artificial mastoids**

Artificial mastoids are sensitive to ambient conditions and should be allowed to come to equilibrium with the environment before testing. IEC 60318-6:2007 should be used as a guide, although the artificial mastoid's impedance must meet the specifications in IEC 60318-6:2007, Table 1. The force sensitivity (e.g. in units of dB re 1 V/N, or dB re 20  $\mu\text{Pa}/\mu\text{N}$ ) as a function of frequency should also be stated. Calibration reports of artificial mastoids must include reference to the calibration of the impedance head used in the calibration. This head provides the traceability to the measurements.

### **Acoustic calibrators and pistonphones**

To be accredited for field acoustics measurements, a suitably calibrated sound calibrator or pistonphone must be available to perform checks on a sound level meter before and after a set of field measurements. When using a pistonphone to check a sound level meter's acoustic sensitivity, compensation for ambient air pressure must be made with a calibrated barometer.

Facilities performing verification of acoustic calibrators and pistonphones must use Annex B of AS/IEC 60942 *Electroacoustics - Sound Calibrators* as a guide.

Tests shall include:

- sound pressure level;
- output frequency;
- total distortion, if included;
- where supplied, correct indication of an additional barometer.

### **Microphones**

Microphones should be stored in a dry ambient environment (e.g. in boxes with sachets of drying agents or in a desiccator).

Facilities performing frequency response testing using an acoustic coupler or an electrostatic actuator shall use IEC standards IEC 61094 parts 5 and 6 as a guide.

### **Vibration calibrators**

Facilities performing verification of field vibration calibrators should refer to a standard appropriate to the intended use of the field measurement equipment such as ISO 8041 Human response to Vibration, Annex A.

### **Vibration transducers (accelerometers, velocimeters and geophones and vibrometers)**

Facilities performing the calibration of vibration transducers should follow ISO 16063-11 or -21, or ISO 16063-41 for laser vibrometers for guidance. The units given in the calibration report should be appropriate for the intended usage of the transducer and in accordance with the agreement between the customer and the calibration facility. Calibration in SI units is preferred but not always suitable for the client. The Scope of Accreditation must always include a measurement capability in SI units.

Vibration transducers, accelerometers, and vibrometers are to be calibrated at a minimum of two frequencies and two levels that cover the range of use (as far as practicable). Triaxial accelerometers must be calibrated for each axis. .

Interpolation to obtain values between calibration points must be accompanied by evidence of method validation. ISO 16063-11 or -21 should be followed, or ISO 16063-41 for laser vibrometers.

If applicable, transducers should be calibrated in the orientation that they are specified to operate in (e.g. horizontally or vertically with respect to gravity).

### **Piezo-electric accelerometers**

Piezo-electric or charge type transducers should, where possible, be calibrated with the conditioning amplifier such as the charge amplifier that will be used with the transducer in practice. Where the charge amplifier is not part of the transducer calibration it must be calibrated separately as a unit.

### **Powered accelerometers and vibration transducers**

Vibration transducers that are externally powered such as servo accelerometers, strain gauge based or IEPE/CCLD internal impedance conversion types should, wherever possible, be calibrated with the power supply specified for the device which must be clearly stated on the calibration certificate. If the power supply cannot be provided with the transducer for calibration (e.g. it's built into a larger, non-portable system) then the vibration transducer may be calibrated separately, with an appropriate check made of the

power supply. For example, by using a calibrated transducer simulator for IEPE type supplies.

If the vibration transducer has a sensitivity proportional to supply voltage (e.g. some bridge types), then the supply voltage must also be calibrated.

### **Self-generating vibration transducers**

Self-generating vibration transducers, such as coil-based geophones and seismometers should be calibrated with the specified load impedance for the intended use which must be stated on the calibration certificate.

### **Self-contained vibrometers**

Self-contained vibrometers and non-contact vibration measuring systems such as laser vibrometers and vibration meters, should be calibrated, whenever possible, as a unit with all associated acquisition hardware and operating software. For systems with non-portable components, calibration of system elements separately may be required. Often calibrations will state a ratio of the applied acceleration (or velocity) compared to the measured/displayed acceleration (or velocity).

### **Ultrasonic power meters**

Facilities performing the calibration of ultrasonic power meters should follow IEC 61161 (AS/NZS 4714). Calibration of ultrasonic power meters must include a check with the included "standard mass". Between regular calibration intervals, ultrasonic power meters must be checked with this mass before and after measurements of the ultrasonic power of a working transducer.

## Calibration Appendix B: Mass and Related Quantities

This appendix is divided into two sections; the first provides additional guidance and recognition of the general requirements that are applicable to all types of measurements in this discipline, while the latter provides additional guidance and recognition of the requirements that are specific to individual types of measuring equipment. For ease of use and to avoid fragmentation of the guidance, the clauses of ISO/IEC 17025 have not been applied.

### General requirements

#### Acceleration due to gravity

Where the value of acceleration of gravity is required for force, mass, pressure or other calibration purposes, this value must be determined with an uncertainty appropriate for application at the working location. Geosciences Australia and State based geological or mineral organisations can provide a value of acceleration of gravity estimated at a nominated location or can provide a more accurate measured value when needed. It is the responsibility of the facility using this value to estimate an uncertainty for the value used. Acceleration of gravity values obtained from AS 1349, internet or web based searches are approximate values and can only be considered suitable for calibration traceability where the final reported uncertainty of the measurand is not less than 0.05%.

Records on how the acceleration of gravity has been determined and how the associated measurement uncertainty has been estimated are to be maintained.

### Specific requirements for types of measurement equipment

#### Weighing Device calibration

##### Calibration location

Weighing devices or balances are sensitive to transportation, their environment and changes in gravity. Consequently, balances should be calibrated at the location at which they are to be used. When moved, a weighing device is to be recalibrated or have the calibration and performance verified. This is important for high resolution (10 mg or better) weighing machines. NATA Technical Note 13 contains guidance on the relocation of weighing devices.

##### Calibration method

Chapters 6 and 7 of *The Calibration of Weights and Balances* NMI Monograph 4 by Edwin C Morris and Kitty M K Fen provide an accepted method for the calibration of high resolution (10mg or better) weighing devices. For devices with a lesser required accuracy such as industrial weighing appliances and hopper weighing systems, the shorter test methods as found in the National Measurement Institute National Instrument Test Procedure (NITP) 6.1 to 6.4 have traditionally been accepted as a basis of a calibration method. It is acknowledged however that the NITP documents are intended for the

verification of equipment used in trade and thus do not make up a complete calibration method.

Whichever the test method used, the laboratory must be able to demonstrate the method is valid.

### **Preliminary**

Reference masses must have reached thermal equilibrium. The weighing device should have been turned on for the time specified by the manufacturer or at least 30 minutes if this period is not known. Prior to calibration, the auto-calibration or other adjustment feature used by the end-user must be run. Where masses are used for adjusting the device and the calibrated value cannot be entered, then these masses shall have a departure from nominal value that is appropriate to the accuracy required and/or specification. After exercising the device, the error close to full capacity must be recorded. If the device appears to require physical adjustment or repair, the user must be consulted to determine if a full set of before adjustment readings is required.

It should be ensured that the device is correctly levelled and any zero-tracking feature is temporarily disabled.

### **Handling of masses**

Weights used for the calibration of balances should never be touched with bare hands. Small weights should be handled with plastic tipped tweezers and large weights with clean gloves (chamois, cotton or plastic) or with a lifting tool. For devices which include a chamber, the calibrators hands should not enter the chamber during the loading and unloading of the weights as the resulting air currents and temperature effects can affect the measurements.

### **Corrections to reading**

For higher resolution devices a minimum of 10 approximately evenly spaced calibration points must be taken over the range with no less than 5 points taken for devices with a lesser required accuracy. For balances with more than one range an equivalent number of calibration points must be taken in each range. If an instrument has more than 2 ranges and no independent adjustment for each range, a minimum of 5 points per range and one repeatability test in each range would be suitable.

For higher resolution devices the reading sequence for each calibration point must be carried out twice and consist of zero/mass/mass/zero readings.

**Note:** The mass is lifted off the balance between the two mass readings.

In some cases the user may request a limited calibration range. This is permitted provided it is stated on the report and on any calibration label attached to the balance. Alternatively where the user requires a higher precision within a limited section of the range (e.g. at the lower end of range) more points would be accordingly taken in this section.

### **Effect of Off-Centre Loading/Eccentricity**

The effect of off-centre loading must be determined. This may be achieved by placing a weight on the centre of the pan and then lifting and placing it successively to the front, rear, left and right positions on the pan. For those balances with a higher resolution range this should be activated (e.g. by taring).



## Hysteresis

Hysteresis must be carried out on the first calibration of a new device or after a device has undergone a repair to its weighing mechanism.

## Repeatability of measurement

The repeatability of measurement must be determined usually at close to both half load and full load. As repeatability usually increases with larger loads, the full-load repeatability test would be carried out as close as practical (usually within 20%) to the full capacity of the instrument and using the minimum number of masses. For example, it would not be appropriate to use a 2 kg mass to determine the repeatability of a 3.2 kg balance. In that case a 2 kg and 1 kg mass would be used together and care taken in placing them in the same spot each time.

For balances with more than one range, the repeatability must be carried out close to full capacity of the balance and also close to the maximum capacity of each range. The half load repeatability tests are not required unless the actual measuring system is different for each range.

For high resolution devices or where the customer requires a higher level of confidence, a minimum of 10 measurements must be taken for determining repeatability. For devices with a lesser required accuracy such as industrial weighing appliances and hopper weighing systems fewer measurements may be taken with the laboratory required to demonstrate the value calculated for repeatability is statistically valid and supports the required measurement uncertainty.

## Limit of Performance

For customers who use NATA Technical Note 13, the Limit of Performance must be calculated and report for each range using the formula:

$$F = 2.26 \times S_r(max) + C_{max} + U(C_{max})$$

Where:

$S_r(max)$  is the maximum value of the repeatability of measurement of the device for that range (taken from a minimum 10 measurements) or 0.41 of the resolution in that range, whichever is greater.

$C_{max}$  is the magnitude of the maximum correction to the reading for any of the calibration points measured in the range under consideration.

$U(C_{max})$  is the expanded uncertainty associated with the maximum correction in the range under consideration.

## Calibration report

Reports shall include:

- resolution of the device;
- description of the device;
- the precise location of the weighing device;
- pre-adjustment readings. As a minimum, the correction or error close to full load must be reported;
- repeatability of measurement;

- corrections to readings at each calibration point and the associated uncertainty of measurement;
- off-centre loading (description of test and results);
- hysteresis (where verified);
- uncertainty of weighing at each calibration point;
- Limit of Performance (when required by the customer);
- for balances with more than one range the repeatability, corrections and Limit of Performance for each range must be reported.

## **Pressure measuring devices**

### **Test and calibration methods and method validation.**

The facility must unambiguously specify the range of capability over which calibration can be conducted as a gauge pressure range and/or an absolute pressure range and state this capability in their Scope of Accreditation. Where not otherwise specified a range will be taken as a gauge pressure only. Reporting measurements in absolute pressure can only be done if a Calibration and Measurement Capability (CMC) for absolute pressure is stated in the Scope of Accreditation.

The Uncertainty of Measurement as stated in the CMC if reported as a percentage shall be a percentage of reading and not full scale. For gauge pressure, ranges that cross zero must include a minimum value (in SI units) in conjunction with a percentage of reading.

For negative gauge pressure measurements, the maximum negative range must take into account at least the vacuum generating equipment and the reference calibrator range and operation. As the achievable negative gauge pressure will depend on the atmospheric pressure at any one point in time, a maximum negative pressure of -101 kPa should be considered the best case achievable.

## **Flow meters**

A flow meter may be regarded as one of two distinct types of device.

1. An instrument that indicates or generates a signal, representing a volume or mass of a fluid passed through it (for example, the volume in L or m<sup>3</sup> or mass in kg or tonnes) when operating at a flow condition (for example, 15 L/s or 15 kg/s).
2. An instrument that indicates or generates a signal, representing a flow rate or velocity.

In either case the instrument may include a flow computer which provides flow outputs.

### **Reporting of flow meters**

To allow unambiguous declaration of the calibration of a flow meter, a calibration report must include:

- the fluid used during calibration describing relevant physical properties which are not otherwise defined and can impact the calibration including

but not limited to; pressure, temperature, relative humidity, electrical conductivity;

- the calibrated volume or mass and the nominal rate of delivery for a flow meter described as type 1 above;
- the calibrated flow rate and the nominal measured volume or test time for a flow meter described as type 2 above;
- environmental conditions;
- a description of the instrument under test (IUT), including the size of the meter and any upstream pipework such as flow straighteners, filters, gas eliminators or pulsation dampeners.

### **Specification of NATA scope for flow meters**

The accredited scope must unambiguously specify the facility's measurement capability as either a volume or a flow rate capability or both when relevant. When specifying an uncertainty in % units the facility must specify if the accredited uncertainty relates to volume or flow rate. For example, if a facility provides calibration of the volume attribute of fuel oil meters, the specification of capability must include the facility's nominal flow rate range and the minimum test volume which can be accurately delivered.

*Fuel oil in the flow rate range 1 L/s to 50 L/s with a least uncertainty of measurement of:*

*0.1% of volume with a minimum 100 L test volume.*

When defining the accredited scope with the uncertainty a facility must specify:

- type of fluid. Laboratories may also state the relevant delivery condition to inform potential customers (for example CNG at 10 bar to 300 bar);
- either a test volume range or flow rate range which can be delivered from the reference system;
- an applicable uncertainty of measurement for a best typical instrument under test following the guidance for key uncertainty terms below must be declared either in volume or flow units or where uncertainty is declared in % units, a minimum delivery must be specified.

### **Key Uncertainty terms for flow meters**

Uncertainty analysis should include certain key terms such as:

- calibration of the reference meter, collection volume or gravimetric apparatus;
- difference in calibration of the reference meter arising from its use with different fluids or at different pressures than those with which it was calibrated;  
**Note:** This type-B uncertainty could, for example, be estimated using manufacturer's information or published literature but preferably from direct measurements.
- meter-under-test repeatability:  
**Note:** This can be assessed by either repeat testing of one or more calibration points or by a type B analysis for that meter class estimated from prior testing, manufacturer's data, accepted industry knowledge or other demonstrated means.

- uncertainty of relevant physical properties which are not otherwise defined and can impact the calibration including but not limited to: pressure; temperature; relative humidity; electrical conductivity associated with the flow difference between the reference equipment and the Item Under Test (IUT);
- terms specified in industry specific standards.

### **Key operational characteristics of flow meters**

Due to IUT design and test method employed a minimum test volume may be required for accurate calibration.

It is essential to consider the change in volume of the test fluid between the reference equipment and the IUT due to relevant physical properties. For highest accuracy work these properties must be measured, both at the reference and at the IUT and appropriate corrections applied.

Any working fluid loss between the reference equipment and the IUT will result in measurement errors and the facility must have processes to manage this. For highest accuracy work, appropriate leak testing must be considered as part of each test setup. Valid statistical processes may be acceptable for a type B estimate of this error to provide an uncertainty contribution. Acceptable processes would include:

- perform and record standard leak testing at regular intervals (for example, start and end of a shift) using the same type of meter and mounting system as is being routinely tested;
- visually examine the IUT/test rig seals;
- a system of testing during the shift with an interval that maintains confidence in the system.

### **Force Measuring Systems**

#### **(for testing including force testing machines)**

In addition to the uncertainty contribution associated with the reference standard, the uncertainty calculation must also include contributions from the drift of the reference load cell (during its calibration interval or from manufacturer's specifications), the resolution and the repeatability of the force measuring system under test.

Where a force measuring system cannot provide stable force application, factors such as operator reaction bias and response time of the working force standard and/or the force measuring system must also be included in the uncertainty calculation.

Contributions from temperature effect, creep, linearity deviation, misalignment of forces, adaptors and fittings, and the effect of worn or unparallelled platens must also be considered when these contributions apply.

Refer to Appendix E, AS 2193 *Calibration and classification of force-measuring systems* as a guide.

#### **Working Force Standards (for the calibration of force measuring systems)**

The calibration of working force standards must also consider contributions from deflections and the zero deviation as well as a full determination of the

repeatability and hysteresis. Refer to Section 4 and Appendix F of AS 2193 above as a guide.

A separate CMC to differentiate force measuring systems (to be used for testing) and working force standards (to be used for calibration) must be listed in the Scope of Accreditation for facilities that calibrate working force standards.

The classification of working standards to AS 2193 must follow the criteria in Section 4 of that standard. Both continuous class and point class method may be used on a single load cell; however the classification reported must only apply to the section of the range application to the classification method used. For example, when using the point class method, the classification can only be reported for the forces used during calibration. When reporting a range of classification the continuous class method must be used.

## Calibration Appendix C: Dimensional Metrology

This appendix provides additional guidance and recognition of the general requirements that are applicable to all types of measurements in this discipline.

### General requirements

The facility must be familiar with the filtering characteristics of the reference instruments they use. The potential loss or distortion of captured information must be considered when selecting filter settings as well as their effect on any time-related phenomena.

Records of these settings must be retained and/or be specified in the calibration or testing procedures.

In roundness measurement, significant differences in results can occur on test items with certain irregularities depending on the filter type and cut-off value selected. Facilities should normally default to a low level of filtering for high quality surfaces (e.g. 1:500 UPR).

Ideally, all measurements will be carried out under static conditions, however in some force measurements where test machines have limited control or creep effects are occurring, different filtering (indicator averaging and update rates) used on the test and reference instruments can introduce errors into the measurements.

## Calibration Appendix D: Electrical Metrology

This appendix provides additional guidance and recognition of the metrological traceability requirements that are applicable to all types of measurements in this discipline.

### Measurement Traceability

#### Artefact calibration

Some digital instruments are adjusted by a process usually referred to as 'artefact calibration'. This typically consists of connecting the instrument with one or more reference devices such as a DC voltage reference and a standard resistor.

While this procedure is specified by the manufacturer and should be performed at the specified intervals, it does not constitute an adequate calibration by itself. It is still necessary to perform the full calibration (verification) of the instrument as specified by the manufacturer.

#### Global Navigation Satellite System, (GNSS) devices as traceable standards

(GNSS) devices may be used as traceable standards and to check the operation of a calibrated standard. Two traceability paths are possible:

- via calibration of the GNSS device; or
- by operation of the GNSS device in conjunction with careful validation of its outputs.

The most direct traceability path is obtained by calibration of a GNSS device to a national standard. Less frequent calibration may be acceptable, given that the device may not be subject to significant long-term drift. The uncertainty budget will need to take into account variability in operating conditions, such as that due to the ionosphere. It is strongly recommended that the device status be logged and verified for correct operation during use. Status information such as the number of satellites tracked and the accuracy of the timing solution is greatly preferred over simply verifying that the device is 'locked'. The availability of such diagnostics should be considered when purchasing equipment.

In principle, a GNSS device can also be used as a standard traceable to UTC(AUS) without independent calibration.

**Note:** In the case of GPS, the link to UTC(AUS) is via UTC: the offset between UTC(AUS) and UTC and the offset between UTC(USNO) (which GPS time is steered to) and UTC are published, allowing the two to be linked. Similar data exist for BeiDou and GLONASS. For convenience, data linking UTC(AUS) and GPS are published on the NMI Time and Frequency ftp server.

The uncertainty budget also needs to account for uncertainties in the link between a GNSS time scale and a device's outputs; which will typically be the largest source of uncertainty.

**Note:** Guidance on uncertainties can be obtained from the APMP Technical Committee for Time and Frequency's web pages: <http://www.apmpweb.org/fms/guidelines3.php>

When using a GNSS device as a traceable standard without independent calibration, the device's output should be compared during use with at least one other independent GNSS device. Each device should be configured to use a single, different GNSS system e.g. one device using GPS and the other using GLONASS, for maximum independence. Correlations may still exist e.g. single-

frequency receivers will be using approximately the same ionosphere correction, and these should be accounted for in the uncertainty budget.



## Calibration Appendix E: Temperature Metrology

This appendix is divided into two sections; the first provides additional guidance and recognition of the general requirements that are applicable to all types of measurements in this discipline, while the latter provides additional guidance and recognition of the requirements that are specific to individual types of measuring equipment. For ease of use and to avoid fragmentation of the guidance, the clauses of ISO/IEC 17025 have not been applied.

### General requirements

#### Fume exhaust system

Where a facility uses a liquid calibration bath for testing temperature sensors at temperature levels sufficiently high for the liquid (e.g. silicone oil) to fume, a fume exhaust system should be installed above the bath.

In the situation where a fluidised bed bath or a salt bath is used, adequate measures must be made to contain the heated medium to prevent hot particles escaping towards the test operator.

Electric furnaces for calibration purpose should be installed in a manner to obviate AC pick up which may influence the test data.

### Calibration methods and method validation

**Note:** Methods with examples of uncertainty of measurement focussed on Heat and Temperature Measurement applications include:

- *Uncertainty in Measurement:* The ISO Guide – RE Bentley, NMI Monograph 1
- *Applying the ISO Guide to the Calculation of Uncertainty: Temperature* – RE Bentley, NML Publ. No. TIP P1358

The term “reference thermometers” refers to a thermometer which is reserved for the calibration or checking of working thermometers. They should not be routinely used for client calibrations or measurements. In general, the uncertainty of calibration of a reference thermometer, should be no more than 1/5<sup>th</sup> of the uncertainty of calibration required of the working thermometer.

Calibration reports must explicitly state the temperature scale on which the temperature is reported, this will normally be ITS-90. However, it may also be appropriate to specify is IPTS-68 (e.g. historical compatibility reasons) or thermodynamic temperature (e.g. lamp colour or distribution temperatures).

Ice-points must be made with de-ionized or distilled water. Uncertainties of 20 mK or less must be supported by regular measurement of the conductivity of the water. Uncertainties of 4 mK or less require the ice-point to be regularly checked against a calibrated water-triple-point cell.

### Specific requirements for types of measurement equipment

#### Apparatus for fire tests

The critical dimensions of the apparatus must be measured and recorded to establish compliance with the requirements of AS 1530.1, .3 and .4 on Methods for fire tests on building materials, components and structures.

### **Automatic reference junctions**

Where automatic reference ice point junctions are used in place of an ice pot their accuracy and stability of performance should be assessed. Thermocouple logging systems used for field work outside of a facility (at temperatures outside of 20°C to 25°C) should have the effectiveness of their ACJC tested at ambient temperatures appropriate to the field work being undertaken.

### **Calibration baths and furnaces**

Baths and furnaces used for calibration purposes must have their temperature uniformity characteristics determined over the temperature range for which accreditation is required. In addition, the effects of sample loading and thermal losses on bath performance should be assessed. A detailed record covering the testing techniques used and commenting on the suitability of baths for calibration purposes must be available.

### **Dry block calibrators (calibration and use of)**

In calibration of dry-block calibrators, the uniformity must be assessed over a distance of 20 mm and reported or included as an uncertainty component.

When dry-block calibrators are used as a temperature source for sensor calibrations, a “pull up 20 mm” test of the device under test (DUT) and reference needs to be performed at (at least) one temperature, and included as a component in the uncertainty calculations (e.g. propagated proportionally to temperature).

**Note:** Additional guidance on the calibration of dry block calibrators may be found in EURAMET cg-13 Calibration of Temperature Block Calibrators.

### **Conduction errors:**

Conduction errors for probes immersed more than 200 mm into a fluid bath or 250 mm into a tube-furnace can generally be assumed to be negligible, and the corresponding enclosure uniformity value alone used as the transfer error. Probes calibrated in dry-well calibrator or immersed less than this must have an immersion test performed on each DUT. This consists of observing the temperature change when the probe is withdrawn a further 20 mm. This test should be performed at the extreme temperature and propagated proportionally to  $(T - T_{amb})$ .

### **Environmental enclosures (e.g. environmental chambers, conditioning rooms, calorimeter rooms)**

The spatial and temporal uniformity of the enclosures for all required parameters must be determined. Single point measurements are not acceptable.

The enclosures must be tested to ensure that they comply with the requirements of the test procedures.

The method in AS 2853 Performance of Heated Enclosures may be used for the testing of all enclosures and chambers (ovens, baths, furnaces, incubators, freezers, etc.).

The results of characterisation of the environmental enclosure must be available for examination during an assessment.

The loading state of the enclosure must be specified in the report.

### **Ovens and Furnaces**

Ovens and furnaces would normally be calibrated against a standard such as AS 2853 or similar:

- heat exposed wire (for temperatures greater than 400°C) should not be used in the temperature gradient zone in subsequent tests (e.g. cut new wire or move new wire into the gradient zone);
- the furnace or oven must be allowed to stabilise for at least 1 hour, or 5 control cycles, prior to performing the calibration;
- the number of thermocouples must be greater than or equal to that required by AS 2853. Any departure from this must be explicitly stated on the report and the report cannot state that the testing has been performed according to AS 2853;
- the use of MIMs type thermocouples is strongly recommended. However, if ceramic or fibre-glass sheathed wire is used, it is essential to ensure the wire cannot be contaminated by vapours from the binder. In this case, the test method should specify that if possible the thermocouple passes through a vent rather than the oven door, and that if there is evidence of contamination to the wire in the gradient zone the test should be repeated.

### **Autoclaves**

The homogeneity of the thermocouples is the feed-through to the chamber should be regularly checked, as this is usually also the EMF generating temperature gradient zone. This can be achieved by placing thermocouple tips in an ice-point, heating the feed-through with a hot air gun and confirming that changes are negligible.

### **Thermocyclers**

PCR thermocyclers use a variety of technologies to achieve rapid heating and cooling sequences across a number of tubes. The accuracy of temperature and hold time, the magnitude of overshoots and undershoots, the uniformity of temperature, and heating and cooling rates across the thermal block are critical aspects to the performance verification of thermocyclers. A traceable calibration is seen as desirable for quality-control and method portability and to numerically verify the performance of the device.

Due to the dynamic performance of thermocyclers, they must be verified in a dynamic way. Facilities must ensure that the reference equipment used for the calibration of thermocyclers has suitable evidence of metrological traceability and is fit for purpose, giving consideration to:

- each sensor is to have a temperature uncertainty no greater than 1/5th of the uncertainty of calibration required for the thermocycler under test;
- the dynamic response time of the temperature sensors must be suitably rapid to measure the rise and fall time as well as set point over/undershoot. This can be assessed by exposing the sensor to a typical step change in temperature, the time response to measure 63% of the step change should be below 2 seconds;

- simultaneous (or near simultaneous) and continuous logging of multiple well temperatures at each measurement site during the test interval (where the test interval is one complete cycle of the thermocycler). The sensor sampling/logging frequency should be 1 Hz or more. The time accuracy of the logging system should be better than 1 in 105;
- the resolution should be 0.01°C .

A thermocycler calibration system will thermally load the thermocycler in terms of thermal mass and thermal conductivity (heat leaks) differently to a set of PCR samples. Consequently different calibration equipment may lead to different results for the same thermocycler. The facility must consider:

- the magnitude of systematic error due to the combination of the calibration system and the thermocycler, should be taken into account for each combination as part of the calibration method validation process;
- assessment of the systematic effects of loading by the calibration system may be performed by comparing the calibration results from the calibration system to that of a basic method with known small uncertainties. For example, a 0.1 mm diameter calibrated thermocouple wire placed into a sample tube containing a drop of oil. An error of less than 1/5th of the uncertainty of calibration required for the thermocycler under test is considered acceptable. This term would be included in the reported uncertainty of measurement.

Thermocyclers often have a heated lid preventing condensation and evaporation. Opening the heated lid can influence the calibration results therefore when possible calibrations should be performed with this lid closed to replicate in-use conditions.

The test method will report temperature uniformity across the thermal block and as such the number of sensors should be selected proportionate to the number of wells with consideration to the size of the block. The number of sensors should be at least 12.5% of the number of wells for thermocyclers with up to 96 wells, subject to a minimum of 5 sensors for thermocyclers with 8 or more wells, and a minimum of 12 sensors for thermocyclers with more than 96 wells. Sensors must be placed in the four corner positions and spatially and evenly distributed over the middle and edges of the block.

The report must state if the calibration was performed with the heated lid opened or closed, and if closed, report the heated lid temperature. If the lid is open, the report must clearly state this and that temperatures reported may be different to that during normal use with the lid closed.

Additionally in order to suitably verify the performance of a thermocycler, reports should at least include the following items:

- the mean block temperature measured after a 15s to 30s stabilisation period and the temperature correction to the indicated temperatures at the lowest and highest temperature settings, a low- to mid-range setting, and a mid- to high range setting to match the in-use temperature range. For example, 15°C, 55°C, 72°C and 95°C may suit most users or 4°C, 55°C, 72°C and 98°C if the customer intends to use the device at the cyclers' full range;
- the stabilisation period;

- the temperature heating and cooling rates and set point overshoot/undershoot for each sensor which may be stated in a graphical form during a typical cycle;
- the maximum overshoot and undershoot at each measurement point;
- temperature uniformity measured after a 15s to 30s stabilisation period;
- time at temperature after overshoot/undershoot for each temperature set;
- temperature uniformity across the thermal block.

### **Liquid-in-glass thermometers**

The report must state whether the reported uncertainty includes a component for scale-interpolation error, or is valid only at the reported calibration points.

Temporary depression must be measured by measuring the correction at a reference temperature (usually the icepoint) before and after exposure to temperatures away from ambient, and any shift included as a component in the uncertainty calculations.

The report must state any annealing procedure applied to the thermometers prior to calibration.

### **Platinum resistance thermometers**

Hysteresis is usually the largest uncertainty component for resistance thermometers, and needs to be assessed for each DUT.

A measurement of the calibration at the ice-point should be made before and after each temperature excursion (e.g. before and after oil bath measurements etc.)

For low uncertainty sensors used far from ambient (e.g. less than 0.2°C uncertainty AND  $<-40^{\circ}\text{C}$  or  $>100^{\circ}\text{C}$ ), the ice-point hysteresis test is insufficient, and a measurement at  $T_{\text{max}}/2$  on the way back to zero must be performed.

### **Vapour pressure thermometers**

The effect of stiction must be determined by taking readings at both rising and falling temperatures for at least one point in the range, and included as a component in the uncertainty calculations.

The report must state the orientation of the probe (e.g. vertical or horizontal).

### **Thermocouples**

It is important to note that the EMF in a thermocouple is produced in a temperature gradient and not at the thermocouple tip, and thus the effects of inhomogeneity must be considered along with the following:

- thermocouple reports must state the EMF-to-T reference function used (e.g. ASTM...);
- the inhomogeneity of a thermocouple must be included as a component in the uncertainty calculations, For new thermocouples a default value of 0.1% for base metal and 0.02% for rare-metal thermocouples should be used, For used thermocouples it must be measured, for example, by measuring the correction over a range of at least 100 mm in immersion depths;

- the inhomogeneity uncertainty component should be propagated proportionally to temperature;
- because base metal thermocouples can experience significant drift during calibration, the calibration procedure for base metal thermocouples must require measurements over at least a ½ hour period, and the variation obtained included as an additional uncertainty component (drift);
- the calibration procedure for ceramic or fibreglass insulated base metal wire must specify that air can circulate freely to ensure binder vapours do not contaminate the thermoelements;
- for MIMs thermocouples with a head junction, the calibration procedure must estimate any error due to different wires in the MIMs and extension leads, e.g. by putting the sensor in an ice-point and noting any change when the head is warmed or cooled;
- for the calibration of reels of thermocouple wire, inhomogeneity in the reel must be evaluated. The estimated inhomogeneity may need to be revised if the measured variation between samples is significantly different to that estimated (could be lower or higher). In this case additional homogeneity measurements may be required.

### **Digital temperature indicators**

Uncertainties must include a component for interpolation between calibration points, unless the report explicitly states that the calibration is only valid at the measured points and no allowance for interpolation has been made.

Report should state the values of any internal coefficients accessible to the user (e.g. a,b coefficients of ITS-90 PRT equations).

In addition to the requirements for thermocouples (above) the following also must be considered:

- an uncertainty component for the temperature coefficient of the internal ACJC must be included in the uncertainty calculations. If it is not explicitly measured a default value of 0.1°C per °C variation in ambient is typical;
- the report must state if the calibration was performed with internal or external ACJC. If an external ACJC is used, a calibrated thermocouple together with a reference temperature such as an ice-point must be used;
- if the calibration is performed by electrical simulation, the report must state explicitly that it is an electrical simulation calibration and that any sensor must be separately calibrated.

### **Radiation thermometers (e.g. pyrometers)**

The Size-of-Source-Effect (SOSE) is usually the largest uncertainty component in calibration of these types of instruments, and must be explicitly measured for each DUT during calibration at least at one temperature, This can be achieved by recording the change in indicated reading if;

- aperture in the front of the source is reduced by 10mm; or
- the calibration distance is changed by 25%.

The report must state the diameter of the radiation source used and its distance from the DUT.

Because of differences in the spectral responsivity of DUT and reference radiation thermometer, comparison calibrations against grey-body sources require an additional component in the uncertainty calculations.

### **Surface probes and calibrators**

The surface probe sensor needs to be physically reheated several times for at least one temperature (typically the highest) to assess contact variability. The measured variation should be propagated proportionally to temperature, as an additional uncertainty component.

For calibration of surface probes, the report must state the surface used for the calibration, and the nature of the ambient air flow, e.g. "calibrated on a polished aluminium plate in still air".

### **Humidity**

Users of humidity measuring equipment must ensure the temperature component is calibrated to suit the intended use.

The CMC in the Scope of Accreditation shall include the temperature (range) to which the humidity is reported with corresponding uncertainty of measurement across humidity range and temperature range.

A calibration report must state the temperature range for which the humidity range is valid.

### **Electrical calibration of temperature indicators, such as digital multimeters and digital temperature indicators**

The calibration process for devices must include:

- if internal ACJC is used, a calibrated thermocouple, together with a temperature reference, such as ice-point;
- the  $V \Rightarrow T$  or  $R \Rightarrow T$  conversion software within the instrument must be validated at several points over the calibration range. For thermocouple sensors this includes separately checking each of the thermocouple ranges;
- an uncertainty contribution to allow for non-linearity of the resistance or voltage measurement scale of the DUT (e.g. manufacturers specification), when the DUT is calibrated as an ohmmeter or a voltmeter with a subsequent validation of the  $R \Rightarrow T$ ,  $V \Rightarrow T$  conversion. To achieve a lower uncertainty, several points over the range must be checked.

The report must include the following:

- for thermocouple ranges, whether the calibration is performed with external or internal Automatic Cold Junction Compensation ACJC;
- which  $V \Rightarrow T$ , or  $R \Rightarrow T$  conversion equations have been selected (e.g. ASTM table XXX ref. XXX. IEC-60751, ITS-90 SPRT reference equations, etc.);
- any internal coefficients stored as part of the conversion equations (e.g. a,b,c coefficients in ITS-90 SPRT reference equations);

- the temperature scale the calibration of the device is based on (e.g. IPTS-68, ITS-90, etc.);
- explicitly state that the calibration is an electrical simulation only.



## Calibration Appendix F: Optical Metrology

This appendix is divided into two sections; the first provides additional guidance and recognition of the general requirements that are applicable to all types of measurements in this discipline, while the latter provides additional guidance and recognition of the requirements that are specific to individual types of measuring equipment. For ease of use and to avoid fragmentation of the guidance, the clauses of ISO/IEC 17025 have not been applied.

### General requirements

#### Dark rooms

Dark rooms used for photometric measurements commonly have matt black painted walls and provision for screening stray radiation, particularly from ceiling and floor. Baffles are a more effective means of reducing stray radiation. The amount of stray radiation present must be measured and be accounted for.

#### Power supply

Power supplies matching the requirements of reference standard lamps and with a current stability of better than 0.1% should be provided.

### Specific requirements for types of measurement equipment

#### Optical Glass Filters

Colour and neutral density glass filters change the spectral properties of optical radiation. These filters allow investigations to be conducted using optical and radiometric equipment. For example, in the areas of photometry and radiometry, optical filters are used for:

- checking the spectral response and linearity of photocells, photomultipliers, and radiometers;
- checking the accuracy and precision of colour measuring systems (e.g. spectrophotometers and colorimeters).

Since filters are often used as laboratory standards, only glass filters (dyed in the mass) are recommended. Plastic, gelatine or coated filters are not acceptable due to their inferior stability in terms of optical parameters. Various qualitative and quantitative descriptions assist in determining whether a particular glass filter is suitable for a certain use. For example, relevant parameters may include:

- chromaticity co-ordinates;
- luminous transmittance (T);
- chemical resistance;
- bubble quality;
- homogeneity and polish, thickness uniformity;
- tempering and strengthening;
- handling and storage;

Recommendations for each of these parameters are given below:

### **Chromaticity co-ordinates**

Filters should be chosen that have chromaticity co-ordinates in the desired colour region. The usual system used for specifying chromaticity co-ordinates is the CIE 1931 x, y, Y system. Selected filters should be calibrated by a suitable calibration authority (e.g. a facility accredited with NATA for filter measurements and capable of measuring with a least uncertainty of  $\pm 0.005$  units of chromaticity or better).

Any conditions or precautions stated in the calibration report should be strictly adhered to, for example:

- test geometry;
- illuminant source used;
- test area(s);
- sampling interval and bandwidth used;
- ambient environmental conditions.

Chromaticity should be constant over the surface of the filter or, as a minimum requirement, any variations should be known and clearly documented.

### **Luminous Transmittance (T)**

In many applications it will be necessary to know both the luminous transmittance (T) and the spectral transmittance  $T(\lambda)$  of optical filter standards.

Optical radiation filters, regardless of their structure or mode of action, are characterised by their spectral transmission (i.e. their transmittance as a function of wavelength). The luminous transmittance is calculated by integrating the spectral transmittance values with the visibility function and source.

Transmission values quoted for filters are usually for the reference thickness only - this is typically a nominal value of 1 mm, 2 mm or 3 mm. Once selected, optical filters should be sent to a suitable calibration authority for measurement of spectral transmittance over the appropriate wavelength interval and calculation of luminous transmittance. An uncertainty of  $\pm 0.2\%$  or better is desirable for transmittance values.

### **Chemical resistance**

Optical glass filters should be resistant to chemical attack by acids, alkalis and other chemical agents. Under normal conditions of use, no change in optical properties should occur. Only under extreme conditions, such as when subjected to a continuous spray of sea water, or when used in rain or water, could a change in optical properties be expected to occur.

A small change in transmittance may occur with the growth of surface films (blooming). This can be reversed by carefully cleaning the surface of the filter.

### **Bubble quality**

This parameter is usually characterised by stating the total cross-sectional area of any bubbles in  $\text{mm}^2$ , relative to  $100 \text{ cm}^3$  of glass volume, calculated from the sum of the cross-sectional areas of any bubbles in the glass. Inclusions in the glass, such as stones or crystals, are treated in the same way as bubbles of the same area.

It is recommended that the projected area (in mm<sup>2</sup>) of all bubbles/inclusions, having a dimension greater than 0.05 mm diameter, be less than 0.10 mm<sup>2</sup>/100 cm<sup>3</sup> of glass volume.

### **Homogeneity and polish, thickness uniformity**

Optical filters should be homogenous, with respect to optical properties, over their entire area. The variation in refractive index within a filter glass is a good measure of the optical homogeneity. The better the homogeneity is, the smaller the variation in refractive index. Optical filters should have maximum variation of the refractive index (nd) value of  $\pm 5 \times 10^{-6}$ . This should be verified by the glass filter supplier or by calibration.

The two sides of the filter must be adequately polished and accurately parallel to obtain uniformity of transmittance over the working aperture.

### **Tempering and strengthening**

Absorbing filter glass is generally heated unevenly by illuminating radiation. Rapid thermal equilibrium is prevented by the low thermal conductivity of glass.

This results in temperature differences between the front and rear and, in particular, between the centre and the edge of the filter glass. Consequently, different rates of thermal expansion within the filter occur, generating high flexural stress in the glass (and ultimately leading to crystallisation, embrittlement and fracturing).

Improved resistance to large temperature gradients or rapid temperature changes can be obtained by tempering (or strengthening) the glass. Heat tempering glass leads to birefringence in the material and is not appropriate for spectrophotometer measurements where the beam is partially plane polarised.

Constructional methods and illuminator design must ensure that the filter glass is subjected to minimal temperature gradients. This is the sole method of achieving high reliability in operation.

### **Handling and storage**

The following precautions should be observed:

- if there exists a possibility of filters being exposed to moisture or water during transport, it is advisable to use a desiccant when packaging the filters.; Prolonged exposure to intense light sources which have a high proportion of ultraviolet (UV) radiation can cause permanent changes in the transmission of some filter glasses. This effect is called 'solarisation' in glass technology. Solarisation depends on the intensity and spectral distribution of radiation (i.e. the shorter the wavelength of radiation, the greater the solarisation effect in most cases).

In most optical filter glasses, solarisation is characterised by a shift of the short-wavelength edge towards longer wavelengths and a reduction of transmission in the pass band region.

In practical terms, this means filters should never be exposed to bright sunlight or intense UV sources for extended periods;

- filters are obviously very fragile items and should be treated with due care. It is advisable only to handle filters by their edges and store them in a soft, lint-free container that can be locked tight to prevent the entry of moisture and light.

If filters are subjected to any agents or processes that could be expected to change their optical properties, it is highly recommended that they be re-calibrated by a suitable calibration authority.

### **Distribution photometers**

Any mirror on a distribution photometer must be checked for flatness and uniformity of reflection factor. The light path length and the accuracy of angular settings should be established. An accuracy of better than 30 minutes of arc is recommended for angular settings.

### **Goniophotometers**

The accuracy of angular settings must be established. Type 'A' Goniometer must be used for ADR testing, traffic signal lanterns or where testing at large horizontal angles is undertaken. The type of goniometer must meet the requirements of the standards.

### **Illuminance meters**

The accuracy to which the detector matches the  $V(\lambda)$  function must be corrected for and/or accounted for in the uncertainty calculations. Correction may be performed by:

- using a spectral mismatch correction factor (if the spectral response of the detector is known);
- using a correction factor from the manufacturer (if supplied for a particular source); or
- using filters.

This is particularly important for measurement of sources with narrow spectral features.

The linearity of response and cosine response must be checked initially with additional linearity checks to be performed as required. Linearity of response checks may be performed by the inverse square law, multiple aperture or neutral density filter techniques. Glass neutral density filters are recommended; plastic and gelatine filters are not acceptable.

A visual inspection of the photometer detector is recommended every 6 months.

### **Luminance meters**

The accuracy to which the detector matches the  $V(\lambda)$  function must be corrected for and/or accounted for in the uncertainty calculations. Correction may be performed by:

- using a spectral mismatch correction factor (if the spectral response of the detector is known);
- using a correction factor from the manufacturer (if supplied for a particular source); or
- using filters.

This is particularly important for measurement of sources with narrow spectral features. The linearity, sensitivity, spectral responsivity, scattered light and optical alignment must be checked. The size and location of the measurement field, at an appropriate distance, must be determined.

## Photodetectors

The sensitivity and spectral responsivity of the photodetector and filter, if fitted, and associated electronics combination must be checked regularly. Linearity of response must be checked initially with additional linearity checks to be performed as required. A visual inspection of the photodetector and filter, if fitted, is recommended every 6 months.

Where the photodetector is designed to have a spectral responsivity matching the  $V(\lambda)$  function, e.g. photometer heads, the accuracy of the spectral response to  $V(\lambda)$  must be corrected for and/or accounted for in the uncertainty calculations. Correction may be performed by:

- using a spectral mismatch correction factor (if the spectral response of the detector is known);
- using a correction factor from the manufacturer (if supplied for a particular source); or
- using filters.

For all visible range detectors, including  $V(\lambda)$  detectors, the stability of the spectral response should be checked periodically, and this may be performed using glass colour filters. The following types of filters are recommended:

- Blue filter Schott type BG28 (1 mm or 2 mm)
- Green filter Schott type VG6 (1 mm)
- Red filter Schott type RG610 (3 mm)

As glass filters are subject to aging, filters must be calibrated before each use or the facility must determine a suitable calibration interval depending on accumulated history of stability.

## Laser Power Meters

The sensitivity of the photodetector and filter, if fitted, and associated electronics combination must be checked regularly.

Linearity of response must be checked initially with additional linearity checks to be performed as required.

A visual inspection of the laser power meter detector receiving surface must be performed regularly due to the risk of laser induced damage.

## Radiometers

The spectral response, over the region of interest, and linearity must be checked.

If fitted with a diffuser device, the cosine correction must be checked. Band pass should be verified.

## Spectrophotometers

The wavelength accuracy, band pass, stray radiation, linearity of response, repeatability and optical alignment of a spectrophotometer must have been checked within six months prior to its use for the ranges of use.

Glass colour filters should be used to check the spectral characteristic of the spectrophotometer and the accuracy of colour measurements. Configuration changes will require recalibration.

### **Spectroradiometers**

The wavelength accuracy, band pass, stray radiation, linearity of response, spectral response and repeatability must be checked regularly. Configuration changes will require recalibration.

### **Standard lamps – discharge**

A group of at least three reference lamps plus three working lamps is recommended for each type of discharge lamp tested with ballast in matching pairs. Unfortunately, there is a great variety of types of these lamps which also exhibit poor stability. Lamps must be shown to be stable before nominating as standards. Alternatively, discharge lamps may be compared with reference incandescent lamps. This procedure reduces the number of lamps needed, but requires a knowledge of the spectral properties of each lamp type tested, as well as a knowledge of the photometric integrator and of the  $V(\lambda)$  correction of the photocell used.

### **Standard lamps – incandescent**

A group of at least six lamps is recommended for each calibration type, three reference and three working. Lamp current and voltage must be measured and recorded using instruments with accuracies of  $\pm 0.1\%$  or better. There must be an appropriate warm-up time and the burning times of lamps must be recorded.

# Calibration Appendix G: Ionising Radiation Measurements

This appendix is divided into two sections; the first provides additional guidance and recognition of the general requirements that are applicable to all types of measurements in this discipline, while the latter provides additional guidance and recognition of the requirements that are specific to individual types of measuring equipment. For ease of use and to avoid fragmentation of the guidance, the clauses of ISO/IEC 17025 have not been applied.

## General requirements

### Personnel

The staff shall be conversant with the facility's operational and safety procedures in the handling and use of radioactive material and ionising radiation.

### Accommodation and environmental conditions

The safety features and operational procedures of the facility shall comply with the relevant requirements of AS 2243.4 Safety in Laboratories - Ionizing radiations and State regulatory authorities to assure adequate radiation protection. A radiation protection program shall be established and documented.

The facility's ambient conditions for temperature, relative humidity and where appropriate barometric pressure shall be monitored and records kept.

### Measurement traceability

**Note:** The Chief Metrologist of Australia's National Measurement Institute (NMI) has issued authorisations to the Australian Nuclear Science and Technology Organisation (ANSTO) and the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) under the National Measurement Act 1960 (Cth) to maintain the necessary Australian primary and secondary standards of ionising radiation.

Responsibility for these Australian Standards for ionising radiation are distributed between ANSTO and ARPANSA as follows:

	Primary Standard	Secondary Standard
activity	ANSTO	ANSTO
exposure	ARPANSA	ANSTO, ARPANSA
absorbed dose	ARPANSA	ANSTO, ARPANSA
air kerma	ARPANSA	
Ambient dose equivalent		ARPANSA

When measurements are for legal purposes in Australia and there is a necessity for them to have legal traceability, the measurements must be traceable to the standards maintained by either ANSTO or ARPANSA under their Authorisations from the NMI's Chief Metrologist or covered by a regulation

21 certificate. Traceability is only valid where the measurements are carried out using a technically valid procedure and calibrated measuring instruments or a calibrated radioactive standard, as appropriate. The determination of the uncertainty of the measurement is also part of the chain of traceability and shall include any uncertainty associated with the working radiation standard.

## **Specific requirements for types of measurement equipment**

### **Alpha-particle Measuring Instrument Calibration**

#### **Test and calibration methods and method validation**

The calibration procedure shall also describe the handling of the source. It shall ensure that the distance between the surface of the radiation detector and that of the alpha source is not greater than 3 mm and the source beam shall overlap the detector in all directions from their common axis.

#### **Measurement traceability**

The radionuclide shall be calibrated for alpha emission rate per unit area and shall be traceable to a primary standard.

Alpha radiation sources (planar or pseudo-planar) shall be used and their  $2\pi$  surface emission rate (per unit area) shall be known.

$^{230}\text{Th}$  and  $^{241}\text{Am}$  are acceptable sources.

The radiation fields produced by the sources shall cover a range of at least three decades of alpha emission rates suitable for protection-level calibration.

#### **Reporting the results**

The calibration report shall include the identity of the radionuclide used, its traceability to the national standard, the emission rates at which the instrument was calibrated, the instrument detector response at each measurement point and a linearity check for each range.

### **Beta-particle for Contamination Monitoring Instrument Calibration**

#### **Accommodation and environmental conditions**

The radiation room shall be such that scattered radiation, at the positions where the instruments are positioned for calibration, does not introduce significant errors in air kerma rate.

#### **Test and calibration methods and method validation**

The calibration procedure shall also describe the handling of the source. It shall ensure that the distance between the surface of the radiation detector and the beta source is not greater than 10 mm for low energy emissions and 50 mm for high energy emissions. The source beam shall overlap the detector in all directions from their common axis.

#### **Measurement traceability**

The radionuclide shall be calibrated for beta emission rate per unit area and shall be traceable to a primary standard.

Beta radiation sources for calibrating contamination survey instruments have low energy levels. ISO 8769 recommended radionuclides such as  $^{14}\text{C}$ ,  $^{147}\text{Pm}$ ,  $^{204}\text{Tl}$ ,  $^{36}\text{Cl}$ ,  $^{90}\text{Sr}$  +  $^{90}\text{Y}$  are acceptable sources.



The surface emission rate (i.e. number of particles of a given type above a given energy emerging from the face of the source or its window per unit time) shall be known to be better than  $\pm 10\%$ .

### **Reporting the results**

The calibration report shall include the identity of the radionuclide used, its traceability to the national standard, the emission rates at which the instrument was calibrated, the instrument detector response at each measurement point and a linearity check for each range.

## **Beta-particle Field Measuring Instrument Calibration**

### **(Integrating dosimeters and dose-rate meters)**

#### **Accommodation and environmental conditions**

The radiation room shall be of sufficient size such that scattered radiation, at the positions where the instruments are positioned for calibration, does not introduce significant errors in air kerma rate.

#### **Test and calibration methods and method validation**

The calibration procedure shall also describe the handling of the source and shall include the timing of the radiation beam used for calibration of fluence measuring instruments. It shall state that the beta-particle beam (field) size shall be large enough to accommodate the instrument being calibrated. The uniformity of the beta dose rate field shall be verified by measurement with a small area detector or film.

The beta radiation fields shall be characterised for absorbed dose rates and at each distance of irradiation from the source used.

There shall be no attenuation from the source self-absorption, containment or from beam flattening filters or air attenuation which may significantly change the beta spectrum. The same criteria for  $E_{res}$  listed below shall apply.

#### **Measurement traceability**

The radionuclides shall be characterised for dose rate at a given distance and this value shall be traceable to a primary standard.

Any radiation response measuring system used as a transfer standard for dose rate shall be traceable to appropriate national standards.

The radiation source shall provide a uniform field. This may be achieved by the use of a source small enough to be considered as a point source or by the use of beam flattening filters. However, distributed sources may be used where the instrument to be calibrated presents extreme measurement geometry.

ISO 6980 recommends suitable reference sources for beta radiation instrument calibration. Sources, such as  $^{90}\text{Sr} + ^{90}\text{Y}$ ,  $^{204}\text{Tl}$  and  $^{147}\text{Pm}$ , may be used with suitable beam flattening filters to produce a uniform dose rate over a large area at a specified distance.

Contamination by other radionuclides may change the beta or gamma radiation field emitted from a source. The beta spectral purity is considered to be adequate if the plot used to measure  $R_{res}$ , in an absorbing material, has a linear section, and the  $E_{res}$ , residual maximum energy, value meets the criteria below:

$E_{\max}$	$E_{\text{res}}/E_{\max}$
<100 keV	$\geq 0.6$
100 to 800 keV	$\geq 0.7$
>800 keV	$\geq 0.8$

Standards consisting of a thin-window fixed volume ionisation chamber or an extrapolation chamber shall be suitable for the range of beta energies, intensities and depth of dose measurement point being measured.

### **Reporting the results**

The calibration report shall include the identity of the radionuclide (point source) and radiation field type (flat field) used, the reference dose rates and the dose rate (or dose) indicated by the instrument at each calibration point. The orientation of the instrument with respect to the radiation beam shall be described.

## **X-Ray Measuring Instrument Calibration**

### **(Dosimeters and dose-rate meters)**

#### **Accommodation and environmental conditions**

The radiation room shall be of sufficient size such that scattered radiation, at the positions where the instruments are positioned for calibration, does not introduce significant errors in air kerma rate.

#### **Test and calibration methods and method validation**

The X-ray field shall be characterised for ambient dose equivalent rate or exposure rate (air kerma) at the location of the detector of the instrument for calibration.

If the exposure delivered to the measuring instrument is controlled by a shutter operated by a timer, then any associated timing errors due to shutter transit times or high voltage ramping, shall be accounted for.

There shall be a system in place to check the radiation qualities and the output of the X-ray unit on a regular basis.

#### **Measurement traceability**

The kVp shall be measured with a high voltage divider and the measuring system should be calibrated and be traceable to an appropriate national standard.

If a high voltage divider is not used, then it must be demonstrated that the method is capable of determining the kVp to within a given percentage of its true value and this must be stated.

The X-ray beam produced shall be evaluated according to the provisions of ISO 4037.

Acceptable sources of radiation shall be as stated in ISO 4037.

### **Reporting the results**

The calibration report shall include details of the X-ray beam, the reference value of the exposure (air kerma) rate or exposure (air kerma), the corresponding instrument reading and range setting.

The orientation of the instrument or detector shall be described.

## **Gamma-Ray Measuring Instrument Calibration**

### **Accommodation and environmental conditions**

The radiation room shall be of sufficient size such that scattered radiation, at the positions where the instruments are positioned for calibration, does not introduce significant errors in air kerma rate.

Radiation source storage containers shall provide sufficient shielding such that leakage radiation does not raise the background to a level where it contributes more than 10% of the measurement being made. The scattered radiation in the useful beam shall not exceed what is specified in ISO 4037 for the air kerma rate at any location where a detector is positioned for calibration. The approximate energy spectrum of the scattered radiation should be known.

An appropriate source shall be used as specified in ISO 4037.

The radiation fields produced, shall cover a range of air kerma rates covering the operating ranges of the instruments for calibration. The gamma beam shall be controlled from the source's storage container and the central axis shall be defined. The standard ionisation chambers and electrometer shall be able to cover the energy and intensity ranges used.

### **Test and calibration methods and method validation**

The calibration method shall also describe how the source is manipulated and positioned.

The gamma radiation field shall be characterised for air kerma rate as a function of distance from the source.

The intensity of the gamma beam shall not vary by more than 5% across the useful area of the beam or as specified in ISO 4037.

If the beam of radiation is controlled by a shutter operated by a timer, then any associated timing errors due to shutter transit times, shall be accounted for.

If an attenuator is used to reduce air kerma rate at any location in the beam field, its effect on the energy spectrum shall be specified or the effect of the altered spectrum on the accuracy of the calibration of each instrument type shall be specified.

### **Measurement traceability**

The source shall be characterised for gamma air kerma rate and be traceable to the appropriate primary standard.

The radiation response measuring system shall be calibrated and shall be traceable to the appropriate national standards.

### **Reporting the results**

The calibration report shall include the identity of the radionuclide used, the reference value of the air kerma rate or air kerma and the instrument detector response at each measurement point for each range of the instrument.

## Neutron Measuring Instrument Calibration

The specific requirements for the calibration of portable instruments for measuring neutron ambient dose equivalent rate at radiation protection levels are described below.

### Accommodation and environmental conditions

The radiation room shall be of sufficient size such that scattered radiation, at the positions where the instruments are positioned for calibration, does not introduce significant errors in the air kerma rate at the calibration position.

The neutron source shall preferably be used for calibration in a low-scatter environment, in an open area or at the centre of a large room (e.g. 10 m x 10 m with the source 4 m from both floor and ceiling). The room-scattered neutrons at the point of calibration should be less than 25% of the total instrument response and the appropriate corrections shall be made.

### Test and calibration methods and method validation

The calibration method shall also describe the handling of the source capsule. The neutron radiation field shall be controlled and monitored when moving the source from a shielded to an exposed position. Appropriate timing control shall be used for the calibration of integrated ambient dose equivalent measuring instruments.

The radiation field shall be characterised for fluence rate (flux density) and for spectral composition at the point of calibration. The ambient dose equivalent rate shall be calculated on the basis of these characteristics as a means of setting calibration points for specific instrument types.

Correction for room scatter, air attenuation, air in-scatter and anisotropy of the calibration source shall be accounted for.

### Measurement traceability

The radionuclides shall be characterised for neutron fluence rate (flux density) and be traceable to a primary standard. The fluence rate shall be converted to ambient dose equivalent rate based on conversion coefficients in ISO 8529. The source should be spherical or cylindrical and its anisotropy should be measured and accounted for.

The radiation response measuring system shall be calibrated and corrections shall be applied for any effects due to contamination of the neutron field by other types of radiation (e.g. photon or beta) if any.

The selection of a neutron source shall be such that the radiation field produced will provide an energy spectrum and ambient dose equivalent rates appropriate to the instrument being calibrated.

$^{241}\text{AmBe}$ ,  $^{238}\text{PuBe}$  and  $^{252}\text{Cf}$  or sources as recommended in ISO 8529 are acceptable sources.

### Reporting the results

The calibration report shall include the identity of the radionuclide anisotropy of all sources used, and radiation field type (moderated or unmoderated), fluence rate, the scatter-corrected instrument reading at each calibration point and the conversion coefficient for calculating ambient dose equivalent rate from fluence rate. The orientation of the instrument with respect to the radiation field shall be described. The values of all corrections used shall be stated.

## Personal Radiation Monitoring Devices

Personal radiation monitoring devices used to assess the radiation dose received by occupationally exposed persons include:

- film badge dosimeters;
- thermoluminescent dosimeters (TLD);
- track etch plastic plaque (CR39) dosimeters;
- quartz fibre electrometer dosimeters; and
- direct reading electronic dosimeters.

A facility which issues film badge dosimeters, TLDs or plastic plaque dosimeters shall have available calibration facilities which may be used to expose reference personal dosimeters to known doses of beta, X-, gamma or neutron radiation, as appropriate. In the case of film badge dosimeters these facilities allow the production of calibration curves (optical density versus radiation dose) to be produced, from film badges exposed to known radiation doses, to enable the optical density of the wearers' film badge dosimeters to be interpreted in terms of the radiation dose received. For personal monitoring systems using TLDs as the sensing element, these facilities allow the production of similar calibration data (relating TLD light output to radiation dose) as a function of radiation type and energy.

Quartz fibre dosimeters and direct reading electronic dosimeters shall be calibrated in a manner similar to that for other ionising measuring instruments. (See Sections 'X-Ray Measuring Instrument Calibration' and 'Gamma-Ray Measuring Instrument Calibration'.)

### Test and calibration methods and method validation

ISO 4071 should also be consulted.

The calibration method shall provide details of:

- the method of calibration of the radiation output from each radiation source used in the calibration process and details of its traceability to the appropriate national standard;
- each 'secondary standard' instrument (e.g. ionisation chamber and electrometer) used to calibrate the radiation sources/fields of the calibration facility and of its calibration traceability;
- the phantom used and the positioning of the dosimeter.

The intensity of X- and gamma radiation fields should not vary by more than 5% across the useful beam at the position of the personal dosimeter being calibrated. Corrections for lack of field uniformity shall be applied if the variation exceeds 5%.

Appropriate timing control shall be used for the calibration of the personal dosimeters.

If an attenuator is used to reduce the air kerma rate at any location in the radiation beam its effect on the energy spectrum must be specified or the effect of the altered spectrum on the accuracy of the calibration of the personal radiation monitoring device shall be known.

Dosimeters shall be calibrated in terms of  $H_p(10)$ , i.e. personal dose equivalent and  $H_p(0.07)$  directional dose equivalent using the conversion coefficients in ICRP74.

### **Measurement traceability**

The X- and gamma radiation fields used for calibration shall be characterised in terms of air kerma rate and shall be traceable to an appropriate national standards.

The beta radiation fields used for calibration shall be characterised in terms of absorbed dose to tissue or air (at a depth in tissue of  $7 \text{ mg/cm}^2$ ) at a given position or distance from the source and shall be traceable to appropriate national standards.

The neutron radiation field used for calibration shall be characterised in terms of the fluence rate (flux density) and spectral composition at the point of calibration and shall be traceable to an appropriate national standards.

The calibration of the standard ionisation chamber(s) and electrometers used in the calibration facility shall be traceable to an appropriate national standard.

Appropriate neutron energies are specified in ISO 8529.

Radioactive sources used for calibration shall be stored in a manner such that any leakage radiation from them does not raise the background, in the calibrating area, to a level which contributes more than 1% of the dose rate used for each calibration.

The radiation sources used for calibration shall be such that each reference film badge dosimeter and reference TLD can be exposed to X- and gamma radiation doses in the range 50 to 20,000 microsievert.

The standard ionisation chamber(s) and electrometer used in the calibration facility shall be able to cover the energy and intensity ranges used.

A phantom that represents a body should be used when calibrating personal radiation dosimeters. A suitable phantom is a 30 cm x 30 cm x 15 cm poly methyl methacrylate.

### **Reporting the results**

The calibration report shall include details of the radionuclides and X-ray machines used, details of their traceability to the relevant national standards, the dose to which each reference film badge or TLD was exposed, the conversion coefficients used to determine  $H_p(0.07)$  and  $H_p(10)$  and reference to ICRP74.

### **Measurement of Radionuclide Activity**

**(used in medicine, pharmaceutical industry and research)**

#### **Test and calibration methods and method validation**

The test method shall also describe the handling of the radionuclide. There shall be a test procedure for checking the measuring system to monitor the validity of the test data.

Examples of derivation of uncertainties of measurement of radioactivity covering the required ranges shall be documented.

### **Measurement traceability**

The measuring system shall be capable of measuring the range of activity for the radionuclides to be characterised. There shall be a means of recording of the time and date.

Radionuclide standards traceable to an appropriate national standard shall be used to calibrate the measurement system.

Differences in geometry between the source under test and the reference standard shall be accounted for.

Consideration shall be given to the effects of shielding, impurities and background.

The measuring system shall be calibrated for the range of radionuclides to be tested. The calibration shall be traceable to the appropriate primary standard of activity for specific radionuclides. In-house checks on the measuring system shall be carried out daily for linearity and at three-monthly intervals for stability.

### **Reporting the results**

The certificate of measurement (can be called characterisation) of the radionuclide activity shall include the calibration time and date associated with the measured radioactivity, life time and a statement of the uncertainty of measurement accompanied by a confidence level or coverage factor.

## Glossary for Ionising Radiation Measurements

### **absorbed dose**

The quotient of  $dE$  by  $dm$ , where  $dE$  is the mean energy imparted by ionising radiation to matter of mass  $dm$ . The unit of absorbed dose is joule per kilogram ( $J.kg^{-1}$ ) with the special name gray (Gy).

### **air kerma**

When the material referred to in the definition of 'kerma' (see below) is air.

### **attenuator**

Absorbing material intentionally placed in the path of a radiation beam to reduce its intensity.

### **beam flattening filter**

A specially shaped attenuator used to modify a radiation beam profile so that the beam profile perpendicular to the beam direction is flat in accordance with a specified tolerance.

### **calibration**

The set of operations which establish, under specified conditions, the relationship between values indicated by a measuring instrument or measuring system, or values represented by a material measure, and the corresponding known values of a measurand.

### **conversion coefficient**

Coefficient used to convert air kerma free-in-air or exposure to ambient dose equivalent for the radiation beam under investigation.

### **E<sub>max</sub>**

The maximum beta particle energy emitted by an unattenuated source of beta radiation.

### **E<sub>res</sub>**

The residual maximum beta energy after the beta spectrum is modified by absorption and scattering in the source material itself, the source holder, the source encapsulation and other media between the source and the calibration position.

### **extrapolation chamber**

A parallel plate ionisation chamber in which the distance between the plates can be varied, thereby enabling a series of measurements with decreasing separation, so that the measured ion current per unit volume can be extrapolated to the case of infinitesimal volume.

### **flux density**

The number of neutrons, which, per unit time, enter a sphere of cross sectional area; it is expressed in  $neutrons.m^{-2}.s^{-1}$ .

### **free-air facility**

A calibration facility in which the radiation emitted by the source reaches the instrument under calibration with minimal scatter from nearby structures.



**kerma**

The kinetic energy released in material by ionising radiation. Kerma is determined as the quotient of  $dE_{tr}$  by  $dm$ , where  $dE_{tr}$  is the sum of all the kinetic energies of all the charged ionising particles in a material of mass  $dm$ . The unit of kerma is joule per kilogram ( $J.kg^{-1}$ ) with the special name gray (Gy).

**leakage radiation**

All ionising radiation coming from the source except the useful beam.

**measurand**

A specific quantity subject to measurement.

**neutron fluence**

The time integral of neutron flux density.

**neutron fluence rate**

The number of neutrons per unit cross-sectional area per unit time.

**point source**

A radiation source the maximum dimension of which is small compared to the source-to-detector distance used for the irradiation of an instrument or dosimeter.

**R<sub>res</sub>**

The residual maximum beta range in an absorbing material of a beta spectrum of residual maximum energy  $E_{res}$ .

**reference personal dosimeter**

A personal dosimeter which is exposed to a known dose of ionising radiation and used to provide calibration information for measuring the dose received by personal dosimeters worn by customers of a personal radiation monitoring service.

**scattered radiation**

Radiation that, as a result of interaction with matter, has had its direction changed and, in some cases, its energy also changed.

## References

This section lists publications referenced in this document. The year of publication is not included as it is expected that only current versions of the references shall be used.

### NATA Publications

*NATA Rules*

*ISO/IEC 17025 Standard application document (SAD) for the accreditation of testing and calibration laboratories*

*NATA Policy Circular 11, Policy on Metrological Traceability*

*NATA Policy Circular 12, NATA Policy on equipment assurance, in-house calibration and equipment verification*

### Standards and other references

*AS 1000 The International System of Units (SI) and its application*

*ISO/IEC Guide 98-3 Uncertainty of measurement - Part 3: Guide to the expression of uncertainty of measurement*

### Appendix A: Acoustic and Vibration Measurement

AS 1259.1	<i>Sound level meters: non-integrating</i>
AS 1259.2	<i>Sound level meters: integrating - averaging</i>
AS/NZS 2399	<i>Acoustics – Specifications for personal sound exposure meters</i>
ISO 16063–11	<i>Methods for the calibration of vibration and shock transducers – Part 11: Primary calibration by laser interferometry</i>
ISO 16063–21	<i>Methods for the calibration of vibration and shock transducers – Part 21: Vibration calibration by comparison to a reference transducer</i>
AS/IEC 60645.1	<i>Electroacoustics – Audiological equipment Part 1: Pure-tone audiometers</i>
IEC 60318-6	<i>Electroacoustics – Simulators of the human head and ear – Part 6: Mechanical coupler for the measurement of bone vibrators.</i>
IEC 60651	<i>Sound level meters (superseded)</i>
IEC 60804	<i>Integrating-averaging sound level meters (superseded)</i>
AS/IEC 60942–2004 (IEC 60942)	<i>Electroacoustics – Sound calibrators</i>
IEC 61094	<i>Measurement microphones</i>

IEC 61161	<i>Ultrasonics – Power measurement – Radiation force balances and performance requirements</i>
IEC 61672	<i>Electroacoustics - Sound Level Meters</i> <i>Part 1: Specifications (Also published as an AS standard)</i> <i>Part 2: Pattern evaluation tests (Also published as an AS standard)</i> <i>Part 3: Periodic tests (Not yet released as Australian Standard at time of print)</i>
ISO 3741	<i>Acoustics -- Determination of sound power levels of noise sources using sound pressure -- Precision methods for reverberation rooms</i>
ISO 3745	<i>Acoustics -- Determination of sound power levels of noise sources using sound pressure -- Precision methods for anechoic and hemi-anechoic rooms</i>
OIML R88	<i>Integrating-averaging sound level meters</i>

## **Appendix B: Mass and Related Quantities**

*The Calibration of Weights and Balances*, E C Morris and K M K Fen, National Measurement Institute, Australia NMI Monograph 4.

AS 2193	<i>Calibration and classification of force-measuring systems</i>
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## **Appendix E: Temperature Metrology**

AS 1530.1	<i>Methods for fire tests on building materials, components and structures - Combustibility test for materials</i>
AS 2853	<i>Enclosures – Temperature Controlled-Performance testing and grading</i>
EURAMET cg-13	<i>Calibration of Temperature Block Calibrators</i>

*Uncertainty in Measurement: The ISO Guide – RE Bentley, NMI Monograph 1*  
*Applying the ISO Guide to the Calculation of Uncertainty: Temperature – RE Bentley, NML Publ. No. TIP P1358*

## **Appendix G: Ionising Radiation Measurements**

AS 2243.4	<i>Safety in Laboratories - ionising radiations</i>
ICRP74	<i>Conversion coefficients for use in radiological protection against external radiation</i>
ISO 4037	<i>X- and gamma reference radiations for calibrating dosimeters and dose ratemeters and for determining their response as a function of beta radiation energy</i>
ISO 6980	<i>Reference beta radiations for calibrating dosimeters and dose ratemeters and for determining their response as a function of beta radiation energy</i>

- ISO 8529            *Neutron reference sources for calibrating neutron-measuring devices used for radiation protection purposes and for determining their response as a function of neutron energy*
- ISO 8769            *Reference sources for the calibration of surface contamination monitors. Beta emitters (maximum beta energy greater than 0.15 MeV) and alpha emitters*
- ISO 4071            *Exposure Meters and Dosimeters – General methods for Testing*

## Amendment Table

The following amendments were made to the *Calibration ISO/IEC 17025 Application Document*.

Please refer to this sheet in conjunction with the *NATA Procedures for Accreditation* and the associated ISO/IEC 17025 Application Document and Annexes to ensure that you are familiar with these amendments.

<b>AMENDMENT TABLE</b>		
<b>Title</b>	<b>Clause or Class of test amended</b>	<b>Amendment</b>
	All sections	Editorial revision of all section providing a correction to grammar and uniformity of style.
Review of requests tenders and contracts	Clause 4.4 of 17025	Providing additional clarity and criteria applied when the calibration laboratory's uncertainty may not be appropriate for the level of accuracy the device under test may achieve.
Reporting the uncertainty of measurement	Clause 5.10.4 of 17025	A slight lessening of the criteria applied when rounding the reported uncertainty of measurement, making reference to the GUM.
Weighing device calibration	Annex B	Significant revision of the guidance and requirements applicable to the calibration of weighing devices.
Working Force Standards	Annex B	An interpretation to the methodology provided in AS 2193 when classifying a working force standard. Both the continuous class and point class methods may be used, however the classification reported must only apply to measurement points applicable to the method used.
Acceleration of Gravity	Annex B	New guidance and requirements added.
Time and Frequency Standards	Appendix D	Update of the guidance provided when using Global Navigation Satellite Systems as traceable standards.
Thermocyclers	Appendix E	Guidance added to assist with the calibration or periodic verification of thermocyclers (PCR machines).
Reels of thermocouple wire	Appendix E	Revision of the criteria for the calibration of reels of thermocouple wire to a less prescriptive requirement, that being a need to assess inhomogeneity in the reel.
Humidity	Appendix E	Addition of specific criteria for stating the CMC of a humidity calibration capability.