




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 but since not all clauses require interpretation the numbering may not be consecutive.

The terms facility and laboratory are interchangeable in this document.

4 Management requirements

4.1 Organisation

4.1.3 In-situ testing

Facilities can be accredited for carrying out in-situ, at the customer's site and/or mobile calibration of equipment. Specific ranges and least uncertainties applicable to in-situ work and mobile facilities will be included in the facility's scope of accreditation if the calculated uncertainties are different to work carried out at the main laboratory.

The facility bears the responsibility for ensuring that conditions at the customer's premises are suitable for the work to be carried out.

Special precautions shall be adopted and documented with regard 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 that it meets the requirement of the test specification. Temperature shall be monitored and recorded during stabilisation and calibration work;
- ensuring that reference equipment has reached thermal equilibrium.

As well as factors such as temperature and humidity, additional care needs to be exercised that other factors outside of the control of the facility staff (e.g. the electromagnetic environment, stability of the available power supply) are considered when setting up and conducting calibrations and tests.

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.

Agreement of the customer is needed for inclusion of a recalibration interval on the report and calibration label on the instrument. This should be addressed at the review phase (refer Clause 5.10.4.4 of ISO/IEC 17025) unless there is an overriding legal requirement.

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

When a facility's calibration uncertainty is known to be larger than the Instrument Under Test (IUT) manufacturer's specification, then evidence that this was discussed with the customer must be retained.

4.13.2.1 Control of records

Information on the sources of uncertainty

Calibration certificates on reference equipment need to be kept for longer periods than just their validity in order to be able to determine the equipment stability. This 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 including the issuing of test reports and/or assuming technical control of the 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 and the information on which it has been made must be maintained.

5.2.5 Persons issuing test reports

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.

Individuals who issue test results assume responsibility for the technical validity and accuracy of all information contained in test reports. 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 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 test results shall hold a position within the organisation which provides authority over the calibration and/or testing activities and, where necessary, results to be rejected when they consider them to be inadequate.

Consultants to the facility may issue test reports provided they have the knowledge necessary to allow them to have authority over the testing and/or calibration activities. Consultants must also hold a written contract or agreement with the facility in which their role and authority is clearly defined and that they agree to hold confidential information relating to customers of the facility. The agreement should further indicate that the facility is responsible for work performed by the consultant including acceptance of the indemnity responsibilities detailed in NATA Rules.

Persons who have overall technical control of the calibrations

For calibration activities, the facility shall have one or more key personnel who assume full 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).

The facility 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 or issue calibration 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 higher level than which has been supported or demonstrated through suitable proficiency testing or measurement audits.

Where a facility's approval process for assigning staff to critical tasks including the release test results or assuming full technical control of the calibrations, is found to not satisfy the requirements for accreditation, the facility will be required to review all reports 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.

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.

The environmental conditions shall be monitored at appropriate intervals and measurement activities suspended when the environmental conditions fall outside the specified limits.

5.4 Test and calibration methods and method validation

5.4.1 General

Where a facility is requesting a minor variation that relates to changes or additions of published standards, the application for addition must be supported by a gap analysis between relevant standards that are already in the scope and the new standard.

5.4.2 Selection of methods

Facilities accredited for tests to published test methods must have a system in place to ensure that such documents are the current version.

Recommended reference literature and test methods that are acceptable may be found in the metrology discipline sections below.

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 will include the facility's estimate of their least uncertainty of measurement for each measurement range. Associated parameters such as frequency at AC voltage or temperature at humidity must also be stated. Facilities are required to maintain detailed records for these 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 smallest 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. This is generally achieved through employing one or more of the following methods for expression of the uncertainty:

- A single value, which 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.
- An explicit function of the measurand or a parameter.
- Open intervals (e.g., " $U < x$ ") are not allowed in the specification of uncertainties.
- A matrix of measurement points.

The 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., per cent. Usually the inclusion of the relevant unit gives the necessary explanation. The uncertainty in the CMC shall be stated to no more than 2 significant figures.

Calibration 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 CMC, laboratories shall take notice of the performance of the “best existing device” which is available for a specific category of calibrations. Uncertainty contributions 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 should be included in the CMC uncertainty component, when available. There should, on the other hand, 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 recognized 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.

A facility is not permitted to report an uncertainty of measurement which is less than that stated in their CMCs on an endorsed report.

The facility's ability to achieve their stated CMC giving consideration to the extremes of measurement range and smallest uncertainty is evaluated during on-site assessments and by review of proficiency testing results. For customer calibrations, in addition to the requirements as listed for CMCs above, uncertainty calculations must include components for contributions from the customer's device under test including the resolution of the device and observed drift.

Appropriate methods of uncertainty of measurement analysis are contained in;

- the *ISO Guide to the Expression of Uncertainty in Measurement*,

- 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.

5.4.7 Control of data

Facilities shall ensure that appropriate checks of calculations and data transfers have been carried out before results are issued.

Whenever possible, a second staff member should check all calculations and data transfers. Worksheets must have a place dedicated for the signature of the checking officer. Special care should be taken to ensure that correct formulas are used in computer spreadsheets.

Problems may arise when computer files such as spreadsheets, word processor worksheets and/or report files are reused by overwriting previous results. 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 changes to software. It must include careful examination of cell formulae as well as comparison against data sets that have been manually checked. Signed and dated validation records must be kept.

5.6 Measurement traceability

5.6.2 Specific requirements

In-house calibrations

A facility performing its own calibrations will also be subject to technical assessment of these 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. Specialist calibration 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. Accreditation cannot be given for extremes of the measurement range based on extrapolation beyond the maximum and minimum calibration points.

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 this clause, 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 identification and customer are recorded immediately upon receipt.

5.9 Assuring the quality of test and calibration results

The NATA Proficiency Testing Policy (Policy Circular 2) requires each applicant or accredited facility to participate in appropriate proficiency testing where available and/or as instructed by NATA. In line with this policy, 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. 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.

This criteria has been created to inform facilities about the minimum PT requirements for accreditation, so that they can arrange and maintain their own PT activities.

The onus is on each facility to ensure participation in suitable 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.

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

PT participation

Facilities must be able to support their claimed best CMC through participation

of an appropriate measurement comparison conducted as a round robin program or measurement audit with a facility with an equivalent or better CMC. Records are to be made available prior to requests for variations to scope, initial assessment or prior to scheduled reassessments.

In some circumstances where sourcing of an appropriate measurement comparison is difficult, the assessment team will consider other records in support of the claimed CMC, including, comparisons with non-accredited facilities, measurement methodology, reference equipment, measurement uncertainty calculations and 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 lower 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, thermometers and thermocouple calibration will be considered one measurement group, similarly, all measurements related to electrical low frequency calibration, DC volts, AC volts, current, 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 calibration	Survey equipment calibration	

When a facility initiates and conducts its own inter- or intra-laboratory comparison, it must be able to demonstrate that the testing officer is not aware of the reference values. The appropriateness of the proficiency testing 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 detail in the scope of accreditation is to be tested.

For measurement audits, results will be evaluated by E_n ratios. The E_n ratio is used to evaluate each individual result from a facility. E_n stands for 'Error normalised' and 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. $|E_n| \leq 1$ = satisfactory

$|E_n| > 1$ = unsatisfactory

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

The on-going competence of facility staff to perform infrequent tests which are covered by the facility's scope of accreditation must be demonstrated and records must be maintained.

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 ISO/IEC 17025 clause 5.10.4.2, 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 ISO/IEC 17025 clauses 5.10.4.2 and 4.13, 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 test or 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 rounded up and 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.

The measurement results should be rounded to report no smaller resolution than the readability of the instrument being calibrated.

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.

Calibration labels

Calibrations labels that include the NATA emblem shall also include an identification of the facility and the associated NATA endorsed document number.

Calibration Appendix A: Acoustic, Ultrasonic and Vibration Measurement

Acoustic measurements

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.

5.3 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. Instruments with larger masses and specialist materials (such as artificial mastoids) may need many hours to equilibrate before reliable measurements can be made. Always follow recommendations of the Standard relevant to the calibration (see References).

Anechoic and reverberant rooms

Such rooms must be evaluated in terms of the requirements of relevant test procedures. Reports of evaluations must be available 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 acoustic performance tests will be inspected and must comply with the requirements of the test procedures. 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.

5.5 Equipment

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.

5.6.2.1 Calibration

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.

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 part 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 3 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 of a stand-alone unit built of analogue components, the complete tests described in DIN 45657 must be carried out to include 3 ramped down/up amplitude cycles with one cycle centered on the dynamic range limits and the 2 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:

- L_n 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 (in units of dB re 1 V/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

To be accredited for field vibration measurements, a suitably calibrated vibration calibrator must be available to perform checks on a vibration transducer set before and after a field measurement.

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 method validation. ISO 16063-11 or -21 should be followed, or ISO 16063-41 for laser vibrometers

Piezo-electric accelerometers.

Piezo-electric or charge type transducers should be calibrated where possible 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 ICP / CCLD internal impedance conversion types should be calibrated with the power supply specified for the device which must be clearly stated on the calibration certificate.

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 as a unit with all associated acquisition hardware and operating software. Often calibrations will state a ratio of the applied acceleration (or velocity) compared to the measured / displayed acceleration (or velocity).

Ultrasonic power meters

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

Balance calibration

5.3 Accommodation and environmental conditions

Calibration location

Balances are sensitive to transportation, their environment and changes in gravity. Consequently, balances shall be calibrated at the location at which they are to be used.

5.4 Test and calibration methods and method validation

Calibration method

Balances shall be calibrated in accordance with Chapters 6 and 7 of *The Calibration of Weights and Balances* NMI Monograph 4 by Edwin C Morris and Kitty M K Fen.

Preliminary

Reference masses must have reached thermal equilibrium. The balance 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 a balance 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 specified for the balance. After exercising the balance, the error close to full capacity must be recorded. If the balance appears to require physical adjustment or repair, the user must be consulted to determine if a full set of before adjustment readings is required (refer ISO/IEC 17025 5.10.4.3).

It should be ensured that the balance 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 precision laboratory balances, the calibrators hands should not enter the balance chamber during the loading and unloading of the weights on the balance as the resulting air currents and temperature effects can affect the measurements.

Care of masses

Refer to B.3, *The Calibration of Weights and Balances*.

Minimum requirements for the calibration of electronic balances

The *Calibration of Weights and Balances* outlines the full range of balance features that can be measured. The minimum requirements for a balance

calibration when carried out by a NATA accredited facility are summarised below. Note that the relevant section or chapter references from the third edition of the book are nominated in brackets.

Corrections to balance reading (Section 6.3.3)

At least 10 evenly spaced calibration points over the range of the balance must be taken. For balances with more than one range a minimum of 20 evenly spaced calibration points must be taken.

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.

Effect of off-centre loading (Section 6.3.4)

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 (Section 6.3.5)

Hysteresis must be carried out on the first calibration of a new balance or after a balance has undergone a repair to its weighing mechanism. The alternate simplified approach described is permitted in the absence of drift.

Repeatability of measurement (Section 6.3.2)

The repeatability of measurement must be determined at close to both half load and full load. The repeatability can have a significant effect on the Limit of Performance figure for the balance. It usually increases with larger loads, therefore the full-load repeatability test must 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. A separate Limit of Performance must be calculated for each range. The half load repeatability tests are not required unless the actual measuring system is different for each range.

Limit of Performance (Section 6.4.6)

This must be calculated and reported 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 balance for that range or 0.41 of the resolution in that range, whichever is greater.

C_{max} is the magnitude of the maximum correction to balance 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.

5.10 Reporting the results

Calibration report (Section 6.4.6)

Reports shall be laid out in the same manner and include all of the information in the sample report with the exception of 'Uncertainty of weighing of the balance' which is optional (as is the related Note 5). 'Hysteresis' will only be required to be carried out in some calibrations as described above. A traceability statement is also required. Refer to Schedule 2 of the NATA Rules.

Pre-adjustment readings must be recorded (refer to ISO/IEC 17025 5.10.4.3). As a minimum, the correction or error close to full load must be reported.

For balances with more than one range the repeatability, corrections and Limit of Performance for each range must be reported.

For traceability, the precise location of the balance must be reported. The Limit of Performance applies only to the environment the balance was calibrated in.

Corrections, uncertainties of measurement and Limit of Performance figures should be suitably rounded.

Pressure Calibration

5.4 Test and calibration methods and method validation.

The facility will unambiguously specify the range of capability over which calibration can be conducted as a gauge pressure range and/or an absolute pressure range. 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 meter calibration

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 m³ 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.

5.10 Reporting

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

- 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

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:

Any meter 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: 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: 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 IUT.
- Terms specified in industry specific standards.

Key operational characteristics:

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 should 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 or,
- visually examine the IUT/test rig seals; and,
- 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 unparallel 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 for class of test 1.23.04 when a facility calibrates working force standards under the scope of accreditation.

Calibration Appendix C: Dimensional Metrology

5.5 Equipment

Staff 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

Artefact calibration

5.6 Measurement traceability

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.

Multi-channel GPS receivers as traceable frequency standards

5.6 Measurement traceability

NATA has adopted recommendations from the National Measurement Institute on the use of multi-channel GPS (MGPS) receivers as traceable frequency standards.

MGPS receivers have not yet reached a level of reliability to be considered acceptable as standalone traceable frequency references. Some units, however, have reached a level where they may be used in conjunction with a reference oscillator for the purposes of gaining NATA accreditation to perform frequency calibrations.

The following criteria shall apply:

- The GPS and reference oscillator to be used must initially be sent to NMI for determination of stability and general integrity*. Should repairs be performed or the software or hardware be modified or upgraded, the unit must be returned to NMI.
- The facility must obtain from NMI a portable rubidium standard, measure its frequency output and report the results to NMI for verification. This test is to be performed annually.
- The facility must measure at prescribed intervals the frequency of the reference oscillator with respect to the GPS unit. The resolution of these measurements must be consistent with the least uncertainty of measurement stated in the scope of accreditation.
- The reference oscillator, having superior short-term noise performance, must be used as the actual frequency reference. Its frequency must be adjusted only occasionally and not be 'steered'.
- The facility must subscribe to a bulletin board service provided by NMI and make reference to it whenever making measurements of the reference oscillator with respect to the GPS unit. Any corrections for variations between the GPS frequency and the National Frequency Standard must also be made.

- Any appearance of instability outside of the GPS or reference oscillator specifications requires immediate investigation and corrective action.
- Complete records for all measurements, inter-comparisons, adjustments, investigations and other activities must be maintained.

Note: *It is strongly recommended that advice be sought from the National Measurement Institute (NMI) before purchasing GPS based systems.

Calibration Appendix E: Temperature Metrology

5.3 Accommodation and environmental conditions

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.

5.4 Test and calibration methods and method validation

Methods with examples of uncertainty of measurement more focussed on Heat and Temperature Measurement applications are:

- *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

5.6 Equipment Calibration

General Requirements

- 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 1/5th 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.

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 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 report covering the testing techniques used and commenting on the suitability of baths for calibration purposes must be available.

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).

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).

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.

Calibration of Temperature controlled enclosures

- The loading state of the enclosure must be specified in the report.
- Thermocouple wire used for the calibration must be calibrated by an accredited facility. If the facility chooses to calibrate its own wire; it must meet NATA's criteria for performance of in-house calibrations, including participation in thermocouple proficiency tests.

Ovens and Furnaces

Ovens and furnaces would normally be assessed 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 AS2853. 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.

Use of Temperature controlled enclosures

Test furnaces, baths and ovens

Furnaces, baths and ovens used for test work must be examined to determine their compliance with the temperature requirements of the test procedures.

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 down to ambient 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 the effects of inhomogeneity must be considered,

- 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, at least 3 samples (not all from the same end) must be measured, 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 samples may be required.

Digital thermocouple indicators

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

- An uncertainty component for 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 as an (i) aperture in the front of the source is reduced by 10mm, or (ii) 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".

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

5.6 Measurement traceability

The calibration process for devices must include:

- If internal ACJC is used, a calibrated thermocouple, together with a temperature reference, such as ice-point should be used
- 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
- For DUT that are calibrated as an ohmmeter or a voltmeter with a subsequent validation of the $R \Rightarrow T$, $V \Rightarrow T$ conversion, an uncertainty contribution to allow for non-linearity of the resistance or voltage measurement scale of the DUT must be included (e.g. manufacturers specification). To achieve a lower uncertainty, several points over the range must be checked.

5.10 Reporting the results

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.);
- The report must explicitly state that the calibration is an electrical simulation only.

Calibration Appendix F: Optical Metrology

Photometry and radiometry

5.3 Accommodation and environmental conditions

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.

5.6 Measurement traceability

Optical Glass Filters

Colour and neutral density glass filters change the spectral properties of optical radiation. These filters allow scientific and technical 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 (dyed in the mass) glass filters 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:

1. Chromaticity co-ordinates
2. Luminous transmittance (T)
3. Chemical resistance
4. Bubble quality
5. Homogeneity and polish, thickness uniformity
6. Tempering and strengthening
7. Handling and storage

Recommendations for each of these parameters are given below:

1. 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 ± 0.005 units of chromaticity or better).

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

1. Test geometry
2. Illuminant source used
3. Test area(s)
4. Sampling interval and bandwidth used
5. 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.

2. 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 1mm, 2mm or 3mm. 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. Other conditions are the same as for 1 above.

3. 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.

4. Bubble Quality

This parameter is usually characterised by stating the total cross-sectional area of any bubbles in mm^2 , relative to 100 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 mm²) of all bubbles/inclusions, having a dimension greater than 0.05 mm diameter, be less than 0.10 mm²/100 cm³ of glass volume.

5. 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.

6. Tempering and Strengthening

Generally, absorbing filter glass is 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.

7. Handling and Storage of Glass Filters

The following precautions should be observed with Optical Glass Filters:

- 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: 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.

Optical glass filters summary table

Parameters	Comments/Requirements
1. Chromaticity Co-ordinates	C.I.E. 1931 x, y, co-ordinates to be in the appropriate colour region for particular application. Filters to be externally calibrated to have a least uncertainty of ± 0.005 units of chromaticity or better, if the application requires it.
2. Luminous Transmittance T	Spectral Transmittance $T(\lambda)$ - An uncertainty of $\pm 0.2\%$ or better is desirable over the applicable wavelength interval. Luminous transmittance should be determined by a spectrophotometric method.
3. Chemical Resistance	Filters should be resistant to chemical attack by acids, alkalis and other chemical agents.
4. Bubble Quality	Projected area (in mm^2) of all bubbles/inclusions should ideally be less than $0.10 \text{ mm}^2/100 \text{ cm}^3$ of glass volume.
5. Homogeneity & Polish	Optical filters should be homogeneous with respect to optical properties over their entire area. This can be determined by checking that the maximum variation in refractive index is $< \pm 5 \times 10^{-6}$.
6. Tempering	Optical filters should be tempered by the supplier to ensure improved resistance to large temperature gradients or rapid temperature changes.
7. Handling & Storage	<ul style="list-style-type: none"> Avoid exposure to moisture or other chemical agents. Avoid exposure to intense UV radiation. Handle with due care - filters are fragile. Store in an appropriate container.

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

As glass filters are subject to aging, filters must be calibrated before 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. The facility must show that the lamp is stable before nominating it as a standard. 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

General

5.2 Personnel

The facility shall have managerial staff trained in the appropriate scientific disciplines.

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

The testing staff shall be conversant with the testing procedures and test equipment for the measurement of radionuclide activity or for the calibration of ionising radiation survey instruments, dosimeters, surface contamination monitoring instruments and personal radiation monitoring devices.

The staff shall be familiar with and have access to the appropriate publications relating to calibration of ionising radiation monitoring instruments and devices.

5.3 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.

5.4 Test and calibration methods and method validation

The facility shall document procedures for the derivation of and reporting uncertainties of measurement for the radiation quantities or radiation measuring devices.

5.6 Measurement traceability

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

Measurement of ionising radiation quantities shall be traceable to ARPANSA, ANSTO or a recognised overseas national standard, as appropriate. 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.

Alpha-particle Measuring Instrument Calibration

The specific requirements for the calibration of instruments for measuring alpha contamination on surfaces and emission rates of alpha emitting radionuclides at radiation protection level, are described under the following clauses.

5.4 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.

5.6 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 2π surface emission rate (per unit area) shall be known.

^{230}Th and ^{241}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.

5.10 Reporting the results

In addition to the requirements on reporting under clause 5.10.2, 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

The specific requirements for the calibration of contamination survey instruments for measuring beta contamination on surfaces at radiation protection level are described under the following clauses.

5.3 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.

5.4 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.

5.6 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}C , ^{147}Pm , ^{204}Tl , ^{36}Cl , ^{90}Sr + ^{90}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 $\pm 10\%$.

5.10 Reporting the results

In addition to the requirements on reporting under clause 5.10.2, 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

The specific requirements for the calibration of portable instruments for measuring dose rate from external beta sources at radiation protection levels are described under the following clauses. The applicable instruments are integrating dosimeters and dose rate meters.

5.3 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.

5.4 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 under 5.6.3 shall apply.

5.6 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}Tl and ^{147}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_{res}/E_{max}
<100 keV	≥ 0.6
100 to 800 keV	≥ 0.7
>800 keV	≥ 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.

5.10 Reporting the results

In addition to the requirements on reporting under clause 5.10.2, 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

The specific requirements for the calibration of portable survey and diagnostic instruments for measuring X-rays at radiation protection and diagnostic radiology levels are described under the following clauses. The applicable instruments are dosimeters and dose-rate meters.

5.3 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.

5.4 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.

5.6 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.

5.10 Reporting the results

In addition to the requirements for reporting under clause 5.10.2, 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

The specific requirements for the calibration of portable instruments for measuring gamma radiation at radiation protection levels, are described under the following clauses.

5.3 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.

5.4 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.

5.6 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.

5.10 Reporting the results

In addition to the requirements on reporting under clause 5.10.2, 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 under the following clauses.

5.3 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.

5.4 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.

5.6 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.

²⁴¹AmBe, ²³⁸PuBe and ²⁵²Cf or sources as recommended in ISO 8529 are acceptable sources.

5.10 Reporting the results

In addition to the requirements on reporting under clause 5.10.2, 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 personal radiation monitoring service 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'.)

The specific requirements for the calibration facilities used to assess film badge dosimeters, plastic plaque dosimeters and TLDs are described in the following clauses.

5.4 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.
- Details of 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.
- Details of 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.

5.6 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 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.

5.10 Reporting the results

In addition to the requirements on reporting under clause 5.10.2, 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

The specific requirements for the measurement activity of radionuclides used in medicine, pharmaceutical industry and research are described under the following clauses.

5.4 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.

5.6 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.

5.10 Reporting the results

In addition to the requirements on reporting under clauses 5.10.2 and 5.10.3, the certificate of verification 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_{max}

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

E_{res}

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 ($J \cdot kg^{-1}$) 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_{res}

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

NATA Policy Circular 12, *NATA criteria for the performance of calibrations in-house*

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	Sound level meters: non-integrating
AS 1259.2	Sound level meters: integrating - averaging
AS/NZS 2399	Acoustics – Specifications for personal sound exposure meters
ISO 16063–11	Methods for the calibration of vibration and shock transducers – Part 11: Primary calibration by laser interferometry.
ISO 16063–21	Methods for the calibration of vibration and shock transducers – Part 21: Vibration calibration by comparison to a reference transducer.
AS/IEC 60645.1	Electroacoustics – Audiological equipment Part 1: Pure-tone audiometers
IEC 60318-6:2007	Electroacoustics – Simulators of the human head and ear – Part 6: Mechanical coupler for the measurement of bone vibrators.
IEC 60651	Sound level meters (superseded)
IEC 60804	Integrating-averaging sound level meters (superseded)
AS/IEC 60942–2004 (IEC 60942:2003)	
Electroacoustics – Sound calibrators	
IEC 61094	Measurement microphones
IEC 61161–2006	Ultrasonics – Power measurement – Radiation force balances and performance requirements
IEC 61672	Electroacoustics - Sound Level Meters Part 1: Specifications (<i>Also published as an AS standard</i>) Part 2: Pattern evaluation tests (<i>Also published as an AS standard</i>)

	Part 3: Periodic tests (Not yet released as Australian Standard at time of print)
ISO 3741:1999	Acoustics -- Determination of sound power levels of noise sources using sound pressure -- Precision methods for reverberation rooms.
ISO 3745:2003	Acoustics -- Determination of sound power levels of noise sources using sound pressure -- Precision methods for anechoic and hemi-anechoic rooms.
OIML R88	Integrating-averaging sound level meters

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	Calibration and classification of force-measuring systems
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Appendix E: Temperature Metrology

AS 1530.1	Methods for fire tests on building materials, components and structures - Combustibility test for materials
AS 2853	Enclosures – Temperature Controlled-Performance testing and grading

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	<i>Neutron reference sources for calibrating neutron-measuring devices used for radiation protection purposes and for determining their response as a function of neutron energy</i>
ISO 8769	<i>Reference sources for the calibration of surface contamination monitors. Beta emitters (maximum beta energy greater than 0.15 MeV) and alpha emitters</i>
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.

AMENDMENT TABLE			
	Title	Clause or Class of test amended	Amendment
	Estimation of uncertainty of measurement	5.4.6	Inclusion to report the uncertainty of measurement in the scope of accreditation to no more than 2 significant figures.
	Reporting the uncertainty of measurement	5.10.4	Inclusion to the rounding rules to align the rounding of the measurement result and the uncertainty of measurement.