Specific Accreditation Criteria

ISO/IEC 17025 Application Document

Calibration - Annex

Acoustic, ultrasound and vibration measurement

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Purpose

In addition to the *General Accreditation Criteria: ISO/IEC 17025 Standard Application Document* (SAD) and the accompanying *Calibration - Appendix*, this document provides interpretative criteria and recommendations for acoustic, ultrasonic and vibration measurements and related to calibrations for both applicant and accredited facilities.

Facilities must comply with all relevant documents in the *NATA Accreditation Criteria* (NAC) package for Calibration (refer to *NATA Procedures for Accreditation*).

This annex is divided into two parts:

General Requirements:	provides additional guidance and recognition of the general criteria applicable to all types of measurements in this discipline;
Specific Requirements:	provides additional guidance and recognition of the criteria that are specific to individual types of measuring equipment.

For ease of use and to avoid fragmentation of the information, the clauses of ISO/IEC 17025 have not been applied.

General requirements

Accommodation and environmental conditions

As many instruments are sensitive to temperature, pressure and humidity variations, all 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.

Calibration method

The recommended calibration interval for a measurement system is the shortest interval of each of the components of the system. For example, a system consisting of a reference accelerometer (3-year interval), a charge amplifier (1-year interval), a reference capacitor (5-year interval), and a voltmeter (1-year interval), would have a recommended re-calibration interval of 1 year. Alternatively each component may be calibrated individually, for example, a measurement system comprising a charge-type reference accelerometer and a charge amplifier may be calibrated either as a system in $V/(m.s^{-2})$ every year, or as individual instruments with the accelerometer calibrated in $C/(m.s^{-2})$ every three years, and the conditioning amplifier calibrated every year in V/C. The *NATA General Accreditation Guidance, General equipment table* provides information on calibration intervals.

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.

Phase measurements

Some acoustic, ultrasound, and vibration measurements can include a phase component, as well as a magnitude component. Phase is generally reported as an angle (usually degrees), although a phase time-delay (e.g. microseconds) may be appropriate in some situations. Phase uncertainty should be stated in the same units.

When stating phase response, the report should indicate the phase orientation if this has relevance to the measurement. For example, with the calibration of an accelerometer for magnitude and phase to ISO 16063-21, the phase orientation can be stated in the report as:

> *"The phase of the acceleration is considered positive when the acceleration vector is directed from the mounting surface (base in contact with excitation source) into the accelerometer".*

Facilities that wish to report phase as an accredited quantity, must have listed the relevant phase measurement in their NATA scope of accreditation, including a minimum phase uncertainty stated in degrees, or other appropriate measurement unit (e.g. time delay).

Scope of accreditation

A facility's NATA scope of accreditation will specify the CMC 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 applicable to the calibration standard method. Where an applicable standard incorporates maximum test uncertainties the facility must demonstrate that for each test the uncertainties do not exceed the maxima.

Standard methods

Where there is an Australian standard (AS) and an equivalent IEC, ISO or ISO/IEC standard that are both current (e.g. AS IEC 61672-3 and IEC 61672-3), either version may be used. However, it is suggested that the testing facility is aware of any practical differences between the AS and international standards and discuss these with the client as required. Generally, testing to current IEC/ISO versions is recommended if there is a discrepancy.

Whenever stating a reference to a standard within a calibration report, it is recommended the part number (if applicable) and year or edition is also stated (e.g. AS IEC 61672-3:2019).

Specific requirements

Acoustic calibrators and pistonphones

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 IEC 60942 *Electroacoustics - Sound Calibrators*, Annex B *Periodic Tests* as a standard method.

Tests shall include:

- sound pressure level;
- output frequency;
- total distortion plus noise (THD+N);
- where supplied, indication of an accompanying barometer. (Unless the facility has been accredited to perform calibrations of barometers, this shall be clearly indicated as a reading and not a calibration of the barometer).

Acoustic filters

Sound level meters and other similar instruments 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 electronic units, while others may be hosted within measuring instruments as a digital algorithm as firmware.

Facilities performing verification of filter performance should use IEC 61260-3 *Octave-band and fractional-octave-band filters* as a guide, 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.

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 should follow the tests described in IEC 61260-3.

Although testing an analog electronic filter and a fully digital measuring instrument may have similar approaches with respect to implementing the tests described within IEC 61260-3, facilities should be aware of the differences in reportable measurement uncertainties. Facilities will require separate capabilities in their scope of accreditation as applicable for the instrument type (e.g. for an electronic filter with an analogue voltage output and for a digital measuring instrument).

Artificial mastoids

Artificial mastoids are sensitive to ambient conditions and should be allowed sufficient time to come to equilibrium with the environment before testing, this may take several hours. IEC 60318-6 should be used as a guide, however, the artificial mastoid's impedance must meet the specifications in IEC 60318-6, Table 1. The force sensitivity (e.g. in units of C/N, V/N, Pa/N, or dB equivalent), 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 impedance head provides the traceability to the measurements.

Care should be taken to minimise the length of time the impedance head is loading the top of the artificial mastoid, as the materials of the artificial mastoid can slowly compress and may result in a short-term change to the mechanical impedance.

Audiometers

All facilities performing verification of audiological equipment must test to AS IEC 60645-1 *Electroacoustics – Audiological equipment*. The scope of accreditation will indicate the 'type' of audiometer within its capability.

Charge amplifiers, IEPE/CCLD amplifiers and similar conditioning amplifiers

ISO/AWI 19665 for calibration of conditioning amplifiers for dynamic applications is currently under development and in preliminary draft form (as of January 2021). This standard is intended to cover a number of application areas including voltage amplifiers, charge amplifiers, and IEPE/CCLD supplies / amplifiers.

For the calibration of charge amplifiers, a calibrated reference capacitor should ideally be selected that has a nominal capacitance similar to the typical capacitance of the transducer that the charge amplifier is usually used with. However, it is accepted that most calibration facilities will not have a large range of calibrated capacitors available. Thus it is recommended to select an available reference capacitor that is closest to the expected transducer capacitance. The capacitance of all connecting cables and adapters may also need to be considered if a small-capacity reference capacitor is used.

Use of an appropriate, calibrated sensor simulator is recommended when calibrating IEPE/CCLD supplies.

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. IEC 61094 part 8 provides general advice for secondary calibration in a free-field.

For calibration of microphones at low-frequency (less than 10 Hz), electrostatic actuators have been determined to be unreliable due to the increasing influences of the microphone's internal air cavity and vent with lower frequencies.

Facilities performing low-frequency calibrations of microphones must use an acoustic pressure coupler technique. Any reference microphone used for the calibration should also have the same conditions for its cavity vent (exposed, or not exposed to the sound field), which was present during calibration of the reference.

It should also be noted that at frequencies approaching the resonance frequency of a microphone, the electrostatic actuator response is known to provide a response that differs from the true acoustic response of the microphone.

Personal sound exposure meters

Annex B of AS/NZS 2399 (IEC 61252), *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 for the activity to be cost-effective, provided that the reduction of integration time has no effect on the integrity of the calibration and is fit for purpose (e.g. a reduced integration time that fits in with actual use of the instrument).

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 Annex B6 of AS/NZS 2399.

Additionally, if the sound exposure meter includes a measurement of C-weighted peak levels as required in Australian noise standard NOHSC 1007, the applicable test from IEC 61672-3 may be used to demonstrate correct operation.

Piezo-electric accelerometers

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

Powered accelerometers and vibration transducers

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

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

Self-contained vibrometers

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

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.

Sound level meters

Sound Level Meters that have been designed to the specifications of IEC 61672-1 are to be nominally calibrated following IEC 61672-3. When calibrating sound level meters that have not been designed to the specifications of IEC 61672-1 following the method of IEC 61672-3, facilities are to ensure they follow the reporting requirements stated in IEC 61672-3 clause 22 s) and advise the customer accordingly.

Facilities who are accredited to perform calibrations of sound level meters to the superseded and/or withdrawn standards:

- IEC 60651
- AS 1259.1
- IEC 60804
- AS 1259.2

may continue to provide these calibrations if requested by the customer to meet regulatory needs. However, it should be noted that if there is a lack of evidence for pattern approval to these previous standards (if applicable), no conformance statement can be made.

Continuation of accreditation to the above superseded / withdrawn standards will be subject to evaluation of the industry requirements and is anticipated to be phased out following industry consultation.

Statistical noise level analysers

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 using DIN 45657 as a guide, are to take into account the situation described in a) or b) below.

a) Where the analyser equipment comprises a stand-alone unit built of analogue components, the complete tests described in DIN 45657 must be carried out to include three ramped down/up amplitude cycles with one cycle centered on the dynamic range limits and the two other cycles at displaced levels either side of the main cycle. The ramped amplitude must comprise steps no greater than the resolution of the analyser and be over the dynamic range of the instrument with no less than 1 second between step changes.

b) Where the analyser is implemented in a digital algorithm as firmware within host equipment such as a sound level meter, some concession to the breadth of testing is acceptable to avoid unnecessary testing. Once initially tested, unless the firmware version changes in a manner likely to cause a change in the function, the statistical analyser function does not require periodic re-testing.

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

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

Ultrasonic power meters

Facilities performing the calibration of ultrasonic power meters should follow IEC 61161 (AS/NZS 4714). Calibration of ultrasonic power meters should include a check with the included “standard mass”, or alternative masses as provided by the client. If no masses are supplied by the client, then a calibrated mass, usually 1 gram, can be substituted by the facility.

Between regular calibration intervals, ultrasonic power meters must be checked with the included “standard mass” or an equivalent calibrated mass, typically 1 gram, before and after measurements of the ultrasonic power of a working transducer.

Vibration calibrators

Facilities calibrating fixed or portable vibration calibrators or shakers that are used for the calibrations of transducers should generally refer to ISO 16063-21. The calibrators should be tested, where practical, with an approximate external mass loading similar to that which would be generally expected for the vibration calibrator in normal use. A test report or calibration certificate should state the mass loading used at the test.

Facilities performing verification of field vibration calibrators that provide *in situ* checks of vibration and shock transducers under field conditions can refer to ISO 16063-44.

Vibration transducers (accelerometers, velocimeters and geophones and vibrometers)

Facilities performing the calibration of vibration transducers should follow the following ISO standards for guidance:

- ISO 16063-11 or -21 for general calibration of transducers by sine-wave continuous excitation;
- ISO 16063-13 or -22 for calibration by shock impulse / impact;
- ISO 16063-41 for calibration of laser vibrometers;
- ISO 16063-16 and -42 for calibration using Earth's gravity as an acceleration reference.

General recommendations and guidance can also be found in:

- ISO 2041 for general definitions and terminology for vibration and shock measurement;
- ISO 5348 for recommendations for mechanical mounting of accelerometers.

The units given in the calibration report (e.g. acceleration or velocity) should be appropriate for the intended usage of the transducer and in accordance with the agreement between the customer and the calibration facility.

Reporting in SI units (e.g. $m \cdot s^{-2}$, $m \cdot s^{-1}$) is recommended wherever possible. If acceleration is to be quoted as a ratio to the standard value of acceleration due to Earth's gravity (which is not a prescribed SI unit for measuring acceleration), the symbol g_n should be used in accordance with the official definition of the constant within the SI brochure. If local gravity is stated as an acceleration, then the symbol g_L would be appropriate. Values for local gravity across Australia are available from Geoscience Australia, or an approximation and uncertainty can be calculated based on test location latitude and altitude from the equations within ISO 16063-16.

When stating g_n or g_L as units within a calibration report, it is suggested that the report should also state the definition of the unit. For example:

> *g_n represents the value for the standard acceleration due to gravity, published in "The International System of Units (SI)", Bureau International des Poids et Mesures (BIPM), 9th edition 2019, and is equal to 9.806 65 $m \cdot s^{-2}$*
>
> *g_L represents the local measured value for the acceleration due to gravity at the Testing Location, and is equal to (X ± X) $m \cdot s^{-2}$*
> (where X indicates the values for local gravity)

The scope of accreditation will always include a measurement capability in SI units for magnitude response and phase (where applicable).

Vibration transducers, accelerometers and vibrometers are to be calibrated at a minimum of two frequencies and two amplitude levels that cover the range of use, as far as practicable. It is recommended that sufficient additional frequencies and amplitudes within the range are tested to allow reliable interpolation, or as requested by the client.

Multi-axial (e.g. triaxial) accelerometers must be calibrated for each axis, unless otherwise requested by the client.

Interpolation to obtain values between calibration points must be accompanied by evidence of method validation.

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

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.

Standards and other references

SI Brochure	*The International System of Units (SI), Bureau International des Poids et Mesures (BIPM)*. Available as a brochure from the BIPM website.
AS 1259.1	*Sound level meters: non-integrating (superseded by IEC 61672)*
AS 1259.2	*Sound level meters: integrating – averaging (superseded by IEC 61672)*
ISO 2041	*Mechanical vibration, shock and condition monitoring – vocabulary*
AS/NZS 2399	*Acoustics – Specifications for personal sound exposure meters*
ISO 5348	*Mechanical vibration and shock – Mechanical mounting of accelerometers*
ISO 16063–11	*Methods for the calibration of vibration and shock transducers – Part 11: Primary calibration by laser interferometry*
ISO 16063–13	*Methods for the calibration of vibration and shock transducers - Part 13: Primary shock calibration using laser interferometry*
ISO 16063–16	*Methods for the calibration of vibration and shock transducers - Part 16: Calibration by Earth's gravitation*
ISO 16063–21	*Methods for the calibration of vibration and shock transducers – Part 21: Vibration calibration by comparison to a reference transducer*
ISO 16063–22	*Methods for the calibration of vibration and shock transducers - Part 22: Shock calibration by comparison to a reference transducer.*
ISO 16063–41	*Methods for the calibration of vibration and shock transducers - Part 41: Calibration of laser vibrometers*
ISO 16063–42	*Methods for the calibration of vibration and shock transducers - Part 42: Calibration of Seismometers with high accuracy using acceleration of gravity*
ISO 16063–44	*Methods for the calibration of vibration and shock transducers – Part 44: Calibration of field vibration calibrators*
ISO 26101	*Acoustics – Test methods for the qualification of free-field environments*
IEC 60645-1, AS IEC 60645-1	*Electroacoustics – Audiological equipment - Part 1: Pure-tone* AS *audiometers*
IEC 60318-6	*Electroacoustics – Simulators of the human head and ear – Part 6: Mechanical coupler for the measurement of bone vibrators*.

IEC 60651	*Sound level meters* (superseded by IEC 61672)
IEC 60804	*Integrating-averaging sound level meters* (superseded)
IEC 60942, AS IEC 60942	*Electroacoustics – Sound calibrators*
IEC 61252	*Electroacoustics – Specifications for personal sound exposure meters*
IEC 61094-5	*Measurement microphones - Methods for pressure calibration of working standard microphones by comparison*
IEC 61094-6	*Measurement microphones - Electrostatic actuators for determination of frequency response*
IEC 61094-8	*Measurement microphones - Methods for determining the free-field sensitivity of working standard microphones by comparison*
IEC 61161	*Ultrasonics – Power measurement – Radiation force balances and performance requirements*
IEC 61260-3, AS IEC 61260-3	*Electroacoustics – Octave-band and fractional-octave-band filters - Part 3: Periodic tests*
IEC 61672 AS IEC 61672	*Electroacoustics - Sound Level Meters*, *Part 1: Specifications*, AS *Part 2: Pattern evaluation tests*, *Part 3: Periodic tests*
ISO 3745	*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*

NATA Publications

General Accreditation Criteria	*ISO/IEC 17025 Standard Application Document*
General Accreditation Guidance	*General equipment table*
Specific Accreditation Criteria	*ISO/IEC 17025 Standard Application, Calibration - Appendix*

Amendment Table

The table below provides a summary of changes made to the document with this issue.

Section	Amendment
General Requirements	• Replaced Reference to AS 1000 with reference to BIPM SI brochure • Added criteria for phase measurements and scopes of accreditation.
Specific requirements for types of measurement equipment	• Edited advice for sound level meters, and simplified section on using superseded / withdrawn standards. • Added references to ISO 16063 parts 13, 16, 22, 42, & 44. • Edited advice for vibration calibrators, removed reference to ISO 8041 as this is covered by ISO 16063-44. • Added clarification for vibration units. • Removed references to AS/NZS 4476 for acoustic filters, and replaced with IEC 61260-3. Provided additional advice on classification of testing analogue electronic filters, and digital measuring instruments. • Added qualification of allowing integration time concession for personal sound exposure meters, as long as determined not to effect the integrity of the measurement. • Added advice on calibration of microphones at low-frequency and advice on limitations of electrostatic actuation as a calibration method. • Edited advice for artificial mastoids. • Added advice for calibration in Earth's gravity • Started new section for calibration of charge amplifiers and IEPE supplies. • Edited advice for ultrasonic power meters to allow testing lab to provide a calibrated mass when one is not available with the device under test. • Added reference to ISO 26101 for evaluation of anechoic spaces.