ACOUSTICAL INSTRUMENTATION - SPECIFICATIONS AND USE

S P Dowson National Physical Laboratory, Teddington, Middlesex TW11 0LW, UK
R G Tyler AVI Ltd., Northill, Bedfordshire, SG18 9AD, UK

1 INTRODUCTION

Acoustical instruments, such as sound level meters, sound calibrators, filters and personal sound exposure meters are very widely used for a variety of diverse applications, and this paper describes the IEC standardization of these widely-used instruments. It is important for the user to be confident that their instrument is operating as intended and in accordance with the specifications given in the appropriate international specification standard, as well as knowing measurements made with the instrument are traceable to national or international measurement standards. This paper provides an introduction to the IEC standards development process, together with a history of IEC specification standards for these devices, information on the current standards and likely future direction. The paper also covers the terminology and importance of pattern evaluation, periodic testing and calibration and explains the conformance criteria which have evolved over the years, as uncertainties of measurement have been incorporated into these standards documents.

2 THE STANDARISATION PROCESS

2.1 International Standards Bodies

The two main international standardization bodies for acoustics are the International Electrotechnical Commission (IEC)[1], and the International Organization for Standardization (ISO)[2]. Within Europe, the European Committee for Electrotechnical Standardization (CENELEC)[3] works closely with IEC, and the European Committee for Standardization (CEN)[4] works closely with ISO. Within the UK the National Committee is the British Standards Institution (BSI)[5]. For acoustical instrument specification standards the key body is IEC, whereas the parallel ISO committee deals with method standards using acoustical instruments. The aim of IEC, which was founded in 1906, is to promote international cooperation in standardization, and facilitate world trade by removing technical barriers, leading to new markets and economic growth. It achieves this aim through the publication of consensus-based international specification standards and other documents. IEC has two forms of membership Full, or P members, with full voting rights and Associate, or O members, with limited voting rights. Currently there are 60 P member and 23 Associate member countries, 97 technical committees covering different subjects, and over 10,000 experts participating worldwide. In general nowadays, in the acoustical instrumentation field, the UK accepts IEC specification standards without change, re-issuing them as BS ENs. It is interesting to note that IEC standards are voluntary even for member countries, but if the UK decides to adopt an IEC standard and publish it as a BS EN, adoption of that BS EN is mandatory and any conflicting national standards must be withdrawn.

2.2 IEC/TC29 ‘Electroacoustics’

The IEC committee responsible for specification of acoustical instruments is IEC/TC29 ‘Electroacoustics’. It was established in 1953 following the first International Congress on Acoustics in 1953 in Delft, Netherlands, at which the urgent need for international standardization in electroacoustics was recognized. Terminology, sound level meters, hearing aids, electroacoustics, audio apparatus, electromechanical and electroacoustical transducers as well as ultrasonics were included in the initial broad scope of the Committee. Standardization of the description and the measurement of vibration, including transducers, was transferred to ISO at an early stage, and over the years other aspects such as ultrasonics, sound recording and audio engineering have either merged with other committees or become separate committees in their own right. Currently IEC/TC29 has 23 P member and 12 O member countries. The expert members of the committee are nominated by the National Committees in each country, so in the UK the nominations are made by BSI. The related ISO committee is ISO/TC43 ‘Acoustics’.

IEC/TC29 still covers a wide range of areas, and a list of these is given in Table 1. The UK is very active in TC29 and currently provides the Chairman as well as 4 Convenors of the so-called Working Groups (WG) or Maintenance Teams (MT). WGs work on new standards and MTs are charged with revising existing documents.

WG or MT number	Title
MT4	Sound level meters
WG5	Measurement microphones
WG10	Audiometric equipment
WG13	Hearing aids
MT17	Sound calibrators
MT18	Amendments of relevant IEC/TC29 standards with respect to developments on EMC
MT19	Revision of IEC 61260, Filters
MT20	Revision of IEC 60118-4, Induction loop systems
WG21	Head and ear simulators
WG22	Audio-frequency induction-loop systems and equipment for assisted hearing
MT23	Revision of IEC 61265:1995, Instruments for measurement of aircraft noise – Performance requirements for systems to measure one-third-octave-band sound pressure levels in noise certification of transport-category aeroplanes

Table 1: Current IEC TC/29 Working Groups and Maintenance Teams.

2.3 Stages in preparation of an IEC specification standard

The format of specification standards must follow the strict rules detailed in the IEC Directives. The aim is to produce a normative document, developed according to consensus procedures, which has been approved by the IEC National Committee members of the responsible committee in accordance with Part 1 of the ISO/IEC Directives. An International Standard is approved if:

a. a two-thirds majority of the votes cast by the P members of the technical committee are in favour, and
b. not more than one-quarter of the total number of votes cast are negative.

Every member country, no matter how large or small, has one vote and a say in what goes into an IEC standard. Within the UK BSI are now starting to make drafts of IEC standards available on their website, so anyone can register and submit comments to be considered by the National Committee and forwarded to IEC as part of the UK comments where appropriate.

Each published IEC standard is given a Stability Date before which the content will not be changed. The various stages in production of an IEC standard are shown in Table 2.

Stage	Description	Abbreviation	Circulation time
Preliminary stage	Preliminary Work Item	PWI	
Proposal stage	New Work Item Proposal	NP or NWIP	3 months or at Plenary meeting
Preparatory stage	Working Draft(s)	WD	6 months each
Committee stage	Committee Draft(s)	CD	2 – 4 months each
Enquiry stage	Committee Draft for Vote (and French translation)	CDV	3 months
Approval stage	Final Draft International Standard - vote	FDIS	2 months (can skip if CDV 100% approval)
Publication stage		IS	1.5 months
Total maximum time permitted			**≤36 months**

Table 2. Stages in production of an IEC specification standard.

3 CONTENT OF STANDARDS PRODUCED BY IEC/TC29

3.1 Typical structure

One of the key aims of IEC/TC29 is to make the standards it produces easy to use and interpret by those manufacturers designing devices to the specifications given in the document, by the test houses and calibration laboratories making measurements of conformance and also by the end users of the devices. The specifications are stated and more information is included, particularly on the detail for testing. In cases where the standard is quite long or complex it is now quite common for a standard to be issued in Parts. Taking a recent example, for IEC 61672[6] 'Sound Level meters', Part 1 contains 'Specifications', Part 2 'Pattern evaluation tests' and Part 3 'Periodic tests'.

3.2 Conformance criteria and uncertainties of measurement

Over the years there has been increasing emphasis on uncertainty of measurement when performing tests against an instrument specification standard. It is important for users of the standards produced by IEC/TC29 to take note of how the tolerance limits/acceptance limits and uncertainties of measurement are implemented within a particular standard or Edition of a standard, as the Policy has evolved and changed over the years. A new Policy has recently been introduced (2013) with the aim of considerably simplifying this concept for manufacturers, test houses and users alike. It also aims to remove some ambiguities of the earlier standards now that more experience with uncertainties of measurement has been obtained in applying the concept to instrument testing. The recently introduced Policy for future standards removes tolerance limits and instead defines Acceptance Limits within which the measured deviation from a specified design goal must lie; it also separately states maximum permitted uncertainties of measurement for each test, and the testing laboratory must demonstrate that its uncertainty of measurement does not exceed this maximum value. For an instrument to pass a particular test, both of these criteria must be met. The previously-used concept of 'Tolerance Interval', i.e. the range between the upper and lower tolerance limit, can be calculated if desired by adding twice the maximum permitted uncertainty to the Acceptance Interval, i.e. the range between the upper and lower acceptance limit. However, this is not recommended, as this is one source of confusion that has been removed. An example of the implementation of the new uncertainty Policy is given in section 4.3.

3.3 Different tests available

There are two tests usually described as relating to legal metrology (such as may be promoted by the International Organization of Legal Metrology (OIML)[7]). This first of these is pattern evaluation and the second is periodic testing:

Pattern evaluation – this is a wide ranging ***full*** test against ***all*** the specifications of a standard for a ***model*** of instrument. Pattern evaluation (or type testing as it is sometimes known) is mandatory in some countries, although not in the UK, but it is therefore important for manufacturers who are exporting, **and** for users who are keen to ensure they are using a model of instrument whose performance has been independently checked against the specifications of the IEC standard. Pattern evaluation tests are usually performed by National Metrology Institutes, e.g. PTB, Germany.

Periodic testing – this is a ***limited*** test of an ***individual*** specimen of instrument performed on a ***regular*** basis against a key set of tests, which have been carefully chosen by the IEC WG. Periodic testing (or periodic verification as it is sometimes known) aims to assure the user that the performance of an instrument still conforms to the applicable specifications of the standard for a limited set of key tests, for the environmental conditions under which the tests were performed. Many ISO and BSI method standards require use of an instrument, such as a sound level meter, that has been shown to conform to the specifications of the IEC standard through a periodic test performed within a recent specified time interval. Periodic testing is typically performed by accredited laboratories - in the UK the accreditation body is the United Kingdom Accreditation Service (UKAS)[8].

Calibration – specification standards sometimes also cover calibration in addition to the tests above, and a calibration is often requested by a user – for example a calibration of a sound calibrator. The calibration is typically performed at a few points to measure the absolute response of an instrument – in the case of a sound calibrator to provide an actual measurement of the generated sound pressure level for example, rather than just checking that it conforms to the standard, and importantly this provides traceability to national measurement standards for future measurements.

A further test sometimes available to users is a manufacturer’s specification test, the content of which varies and may or may not follow the international specification standard, so the user needs to be aware of what is actually being tested.

4 SPECIFICATION STANDARDS FOR SOUND LEVEL METERS

4.1 History

Sound level meters were the first acoustic measuring instruments to be standardized. IEC 123 appeared in 1960, followed in 1965 with the first precision sound level meter standard (IEC 179) which established the now accepted general purpose and precision measurement grades. IEC 651 (later IEC 60651) for sound level meters updated the requirements in 1979 and Integrating-Averaging meters were specified in IEC 804 (later IEC 60804) in 1985. It took until 2002 for these two specifications to be combined into one document, which revised the requirements substantially, and was published as IEC 61672 in 3 parts. Part 1 defined the specifications, Part 2 the Pattern Evaluation tests required, and Part 3 describes Periodic Testing of a meter’s performance.

The standard contained figures for the uncertainty of measurement of each parameter for the first time, a topic that had caused considerable difficulties to the WG responsible for its writing, and delayed publication for some time. As so often with a significant change of this type, it became clear that the first attempt was not quite what had been intended, and a full revision of all 3 parts of the standard followed, which produced IEC 61672[6] Edition 2 of all 3 parts in 2013.

4.2 Current standard and the future

The main changes in Edition 2 of IEC 61672 were a revised method for specifying the uncertainties, and the effect this had on the 'tolerances' originally quoted. The opportunity was taken to update other features such as under-range indicators, microphone response testing, operation at high level signals, stability during continuous operation, and other small changes and additions that had been found necessary in the intervening years. Also, for acoustical periodic testing the choice of devices permitted has been broadened to include a comparison coupler (assuming the relevant corrections are available) in addition to the electrostatic actuator, sound calibrator or free-field facility included in Edition 1. This gives those performing tests a broader choice consistent with the aim of reducing the testing time.

Edition 2 of IEC 61672 does not fundamentally alter the measurement accuracy for sound level meters. The 1st Edition had tightened some of the design goals from the previous standards to make meters measure more accurately, but with the reduction from 4 Types of meter to 2 classes, it also simplified choosing an instrument down to Precision (class 1) or General purpose (class 2), which was felt to be more in line with both requirement and usage. Microphone performance was specified with greater accuracy, reflecting improvements in the devices available, but some other features such as statistical data were omitted as no clear consensus on a measuring method could be achieved within the WG. Defining precise tests for Pattern Evaluation and Periodic Testing in Edition 1 had standardized for the first time exactly what was needed to be tested. Previously in the UK, BS 7580 had been produced to define a repeatable set of tests for meters meeting IEC 60651 and/or 60804, but this had always been a UK document (although widely used elsewhere), and was indeed the basis for the original Part 3 when it first appeared. Edition 2 changed little in these areas, other than making it consistent with the changes and additions made to the specifications in Part 1.

Edition 2 follows the new TC29 Policy with regard to Acceptance Limits and Uncertainties of measurement. It gives design goals with Acceptance Limits as defined in ISO/IEC Guide 98-4 (JCGM 106) for the Guarded Acceptance Rule. It also requires that anyone making measurements following the standard determine the uncertainty of a measurement for a coverage probability of 95%, including stating the coverage factor where appropriate, depending on the method used to calculate the uncertainty of measurement, adopting procedures given in IEC/ISO Guide 98 (all parts) (equivalent to the JCGM 100 series). Conformance to a performance specification is demonstrated when a measured deviation from a design goal equals or does not exceed the corresponding acceptance limit(s) AND the laboratory has demonstrated that the associated uncertainty of measurement equals or does not exceed the maximum permitted uncertainty given in the standard.

Of course sound level meters manufactured to the earlier standards are still in use and BS 7580 remains the appropriate standard for periodic testing for those instruments originally manufactured in accordance with IEC 60651 and/or IEC 60804, and Part 3 of Edition 1 of IEC 61672 remains applicable to meters originally manufactured in accordance with Edition 1 of IEC 61672.

4.3 Examples of assessment of conformance for sound level meters under the new IEC/TC29 Policy

As an illustration of the implementation of the latest Policy on uncertainty introduced by TC29, consider a sound level meter's overall acoustical response at 8 kHz. From Part 1 of IEC 61672 Ed.2, the C-weighted frequency response is required to be -3.0 dB relative to the response at 1 kHz, and the Acceptance Limit is within +1.5/-2.5 dB of this value. The maximum permitted uncertainty is 0.7 dB, so the first criteria to be met is that any laboratory undertaking instrument testing must be able to demonstrate its uncertainty in making this measurement is 0.7 dB or less, otherwise the measurement cannot be used to determine conformance with the standard. The second criteria for an instrument to meet the requirements of the standard, is that a measured value for the response between -1.5 dB and -5.5 dB is required. Were the measured response to be -1.4 dB or -5.6 dB, the instrument would fail to meet the specification. If the laboratory has a smaller uncertainty than 0.7 dB these values do not change. Both the above criteria must be met for an instrument to be deemed to conform to the specifications of the standard.

5 SPECIFICATION STANDARDS FOR SOUND CALIBRATORS

5.1 History

The first standard for sound calibrators, IEC 942, was published in 1988 (dual-numbered in the UK at that time as BS 7189 published in 1989). Although this was quite a concise standard with no information on test methods it was a major step forward in standardizing these extensively used devices. The standard was revised as Edition 2 in 1997, to include test methods, uncertainties of measurement and electromagnetic compatibility requirements, and it still contained information on effective free-field and diffuse fields sound pressure levels. It was an extremely complex document, and many countries were not happy with all the content, and it only just received a positive vote in the IEC voting process. It is unclear whether any manufacturer ever designed a model of sound calibrator to this version of the standard, and due to the lack of consensus and all the concerns expressed about the document, work started immediately on a revision.

5.2 Current standard and the future

This revision resulted in the current standard IEC 60942, Edition 3[9] published in 2003, dual-numbered as BS EN 60942 : 2003. This standard contains definitions and references, and requirements for: sound pressure level; frequency; influence of static pressure, air temperature and humidity; total distortion; power supply; specification and calibration of microphones; electromagnetic compatibility; and instrument marking and documentation. The standard has 3 normative Annexes – Annex A ‘Pattern evaluation tests’, Annex B ‘Periodic tests’ and Annex C ‘Format for the Pattern Evaluation Report’. Annex C gives the format for the report for laboratories performing the tests to Annex A, with the aim of all countries using the same report under the OIML Certificate System, and ultimately acceptance of reports by various countries, without the need for national retesting. Unfortunately this mutual acceptance position is still not currently embraced by all countries. The aim throughout the standard is to ensure consistency of testing from one laboratory to another, and, for periodic tests, to minimize the number of tests performed and hence the cost, whilst still ensuring a meaningful test of performance.

There are several key changes from the previous Editions of the standard. The tolerance limits include the maximum permitted uncertainties of measurement, which are also given separately, and conformance is demonstrated when the result of a measurement or the absolute value of the difference between the result and the design goal, as appropriate, extended by the actual expanded uncertainty of measurement of the testing laboratory lies within the appropriate tolerance limits, and the actual uncertainty does not exceed the maximum permitted. This was the policy on uncertainty at the time of this publication, but is not now the latest thinking on uncertainties, where the new Policy is described in section 3.2.

The three classes of sound calibrator are class LS (Laboratory Standard) to be used in the laboratory, class 1 and class 2, with the tolerance limits based on the use of a Laboratory Standard (LS) microphone for a class LS calibrator and on a Working Standard (WS) microphone for a class 1 or class 2 calibrator. Class LS has the tightest tolerance limits. Each class LS device (typically a pistonphone) is supplied with its own calibration Certificate which gives for example, the sound pressure level, eg. 124.03 dB, against which conformance testing is performed, whereas for class 1 and class 2 devices the general specified level for the model eg. 94 dB is used. The standard also has a /C class designation to indicate where corrections are required for environmental conditions in order for the sound calibrator to meet the requirements, with further restrictions on the corrections depending on class. The range of environmental conditions over which the specifications must be met are different for each class and are now harmonized with those for sound level meters. There is no 'L' designation of previous editions.

Importantly, a multi-frequency or multi-level sound calibrator must have the same class designation for all combinations claimed to meet the standard. Two sets of tolerance limits are given – one at and around reference environmental conditions, and one outside these narrow limits. Effective free-field and diffuse field levels have been removed from the standard, enabling considerable simplification.

Work has just started within MT17 on a revision of IEC 60942 with the aim of producing a new Edition 4. This will include agreed changes to the text as a result of comments received on the existing standard, incorporate the new IEC TC/29 uncertainty policy, implement drafting changes required by the IEC Directives and make other changes agreed within the MT. The document is at an early stage, currently as a WD within the MT.

6 SPECIFICATION STANDARDS FOR FILTERS

Alongside broad band specifications for acoustic measurement, the introduction of frequency analysis using octave, third-octave and other narrow band filters started as additional instruments but these filters are now nearly all built in to other measuring devices such as sound level meters. A specification standard was first introduced as IEC 225 in 1966. It had one limited specification for octave, half-octave and third octave filters. In 1995, a more comprehensive specification was introduced in IEC 1260 (later IEC 61260) which introduced 3 Classes of filter performance, and requirements for band - to - band performance. There were no prescribed tests to check a filter's performance, but a list of items thought to be worth checking was included.

This year (2014), this document has been revised and updated to include the latest uncertainty policy, and tests for Pattern Evaluation and Periodic Testing have been devised, such that, as with the sound level meter standard, it will now be published in 3 parts. Part 1 has already been published. Confusingly, it is still numbered IEC 61260[10] Edition 1, as the previous version, also called Edition 1, was in a single part.

The latest version has reduced the number of Classes to just 2, and specifications for filters designed to the Base 2 series of frequencies are now only in an informative annex, as they are no longer recommended for new designs, with Base 10 frequencies being used instead.

7 SPECIFICATION STANDARDS FOR PERSONAL SOUND EXPOSURE METERS

Often referred to as Dosemeters or Dosimeters, a standard for these devices worn by people to determine noise exposure during an occupational day was introduced in 1993 as IEC 1252 (later IEC 61252[11]). The tests described in this document can be extremely time consuming to perform, and within TC29 a revision of the document has just started, with the aim of updating and reducing the testing time, but a new standard is not expected for some time yet.

8 CONCLUSION

IEC/TC29 is the committee responsible for the standardization of most acoustical instruments. Over the years it is clear how the standardization process has evolved from documents just giving the basic specifications, to the newer standards that now give not only the specifications, but also prescribe tests for both pattern evaluation and periodic testing, so giving added clarity to users. The aim of TC29 is to ensure consistency of testing from one laboratory to another, both for pattern evaluation and periodic testing. In addition, the periodic tests are carefully selected to ensure that a sufficiently robust examination of the instrument is performed, consistent with the time required and hence the cost incurred by users of the instruments.

9 REFERENCES

1. International Electrotechnical Commission (IEC), www.iec.ch

2. International Organization for Standardization (ISO), www.iso.org

3. European Committee for Electrotechnical Standardization (CENELEC), www.cenelec.eu

4. European Committee for Standardization (CEN), www.cen.eu

5. British Standards Institution (BSI), www.bsigroup.co.uk

6. IEC 61672 Edition 2 : 2013 *Electroacoustics - Sound level meters*, Edition 2 Parts 1, 2, 3

7. International Organization of Legal Metrology (OIML), www.oiml.org/en

8. United Kingdom Accreditation Service (UKAS), www.ukas.com

9. IEC 60942 : 2003 *Electroacoustics – Sound calibrators*

10. IEC 61260-1 Edition 1.0 : 2014 *Electroacoustics – Octave-band and fractional-octave band filters*

11. IEC 61252 : 1*993 Electroacoustics – Specifications for personal sound exposure meters*