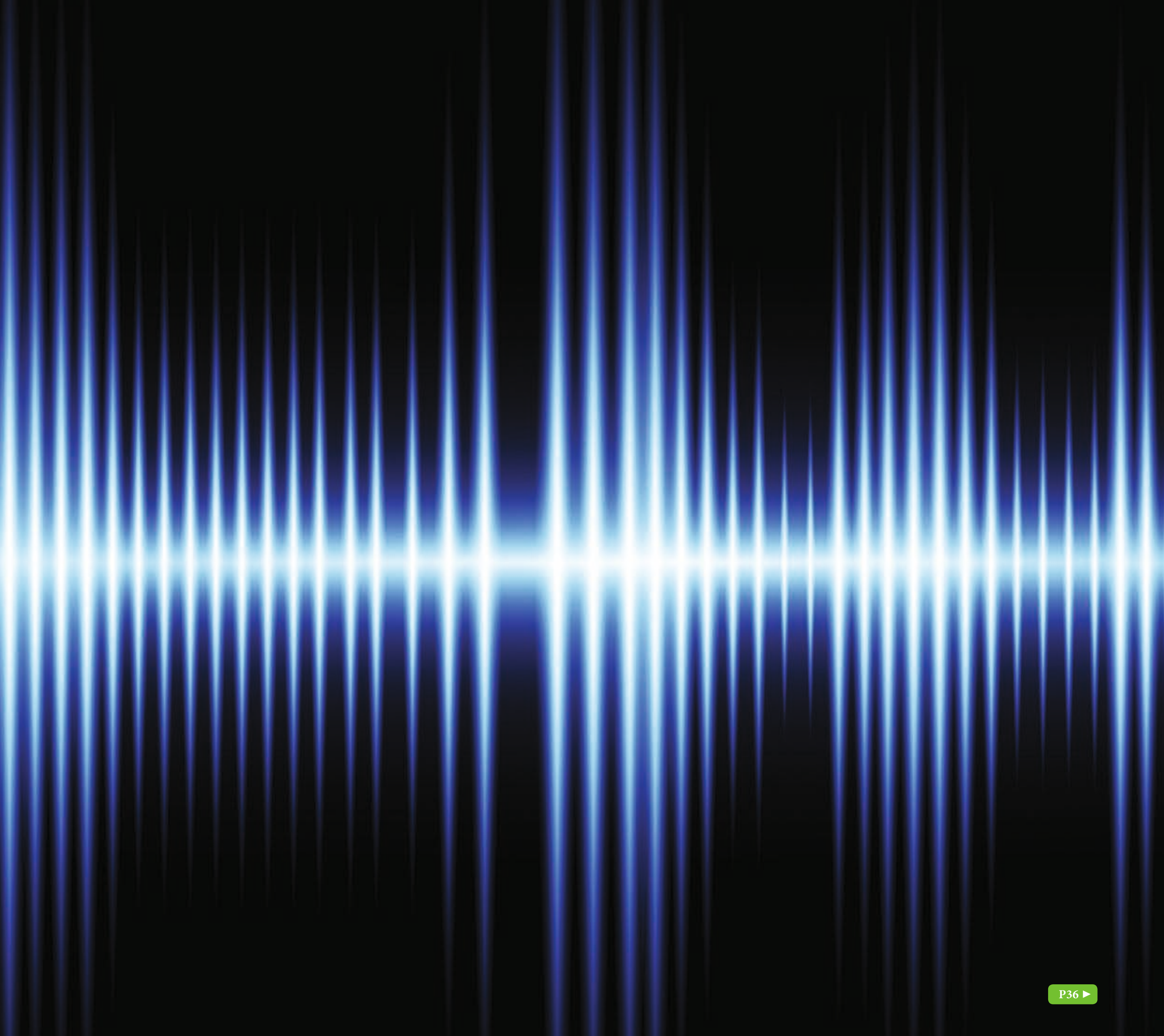
A guide to sound level meters

The Measurement and Instrumentation Group of the IOA is made up of experts in the field of sound and vibration instrumentation, with many years of experience behind them. The fields covered include instrumentation development and manufacture, calibration, international standards, prediction and sales, and each committee member brings their own specialism.



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As well as routine Institute business, such as one-day meetings, conferences and Acoustics Bulletin articles, the committee kick around the latest issues in the business, to keep abreast of any new developments.

Recently, two issues arose which we decided to pursue:
- *the first being the use of smartphones for sound level measurements, and*
- *the second concerning claims of (mostly Far East) manufacturers of compliance with current sound level meter standards.*

In the past, we have covered the former in one of our regular Instrumentation Corner articles, but the second issue came to light when a user of one of these low-cost instruments came to have it tested according to BS EN 61672-3. Suffice to say, there were some issues, prompting the committee to investigate further, and we hope to be able to bring some wider measurements to the attention of the membership in the future.

However, the discussion led to the idea of a summary article for the Acoustics Bulletin, with some of our specialists providing an overview of the key issues, namely standards, calibration, pattern evaluation and 'component' instruments.

The first of our experts, Sue Dowson, is recently retired from National Physical Laboratory (NPL) Teddington, where she headed up the Acoustics Group. She sits on various international standards committees and has been safeguarding UK interests in the latest BS EN 61672 series of standards, covering the performance of sound level meters. Sue is currently the secretary of the Measurement and Instrumentation (M&I) Group committee. Who better to discuss sound level meter standards?

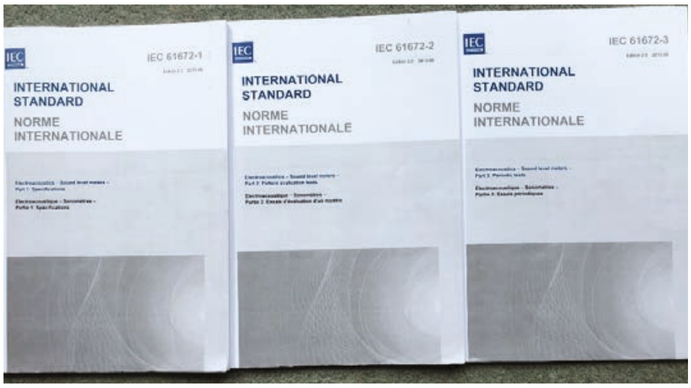
What is a specification standard?

A specification standard is a written document that describes the performance requirements for an instrument or device. For acoustical instruments, these written documents generally also provide test methodologies for ensuring the specifications are met by a specific model or individual specimen of instrument. Specification standards should not be confused with reference standard artefacts, for example, a calibrated microphone or calibrated sound calibrator, from which measurements traceable to national measurement standards can be obtained.


Sue Dowson, M&I Group committee

Why are specification standards important?

International specification standards provide a technical description of the characteristics to be fulfilled by a particular instrument which have been arrived at by international consensus. The standards are widely adopted and applied at national level, and as such, help to facilitate trade and remove trade barriers around the world. They are applied by manufacturers of instruments in their design and manufacture, and by testing laboratories in checking the initial and ongoing performance of an instrument. They provide reassurance to purchasers and users who can look for the international standard number on a particular instrument when making a purchase, but to ensure the performance of the device has been independently verified; it is also necessary to ask the question 'who has validated the manufacturer's performance claims?' In addition, other international standard documents describing a particular measurement method often require the use of an instrument to meet a particular performance class.



How are specification standards produced?

The leading global organisation that prepares and publishes international standards for all electrical, electronic and related technologies is the International Electrotechnical Commission (IEC) founded in 1906. Currently, there are 86 full or associate member countries of the IEC. The documents produced by IEC are also used as the basis for national standardisation. In the UK for acoustical instruments, IEC standards are accepted by our standards body, the British Standards Institution (BSI), and generally re-published without change as BS EN documents.

IEC has 205 technical committees (TCs) or sub-committees for different subject areas. The relevant one for acoustical devices is IEC/TC29 'Electroacoustics', which has a parallel BSI national committee EPL/29. The purpose of TC29 is standardisation in the field of electroacoustics, by producing specification standard documents, which are discussed internationally, and as far as possible, consensus gained prior to publication.

Within each TC there are working groups/maintenance teams (WG/MT) which cover different instruments/devices. In general, a MT works solely on the revision of current standards, whereas a WG will also consider new items. WGs and MTs are truly international with members appointed from many different countries. Nomination is via an individual's own national committee, BSI in the UK, and all nominated members belong to the parallel BSI committee. If you are interested in joining this committee and becoming involved in standardisation work please contact the chair of EPL/29, Dr Richard Barham (email: **richard.barham@acousticsensornetworks.co.uk**), or contact the secretary of the IOA M&I Group, Sue Dowson (email: **acoustics@sandpdow.co.uk**).

TC29 currently has 23 participating countries and 13 observer countries. It has a wide remit with topics ranging from microphones, sound level meters, sound calibrators and filters through to hearing aids and audiometric equipment. TC29 meets about every 18 months for a main session and separate meetings of most of the WG/MTs, with a different country acting as host on each occasion.

Much of the work between the meetings is conducted by email, although occasionally, additional interim meetings are scheduled. Membership of a WG/MT gives early visibility of the documents, and an opportunity to discuss key technical issues with international peers, so giving real input to the finally approved published standards.

The standardisation process itself is well defined by IEC, including guidance on timescales to be met, and documents must progress through various clearly defined stages. These stages are:

- preliminary,
- proposal,
- preparatory,
- committee,
- enquiry,
- approval, and
- publication.

Once a new work item has been approved by a ballot of the relevant national committees, the initial preliminary work is undertaken within the WG or MT.

From the committee stage onwards, documents are sent to national committees for circulation within their own country. Comments and votes, where required, are then submitted by each country through their national committee. Timescales for comments to be received by IEC/TC29 (and voting at the later stages – enquiry stage onwards) are also well defined.

There are prescribed voting approval criteria which must be met to enable the document to advance to the next stage, and ultimately to publication. At publication, a date is also agreed before which the standard will not be revised – the 'stability date'. The target time from agreement for the work to start to publication is 36 months. More detail of the process is available on the IEC website and the same principles apply for revision of existing standards.

So, the WG/MT needs to reach consensus as far as possible for the standard to be successfully approved, and to ensure that the specifications are clear and not open to differing interpretations.

Sound level meter specification standards

The current sound level meter standard is the second edition of IEC 61672. This was revised by IEC/TC29/MT4 and published in three parts:

- Part 1 'Specifications' published in 2013 [1];
- Part 2 'Pattern evaluation tests' published 2013 [2]; and
- Part 3 'Periodic tests' published 2013 [3].

These standards were adopted in the UK as BS EN standards with the same number i.e. BS EN 61672-1.

IEC 61672-1 – 'Specifications' provides the full specifications for a sound level meter. Specifications for each parameter are generally given in terms of a design goal with associated acceptance limits.

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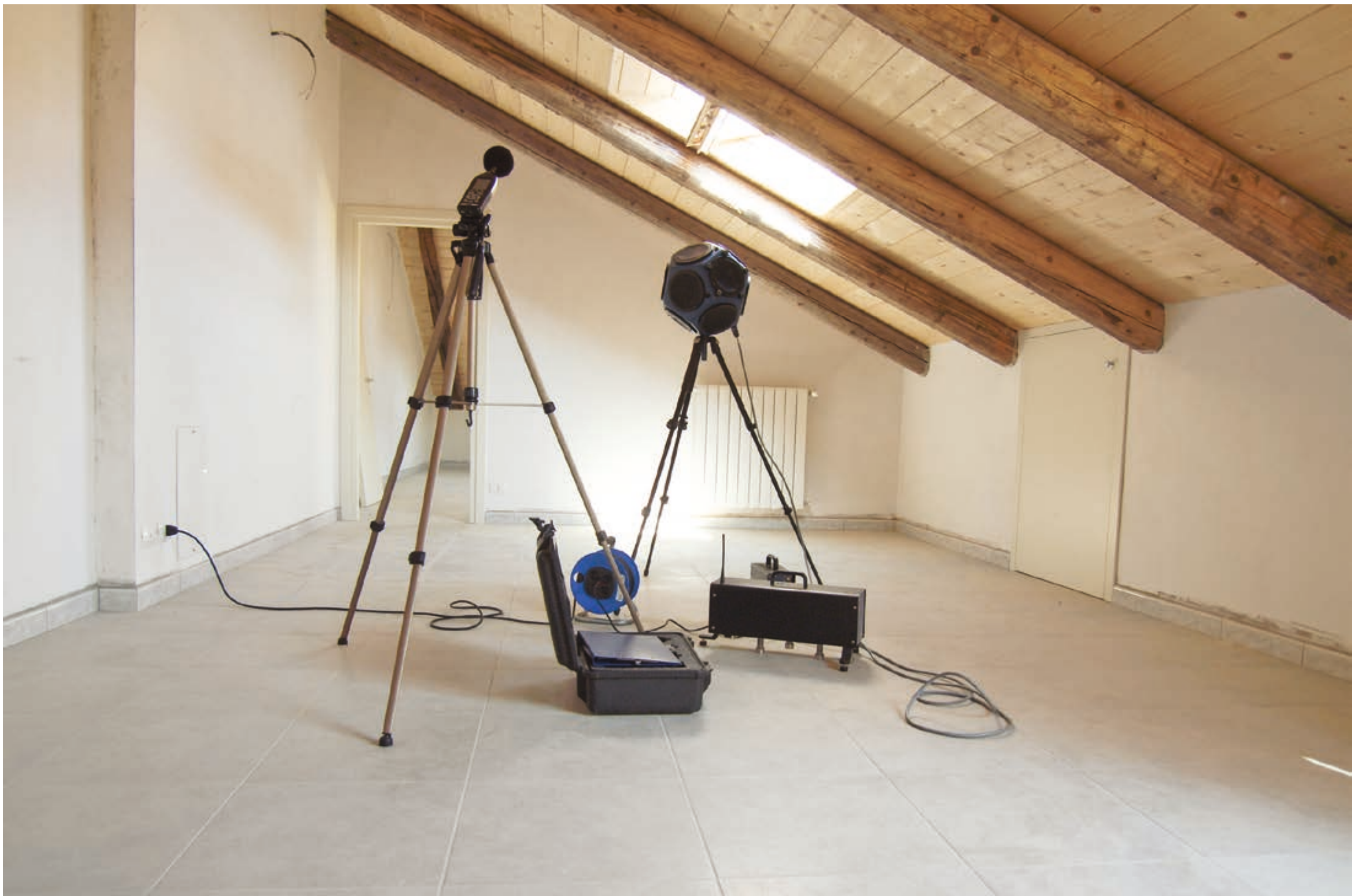


Instrumentation such as sound level analyser, tapping machine and sound source will often require UKAS calibration

The second edition of IEC 61672-1 was one of the first standards within TC29 to apply a simplified policy relating to uncertainty of measurement and conformance testing, and the standard also specifies the maximum permitted uncertainties of measurement for testing.

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 testing laboratory has demonstrated that the associated uncertainty of measurement equals, or does not exceed, the maximum permitted uncertainty. Note these maximum permitted uncertainties are only for the testing of the sound level meter according to Part 2 and Part 3 of IEC 61672 and are not concerned with the sound level meter in use.

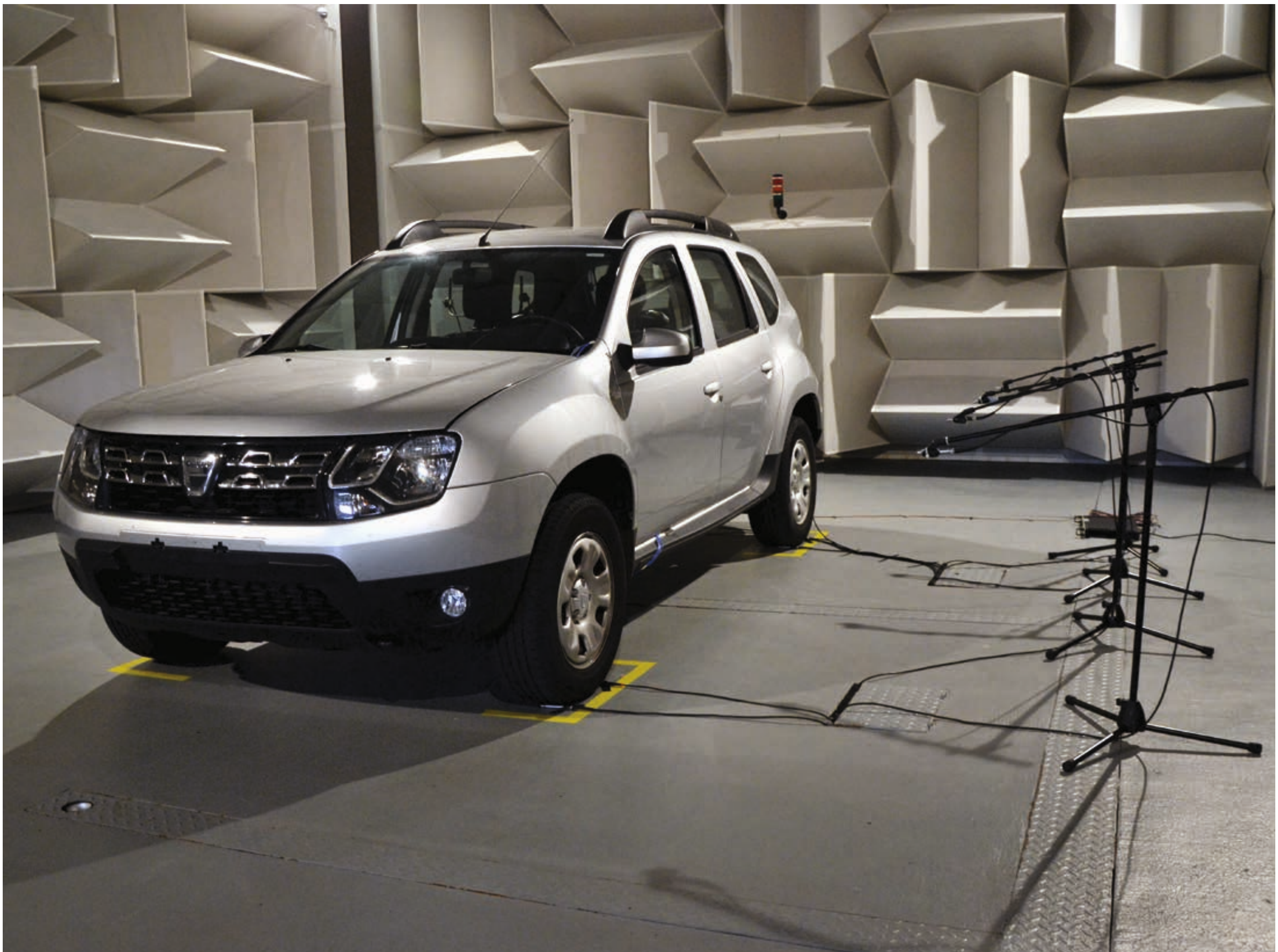
Information on assessment of conformance is given in Annex C of IEC 61672-1, but, as an example, suppose for a particular parameter the acceptance limits around the design goal are +1.0, -1.2 dB and the maximum permitted uncertainty of measurement is 0.5 dB for a coverage probability of 95 percent. If the deviation of the measurement for the specified test from the design goal is greater than +1.0 dB or less than -1.2 dB, then the meter fails to conform to the standard, irrespective of the actual associated uncertainty of measurement.

Similarly, if the uncertainty budget calculation from the testing laboratory shows the actual uncertainty for the test performed is greater than 0.5 dB then the meter again does not conform, irrespective of the deviation from the design goal.

Two performance categories, class 1 and class 2, are specified in the standard. In general, specifications for class 1 and class 2 sound level meters have the same design goals and differ mainly in the acceptance limits and the range of operational temperature. Acceptance limits for class 2 are greater than, or equal to, those for class 1. The standard is applicable to a range of designs of sound level meters.

The specifications themselves are very wide-ranging and cover:

- adjustments at the calibration check frequency i.e. for adjustment of the sound level meter using a sound calibrator;
- corrections to indicated levels e.g. for reflections and diffraction around the microphone and for use of windscreens, and corrections for use during periodic testing;
- directional response;
- frequency weightings;
- level linearity;
- self-generated noise;
- time-weightings F and S;
- toneburst response;
- response to repeated tonebursts;
- overload indication;
- under-range indication;



Measurements of simulated pass-by in automotive applications will follow standards for vehicle certification

- C-weighted peak sound level;
- stability during continuous operation;
- high-level stability;
- reset;
- thresholds;
- display;
- analogue or digital output;
- timing facilities;
- radio frequency emissions and disturbances to a public power supply;
- crosstalk;
- power supply;
- environmental, electrostatic, and radio-frequency requirements
  - static pressure
  - air temperature
  - humidity
  - electrostatic discharge
  - A.C. power-frequency and radio-frequency fields
  - mechanical vibration;
- provision for use with auxiliary devices;
- marking; and
- instruction manual.

So, the standard will be used by manufacturers to inform their design and manufacturing processes, by any laboratories performing pattern evaluation tests of new models or designs, and by those performing periodic testing of particular instruments, ensuring that the end user can have continuing confidence in the results obtained and functions performed by their instrument.

'IEC 61672-2 – 'Pattern-evaluation tests' provides details of the full tests necessary to verify conformance to all mandatory specifications given in IEC 61672-1 for a particular model of instrument, with the aim of ensuring that all laboratories use consistent methods to perform pattern-evaluation testing.

Pattern-evaluation, sometimes known as 'type testing', is mandatory in some countries, so is important for manufacturers who are exporting, and is usually performed by national metrology institutes, with one of the main centres being at PTB in Germany. Pattern-evaluation tests are generally requested and paid for by the manufacturer of the instrument.

IEC 61672-3 – 'Periodic tests' Periodic testing, often known as periodic verification, is limited testing of an individual specimen of sound level meter on a regular basis, and assures the user that the performance of an instrument still conforms to the applicable specifications for a limited set of key tests, for the environmental conditions under which the tests were performed. The aim again is to ensure that all laboratories use consistent methods.

Periodic testing is requested by the user of the sound level meter and often performed by accredited laboratories who have been independently assessed. In the UK, the accreditation body is the United Kingdom Accreditation Service (UKAS). There are a number of laboratories accredited by UKAS to test sound level meters and these can be found by searching under **www.ukas.com** .

The tests in IEC 61672-3 are mainly performed electrically with limited acoustical testing – one of the challenges for the IEC MT was to prescribe tests that are extensive enough to be effective in checking ongoing performance, whilst ensuring that the cost burden for users is not excessive.

Common misconceptions

There are some common misconceptions around the sound level meter standards:

- Users referring to a 'class 1 or class 2 microphone'. **There is no such thing!** – the sound level meter standards specify the acceptance limits for a class 1 or class 2 instrument but this is for the complete instrument not just the microphone. Also, the microphone specification standards, the IEC 61094 series, do not specify class 1 or class 2 microphones. Their nomenclature is in terms of a laboratory standard (LS) microphone or a working standard (WS) microphone, with LS1 referring to a laboratory standard microphone of nominal one-inch diameter, and a WS2 to a working standard microphone of nominal half-inch diameter etc.
- Class and type. Edition 1 of IEC 61672 first introduced two performance classes, class 1 and class 2. The specification standards prior to that, IEC 60651 'Sound level meters' and IEC 60804 'Integrating-averaging sound level meters', provided specifications for four performance classes known as type 0, 1, 2 and 3. Some people believe that an older type 1 sound level meter has the same performance as a newer class 1. **This isn't the case** – although a few specifications may be the same; the majority have changed, and, of course, the newer standards introduced the concept of maximum permitted uncertainty of measurement.
- To help with the periodic, regular, testing of the older sound level meters the then BSI committee wrote and then updated a British Standard, BS 7580 [6], to provide a methodology for periodic testing. Some users think this document can be used for periodic testing of the newer sound level meters manufactured according to IEC 61672, **but this is not the case**. BS 7580 applies only to meters originally manufactured in accordance with IEC 60651 and IEC 60804. For all sound level meters manufactured according to IEC 61672-1, Part 3 of the relevant edition (Edition 1 or Edition 2) applies for periodic testing.

References

[1] IEC 61672-1 Edition 2: 2013 Electroacoustics – Sound level meters, Part 1 Specifications

[2] IEC 61672-2 Edition 2: 2013 Electroacoustics – Sound level meters, Part 2 Pattern evaluation tests

[3] IEC 61672-3 Edition 2: 2013 Electroacoustics – Sound level meters, Part 3 Periodic tests

[4] IEC 60651: 1979 Sound level meters (latest edition)

[5] IEC 60804: 2000 Integrating-averaging sound level meters (latest edition)

[6] BS 7580-1: 1997 Specifications for the verification of sound level meters: comprehensive procedure

So, now the rules of sound level meter performance have been laid down, how can we be confident that what we are purchasing or using meets the requirements?

Many European countries have addressed this by requiring 'pattern evaluation' or 'type approval' before an instrument can be legally sold or used.

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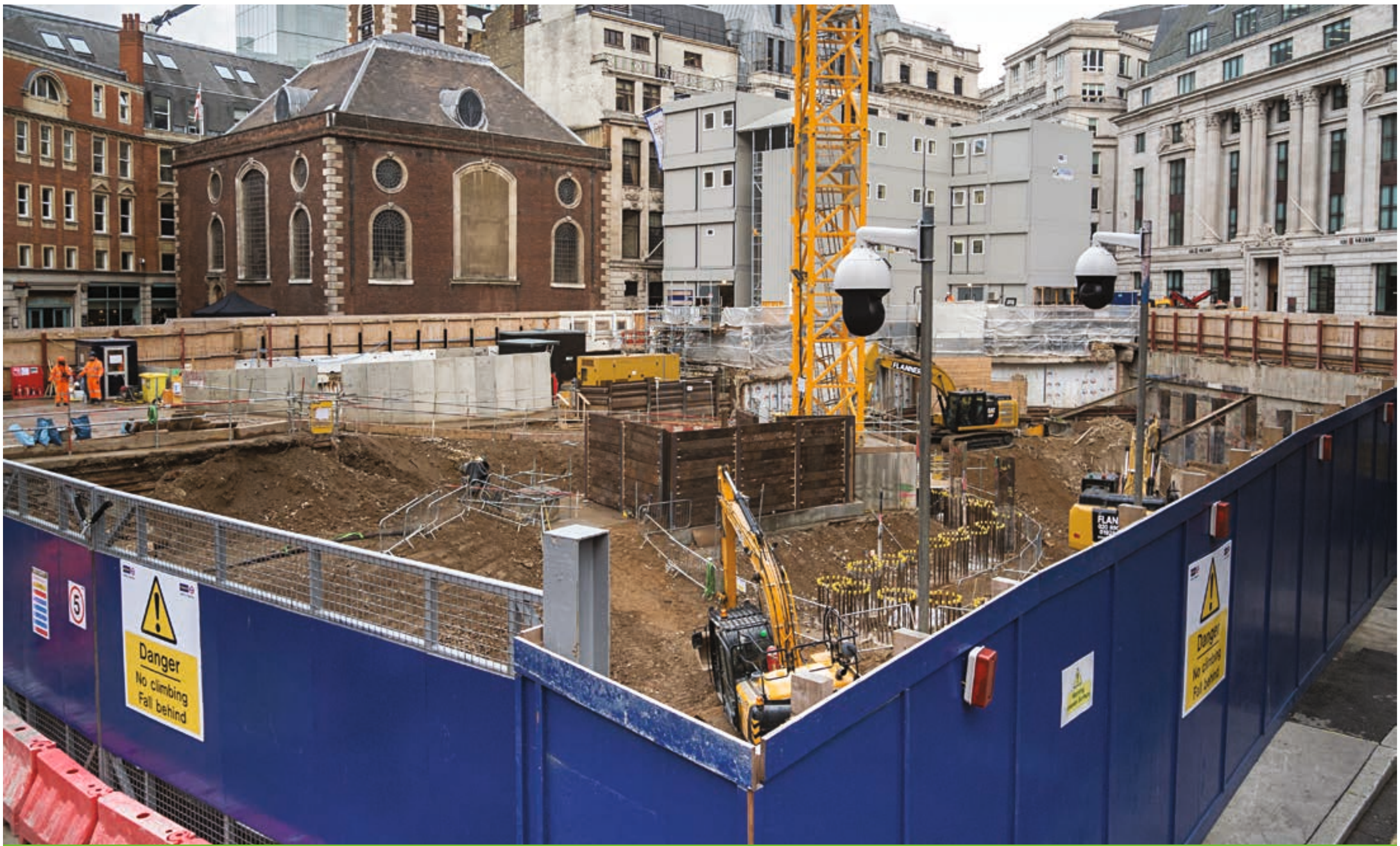


Limits for construction noise and vibration will require standardised and calibrated instrumentation

Ian Campbell addresses this in his contribution. Ian has a long and distinguished career in sound measurement instrumentation, having headed up British manufacturer CEL Instruments (now part of Casella Group), and later Cirrus Research. He is now an independent consultant with Campbell Associates, who market Norsonic instruments, and he is, of course, a past President of the IOA.


Ian Campbell

Pattern evaluation

In our high-tech world, health and safety, along with common sense, dictate that the machines and devices we rely on in our everyday life should do what they 'say on the tin'. Their very complexity dictates that the user of the device cannot reasonably be expected to be able to prove the benefits provided by the product will be delivered; and must therefore rely on the claims of the vendor and manufacturer.

An example would be the family car, a high-tech piece of kit that is full of potential safety and environmental hazards as it comfortably carries us around in our daily lives. This is ensured by the Motor Vehicle Construction and Use Regulations. These are internationally agreed specifications covering all aspects of the design and operational performance of vehicles. Some of these points would be relatively easy to check, like the position of the lights etc., others not quite so easy, such as crash testing, emission of pollutants, etc. These require specific testing environments and techniques hence restricting confirmation to specialists.

On the plus side, however, these parameters tend to be design specific so only need to be determined on a representative sample of that design to confirm that the ensuing volume production can be reasonably expected to conform to the design standard when it is new.

As the product ages and wears however, a situation could arise that would result in it no longer conforming; as brake pads wear, seat belts chafe, silencers become clogged, etc. so some form of periodic testing is necessary to identify and correct these points so that the vehicle continues to conform to the original specification. In the UK this is the annual vehicle MOT test.

So, we have a system of pattern evaluation of a design to ensure that it meets the specification, backed up by a system of periodic verification to ensure it remains compliant throughout its working life. If both these procedures are properly carried out, then it is possible to say that the vehicle conforms to the required standard throughout its working life.

When we come to look at measurement instrumentation, and sound level meters in particular, the same basic principles apply but with the complications of measurement traceability and uncertainty to be considered. These points are dealt with by national measurement institutions, such as PTB in Germany etc., with accuracy and uncertainty specifically dealt with in the product specifications.

When measurements are going to be used as evidence that a legally defined maximum value has been exceeded, then legal metrology rules would apply. Going back to the road transport example, we have the speed cameras that are used to enforce limits. These cameras must have valid pattern evaluation and periodic verifications, so the legal process can be confident on the measurement data and concern itself with the other mitigating factors in reaching decisions. Hence the laws state that the measurements should be made by competent persons using instrumentation that meets a specific accuracy class specified in the standard; in respect of the sound level meter, legal evidence of this would be a certificate of conformance to BS EN IEC 61672 part 1.

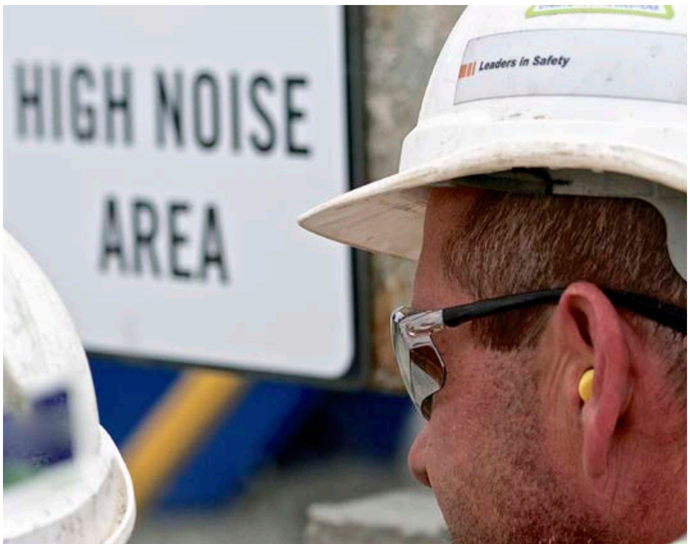
Beyond the strictly legal area, many acoustic professionals will want to be able to assure their clients that their consultants and instrumentation meets the highest professional standards with the lowest possible uncertainty and therefore choose to use pattern evaluated and periodically verified instrumentation alongside their staff CPD programmes. So, if a national metrology institute has provided a pattern evaluation certification and an accredited calibration laboratory has performed periodic verification successfully, then certification of conformance to the specification can be confirmed.

Earlier efforts have stressed the need to keep the costs of the periodic verification to a minimum, so that part of the testing has been restricted to electrical tests of key parameters with minimal acoustic testing.

As a result, the pattern evaluation tests must be more detailed. So, we have an extensive and detailed schedule of work falling into the pattern evaluation phase. Pattern evaluation is clearly the responsibility of the manufacturer, or the importer if the product comes from outside the EU.

Looking at the practical side of pattern evaluation testing, it is obvious that it must be based on measurements made on a sample batch of the model. The standard requires that three samples be provided and two of these would be selected for detailed testing by the national laboratory.

These tests will include acoustic testing of the complete instrument on all weighting networks as well as including directional response and case reflection effects. The influence of front-end accessories, such as windscreens and rain protection, would also need to be considered. In addition, temperature, humidity and barometric pressure effects need to be investigated to make sure the meter still meets the standard requirements over the full range of environmental conditions specified.



Noise at Work is legal metrology, so instrumentation must conform to standards and be regularly calibrated

As the electrical testing undertaken in the periodic verification has been restricted to control costs, very detailed investigations are included in pattern evaluation to ensure that the full range of acoustic signals are correctly processed by the instrument.

Finally, it is necessary to confirm the EMC performance of the instrument to ensure that it is not affected by radiation from other sources or that it will not itself cause interference. These require expensive test facilities and can also be time consuming, so this is quite an expensive undertaking for a manufacturer; cost can easily run into tens of thousands of pounds to approve each model they produce.

To gauge the level of detail that is required by the pattern evaluation procedure we can look at the environmental and acoustic test schedules in a little more detail.

1. Environmental testing

A class 1 sound level meter is required to operate to specification over the range of barometric pressures from 65 to 108 kPa with a reference level at 101.325 kPa. This would cover the reasonable range of weather and altitudes found in Europe, tighter tolerances apply to the range above 85 kPa as this is typical of the range of pressures expected where most people live and work.

To undertake the tests, it is necessary to have a sound calibrator with known performance over such a wide range of static pressures, this is normally an electro-mechanical pistonphone as these devices can have corrections for barometric pressure calculated from basic principles.

The tests are made in a pressure chamber that will accommodate the meter under test and the sound calibrator. Firstly, at the reference pressure and then at seven other pressures equally spaced between the maximum and minimum values. Tests are repeated twice – once from lowest to highest and then with falling pressures.

In respect of temperature and relative humidity – again, a reference sound calibrator is required that has known corrections for these various environmental conditions and a chamber that covers the range of environments specified. There is a short form test that requires testing at the following levels for a class 1 sound level meter:

Temperature, °C	Humidity, %RH
Reference	Reference
-10	65
5	25
40	90
50	50

Should the meter fail this shortened test, then different tests separately varying the air temperature alone and then with different combinations of temperature and relative humidity must be made.

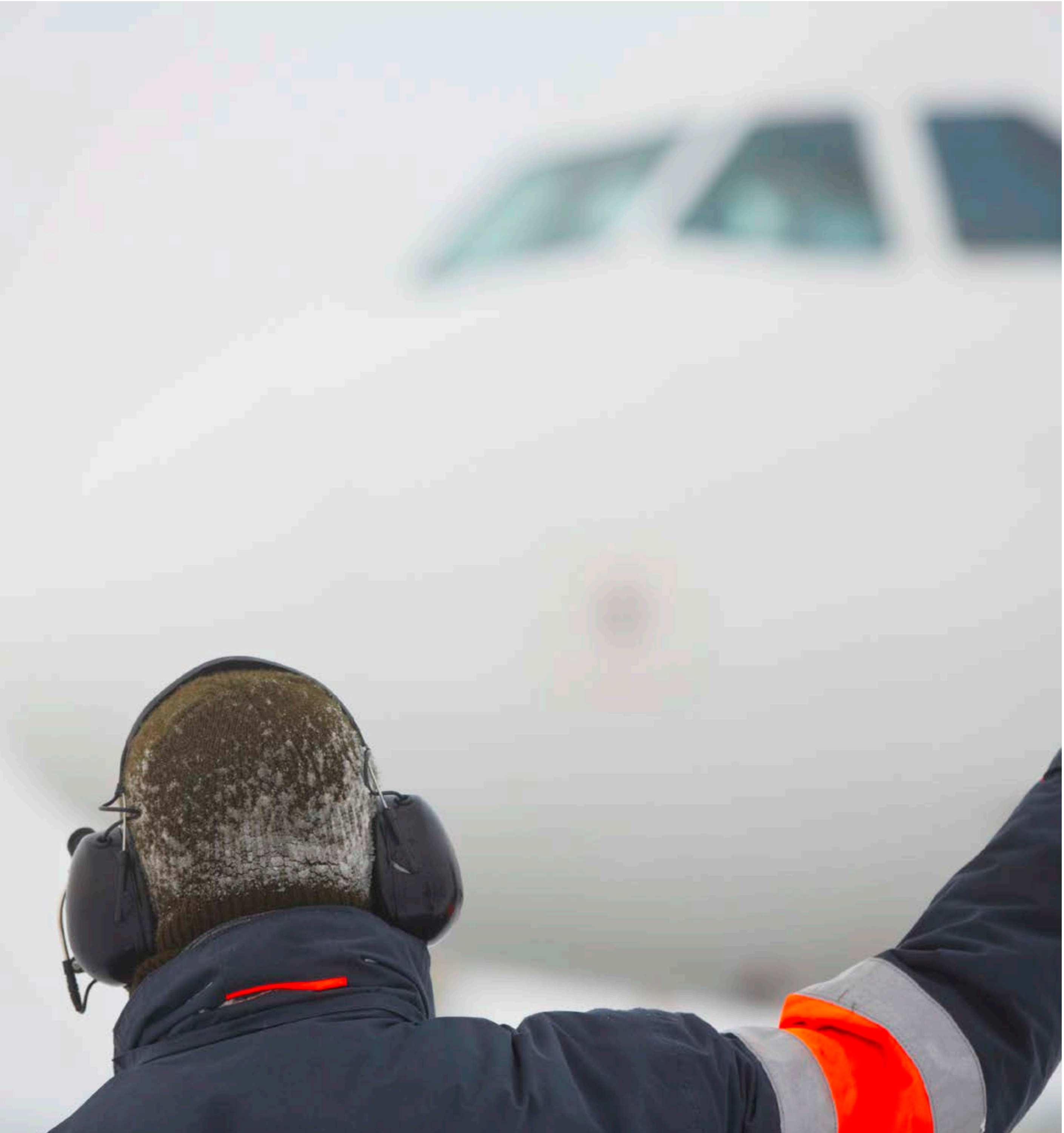
The time required for the tests is determined by the time to allow the conditions in the chamber to settle at the test conditions and then for the instrument and calibrator to normalise ready for the measurements to be made. P42 ►

2. Acoustic testing

To verify the acoustic performance of the complete instrument it is necessary to have a free field environment, such as an anechoic chamber, where the performance of the meter under test can be compared with a reference microphone at each test frequency in turn. The tests have to be performed for each weighting network and front-end configuration that claims conformance. Tests cover the frequency range of 10 to 20 kHz with measurements made at third octave centre frequencies over the range 10 to 2 kHz, sixth octave >2 kHz to 8 kHz and twelfth octaves 8 kHz to 20 kHz (class 1 only).

The verification of the directional response must be performed at the microphone reference direction and measurements also made at intervals of not more than 10° over the full 360° rotation of the microphone.

Tests are required at third octave intervals for frequencies 500 to 2 kHz, in one sixth octave from 2 kHz to 8 kHz and one twelfth octaves from 8 kHz to 12.5 kHz (class 1 only). Should the instrument being tested not have rotational symmetry about this plane, then additional measurements must be made in at other planes to ensure the specification is met.



The performance of hearing protection will be measured using specialised, calibrated instrumentation

So, in conclusion we can see why there is a need for pattern evaluation and the chain of events that are necessary to be able to certify an instrument as conforming to the specification. The costs to the manufacturer are considerable and, in addition, the user must meet the costs of the periodic verification; but it does put legal metrology on a secure basis to ensure only accurate measurements are offered as evidence.

Experience has shown that examples of claims that a sound level meter is just a 'voltmeter with a microphone on the input' or a 'smartphone with some app software' is sufficient. The complex effects of the microphone, environment and the dynamics of acoustic signals usually prove these ideas to be false and products are put on the market that do not do what is said on the tin.

It is not unknown for instruments to be failed when submitted for pattern evaluation, particularly for new entrants into the market. In one particular case, the implications of the environmental parameters were not fully appreciated and others, to my knowledge, have been concerned with the measurement of peak values or the calculation of LAeq,t results with high dynamic range signals.

There is no doubt that legal metrology, which is mandated in many EU countries, has resulted in the Standards authorities concentrating on independent verification of performance and control of uncertainty; and the quality of acoustic measurement has improved as a result.

As far as the UK is concerned, the home of caveat emptor, it is not a mandated requirement; but many government noise control regulations recommend it. So, the acoustic professional can ignore it at their peril if they wish.

The official view in the UK is for the buyer to be aware of what is needed and then use their own resources to ensure they obtain it. This leaves the situation where anyone can claim conformance to the standard, even for a phone app. So, in the UK, for professional applications, it is for the purchaser to establish that this claim to conformance is true or make their own estimates of the impact of instrument uncertainty that they need to build into their measurement report.

We see examples of meters submitted to calibration laboratories that are clearly marked with the BS EN 61672 standard that fail the periodic verification due to basic design flaws. But then when you consider that the meter cost less than the cost of the periodic verification, then the client should be asking themselves why the meter is so inexpensive.

It is perfectly in order for a manufacturer to claim conformance to the standard without having their internal testing confirmed by a national laboratory. However, if they have not established that the meter actually meets the standard it would be an offence under the trade description laws. There will obviously be occasions where the added costs of legal metrology cannot be justified, and in these cases, it is for the technician making the measurements to decide on the uncertainty contribution from the instrument. Omitting the pattern evaluation but completing the periodic verification would point to possible areas of error to be associated with the acoustic, environmental, EMC or electrical performance near the range limits. If the periodic verification is also skipped, then well, the errors could be anywhere.

When a sound level meter is purchased, the supplier will typically provide a certificate of calibration to internal factory procedures. How can we be sure that the instrument continues to perform to its published specification? The answer, of course, is regular laboratory calibration using an independent test house.

Richard Tyler

Anything our next contributor, Richard Tyler, does not know about calibration is probably not worth knowing. Richard's career includes research and development at CEL Instruments, and Casella Instruments in Bedford, and later he founded the well-known calibration laboratory, AV Calibration. He also ran his own company, AVI, which continued to develop both commercial and bespoke OEM instruments until recently. He was the founding father of the M&I Group of the IOA, and successfully chaired the committee for many years until his retirement.

Calibration

The concept of calibration is used in a variety of contexts, but this section deals with two of the most common practical applications for acousticians:

1 calibration of equipment in the field by the application of a calibrator of some description to a measuring instrument; and

2 having an instrument verified by a calibration laboratory in some fashion.

Before any further detail, the meaning of the word 'calibration' needs clarification. In the context of item 1 (above), it is usually taken to mean 'applying a known level of sound to a transducer, noting the reading obtained on the instrument connected to the transducer, and comparing it with the known level of the applied source, making any corrections necessary as appropriate' (which will be discussed later). Often, if the reading obtained is not exactly the same as the known applied level, the instrument will be adjusted to remove any difference. This is NOT calibration, but adjustment.

However in the context of item 2 (above), if an instrument of any type is sent to a test laboratory for calibration, the laboratory should measure that instrument and report their findings, usually comparing them to a known international or national standard as regards the relative accuracy of the device.

The comparison device should have direct traceability to a national standards laboratory if at all possible. NO adjustment should be made at that stage. If the instrument does not meet the requirements of its design criteria, or the owner of the equipment requires it optimised for best accuracy, then the laboratory may, if so instructed and able, make adjustments. The equipment should then be fully re-measured so that the new calibration reports the latest measurements and accuracy, together with its associated uncertainty.

Calibration therefore should not be expected to automatically include any form of adjustment.

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Quick summary

Field calibration – apply calibrator to transducer both before and after measurement. Adjust instrumentation to match certified value of calibrator plus any corrections required
Laboratory calibration – have equipment regularly calibrated – calibrators once per year, most other equipment once every two years unless otherwise specified.

Field calibration

An acoustic calibrator, usually operating at 1 kHz, is the most common device used to check the accuracy of instrumentation in the field. Good practice requires the calibrator to be applied to the measurement chain both before and after measurements have been made.

The acoustic level of the applied calibrator should be known to the best accuracy available, so normally this should have been sent to a laboratory for calibration fairly recently, and the exact value, together with its associated uncertainty, reported on the certificate supplied by the laboratory used to adjust any instrumentation being used.

'Fairly recently' is obviously relative, but in the UK, UKAS recommend that this is performed annually. However, if the calibrator has been dropped or has received any significant knocks, it may be sensible to reduce this interval. There are no mandatory requirements for the calibration interval in the UK, only recommendations, but in certain applications, the interval may be defined for a particular task. It is obviously sensible to have full confidence in the level of this device, as if the level is incorrect, then any adjustments of the measuring instrumentation will only carry through any error in the level of the acoustic calibrator.

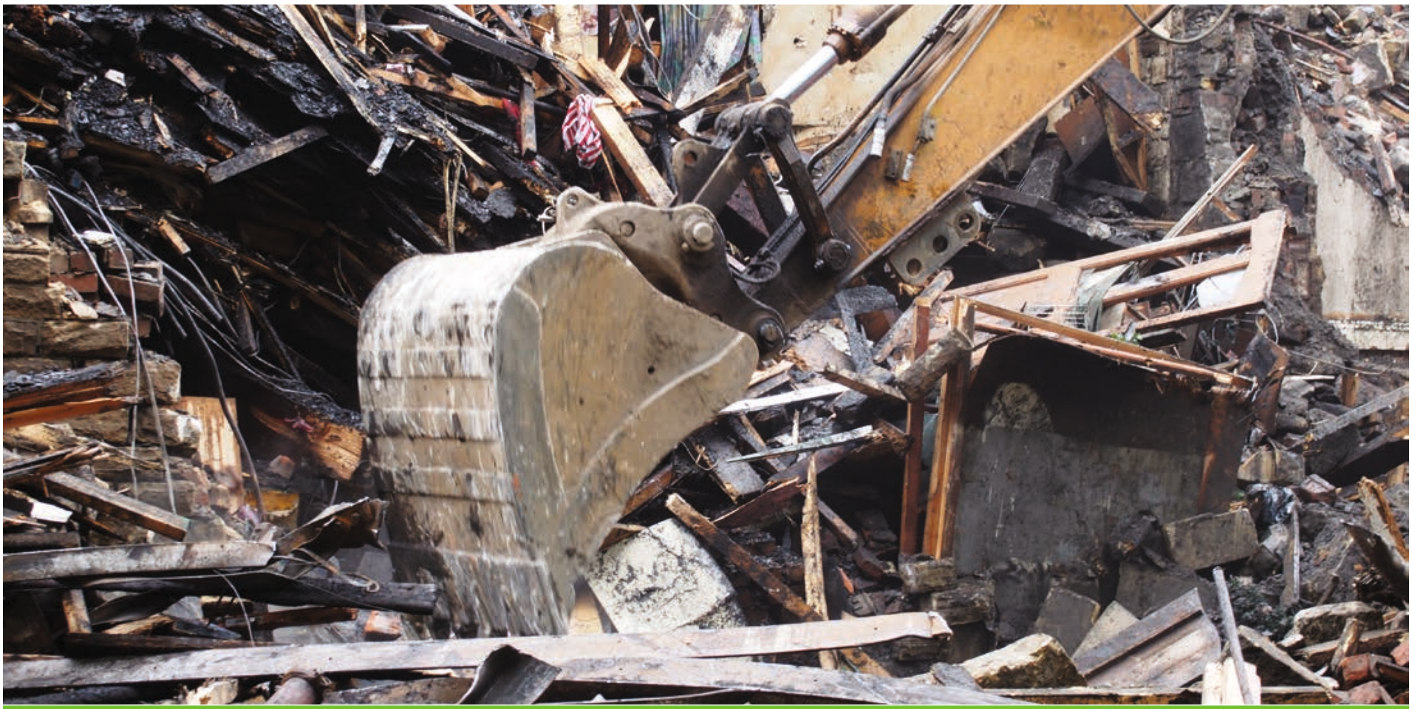
As well as the value of sound pressure level reported by a calibration laboratory for a given acoustic calibrator, consideration must be given to any corrections that may need to be applied. An acoustic calibrator generates a known acoustic pressure in a sealed cavity. This is not the same as a free field acoustic level. Correction factors may be needed to adjust the pressure level to an equivalent free field level, and these will be dependent on the type of microphone to which the calibrator is fitted and the modus operandi of the acoustic calibrator. Many modern devices need only a correction for the size of microphone, as the level inside the cavity is compensated for by feedback principles.

However, if a pistonphone or calibrator with the class category ending in /M is used, (or /C for older calibrators), other corrections are required. The most common is for atmospheric pressure, which directly affects the level of pistonphones, and requires a knowledge of the atmospheric pressure at the time of use to produce the best accuracy. Other devices may require manufacturer information to obtain the correct level at any given time. For best accuracy, the required corrections must be applied at the time of adjusting the instrumentation before and after measurement. Corrections should have been derived using methods detailed in IEC 62585:2012 and published by the instrument manufacturers.

If the levels before and after measurement differ by anything significant, then consideration must be given to the values reported for those measurements, or in cases of significant change, the measurements should be repeated.

Laboratory calibration of instrumentation

To check the performance of measuring equipment, they should be sent for 'verification' to a laboratory capable of undertaking testing to whatever Standard or accuracy the instrument was designed to meet. Modern designs of sound measuring equipment are usually remarkably stable with time, and therefore do not require as frequent calibration as the applied field or laboratory calibrator discussed earlier. In most cases, a two year interval suffices, but if frequent adjustments during the application of field calibrators is observed, then shorter intervals are likely to be needed.



Limits of demolition noise and vibration will need to be determined using traceably calibrated monitors

Calibration to national or international Standards

Most acoustic measuring instrumentation will claim compliance to a variety of Standards, depending on the country of origin and its intended market. IEC 61672:2013, available in three parts, forms the basis of the most widely accepted requirements for sound level meters, and many other countries have used this as the basis of their own requirements (e.g. USA, Japan etc.) sometimes with minor amendments. Part 1 gives the requirements for what the meter measures, part 2 defines the tests it must pass when fully tested (pattern approval), and part 3 defines a reduced subset of tests used for periodic verification. These are the tests that most calibration laboratories perform on a regular basis.

Standards for octave and third octave filters (IEC 61260:2014 and 2016 in three parts), personal sound exposure meters (dosemeters) (IEC 61252:1993) and acoustic calibrators (IEC 60942:2017) are similarly referenced as the basis for laboratories to verify the current performance of measuring instrumentation.

Older instruments should be tested to the version of the Standard they were designed to meet. For sound level meters, testing to BS 7580:1997 parts 1 and 2 apply to sound level meters designed to IEC 60651:1979 and 60804:2000 (often used outside the UK), otherwise the correct version or edition as quoted on the instrument or in its handbook should be used when tested. This can be established by the year quoted after and with the Standard number.

In the UK, British Standards have been harmonised with European requirements (EN European Norm) as well as the international ones, so they are then published as BS EN IEC or BS EN ISO XXXX.

Laboratory accuracy

There is a wide variety in the extent, accuracy and uncertainty of what a calibration laboratory does when testing an instrument. A lot depends on what the customer requires and specifies to the laboratory. Ignorance of the precision measurements specified in the Standards is quite widespread, and as anyone can set themselves up as a calibration laboratory in the UK without any inspection or checking of what service they offer, it can be a question of knowing details of the exact service on offer. For example, one laboratory offering calibration of a sound level meter merely applied their acoustic calibrator to it, adjusted the meter to read the calibrator's level, and claimed the meter was fully calibrated. Another just carried out the electrical tests specified in the Standard, but did nothing acoustic at all. Neither process can be recommended as a full verification of the meter.

All laboratories should claim a degree of accuracy traceable to national or international Standards in some fashion. In the UK, the highest level of this is verified by the United Kingdom Accreditation Service (UKAS), and only laboratories that have undergone rigorous examination by UKAS officials can claim UKAS accreditation, and will have their own specific laboratory number. UKAS will independently re-inspect these laboratories annually to ensure the claimed accuracies and uncertainties of measurement are maintained, as well as the relevance and competence of staff and the procedures they are working to. Outside the UK, similar arrangements are often available through national sources.

Laboratories that do not claim UKAS accreditation can still have their reference measuring systems verified to national Standards for accuracy, but will usually only be able to claim a greater degree of uncertainty in their measurements.

Traceable or national standard calibration

For best precision, backed up by independent cross checking of the calibration process, a national standard laboratory, or a laboratory accredited via a national accreditation process such as UKAS in the UK, will always be the best measuring capability. Not too surprisingly, it will almost always be the most expensive as well.

Any secondary laboratory should define exactly what it tests, its accuracy in performing those tests, and the associated uncertainty of those results. Customers can usually specify which tests they require, as these laboratories are not usually bound to carry out the full range of tests each time they measure an instrument, and with some measuring systems, the laboratory may only be able to receive part of the full measuring chain for testing.

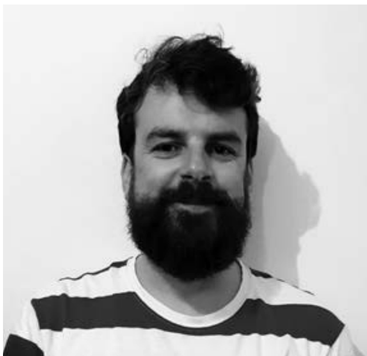
Depending on what application the measurements are aimed at, less than top-notch accuracy and uncertainty may be quite acceptable, especially if outdoor acoustic measurements are being taken, as the uncertainties of wind, temperature, proximity to buildings and people etc. will often contribute far greater uncertainty to the measurement process than that from the instrumentation.

As with so many instrumentation issues, the user must decide exactly what degree of calibration they need and ensure that any laboratory used is capable of delivering the specification they expect. This can be quite demanding on the user, but in most countries, unless a full test is carried out to the Standard the instrument is designed to meet, anything less must be carefully evaluated.

If measurements are to be used in any legal framework, anything less than recent calibration by a laboratory independently assessed and accredited (e.g. UKAS in the UK) can be considered risky if the measurements are likely to be challenged in court.

All of the above assumes a complete measuring instrument, right the way through from microphone to displayed results. There may come a time, however, when a measurement system uses parts of the chain, all of which conform to the specifications of parts of the standards. For example, an outdoor microphone might be connected to a data acquisition unit, which performs the measurement, and displays the result remotely over the internet. These devices are typically used for wide-area noise monitoring, long-term applications and 'smart city' applications using IOT devices.

Our next contributor, Ben Piper, is well placed to discuss these issues, having been at NPL Teddington, and now running his own company, Acoustic Sensor Networks, specialising in smart city applications and MEMS sensor technology. P46 ►



Ben Piper

Noise monitors and sound level meter standards

Advances in computing and communications technology have allowed for a shift in approach when it comes to measuring environmental noise. The speed of change has meant that there are no current standards that apply for a lot of systems that are used, or that a cumbersome and potentially expensive fudge is required for these systems to be able to claim conformance with a specific standard.

For the purpose of this article there are two separate categories of system that need to be considered. These are sound level meters (SLMs) and sound monitoring systems (SMSs).

SLMs have been around for decades, they have well-defined performance and should be covered by fully appropriate standards such IEC 61672. They generally consist of a hand-held unit with on-board processing, a display and a high-quality condenser microphone and preamplifier. Increasingly, they also have some data logging and transmission features.

SMSs are distributed systems typically with a microphone, local processing unit, and some means of data transmission (Wi-Fi, 4G etc) at the point of measurement with data stored in a cloud where further processing can take place and feed a web-based display. There are many variations on this theme with some systems performing machine learning at the node, whilst others monitor a single broadband level as part of a sensing platform that includes other measurands such as air quality, light and parking availability. The components used to make these systems have a wide variety in quality and cost. The key advantage of using this type of system is they are much more flexible in the number of points, length of measurement campaign, or indeed, what they are measuring. The quality of the data measured is very variable though.

For any measurements which require conformance to a standard such as aviation noise or planning compliance there is no choice but to use a type approved SLM, at least for that aspect of the measurement campaign. It is entirely possible to build a distributed network based on type approved equipment and these exist for some critical applications such as airport noise monitoring. This is a very expensive and inflexible option though.

SMSs are mostly suited to measuring noise trends and identifying noise events. Even in these contexts it is important that the quality of the data is considered. It would be very easy to deploy hundreds of sensors using cheap, unverified equipment and end up with terabytes of meaningless data. In designing a monitoring network, consideration must be given to the trade-off between quantity and quality of data.

Some example applications of SMSs include adding real time layers to traffic noise such as the DYNAMAP project in Italy, source localisation and attribution, such as the Crossrail Moorgate construction noise monitoring project in London, and sound identification such as the work undertaken in the SONYC project in New York.

SMSs clearly require some standardisation and this is currently under discussion in a working group of the IEC TC29 electroacoustic standards committee. There has been progress on discussing the flexibility of systems which could be tested, but input from testing laboratories is still required.

Conclusion

From the above, it should be clear that sound level meters are more than just a voltmeter with a microphone plugged in, or similarly, a smartphone with an SLM app! As professional acousticians, members of the IOA should be aware of what goes into the design and manufacture of a sound level meter, and how it is not only expedient but essential to invest in credible instrumentation, particularly for legal metrology.

If any issues are unclear, the M&I Group exists to inform and educate in such matters, so always feel free to contact us via the Institute.

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