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Instrumentation Standards for Noise Measurement

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Sound Level Meters

The ever increasing interest in noise in recent years both nationally and internationally has made standardisation of the performance characteristics of measuring equipment of vital importance.

Historically the original requirement in this Country was to measure the loudness of the noise. Considerable effort was applied to designing "objective noise meters" [1, 2] which would measure the loudness level in phons. However many investigations have shown that the human hearing mechanism is very complex indeed and thus the emphasis changed to standardising a measuring equipment which would provide reproducible readings so that noises of similar character could be satisfactorily compared. This had been the philosophy in the USA where the first sound level meters were developed in the early 1930's and by 1936 an American Tentative Standard[3] was published.

Efforts in Europe at about the same time to standardise sound level meters on an international basis were interrupted by the Second World War. In the mid-1950's the IEC Technical Committee 29 : Electroacoustics took on the task of preparing an international standard. Several countries had published standards for sound level meters which were broadly similar, but differed in important details. For example the frequency weighting responses given in the German DIN 5045 : 1942[4] differed from those in the American Standard. Even the name of the measured quantity differed. The American sound level meters were calibrated in decibels and the German instruments in DIN-phon.

After considering proposals to use the then recently published Robinson and Dadson equal-loudness contours[5], the weighting curves finally agreed in the first international standard on sound level meters, IEC Publication 123[6], approximately divided the difference at low frequencies between the American and German response curves. And, of course, the calibration in decibels was firmly established.

Work on a standard for an international "precision" grade sound level meter with closer tolerances, IEC Publication 179[7], had been carried out in parallel with the specification for the general purpose instrument.

From the experience gained with IEC 123, the way in which some of the tests were specified was changed but this made it difficult to compare the relative performance of the two specifications. Thus in IEC 123 the tolerance shown for the weighting curves is for the overall absolute acoustic calibration of the instrument whereas for IEC 179 it is the relative frequency response to which the ±1dB tolerance on the absolute sensitivity at the reference frequency must be added to obtain the overall accuracy.

IEC Publications 123 and 179 were adopted as the bases for British Standards 3489 : 1962[8] and 4197 : 1967[9] respectively. A Second Edition of IEC 179[10] was published in 1973 with closer tolerances at low frequencies and these have been incorporated as an amendment to BS 4197.

It was recognised in the preparation of the IEC publications that the conventional sound level meter was not likely to be suitable for measuring sounds of very short duration. Unfortunately the results of investigations on the response time of the human ear varied widely and the "impulse" characteristic which was standardised in Germany and used as the basis of the IEC Publication 179A[11] for impulse sound level meters was a compromise between extremes of questionable validity. Reservations expressed by the British National Committee regarding the impulse response were subsequently confirmed by the work[12] of Study Group B of ISO Technical Committee 43/SC1 which, in respect of the loudness of repeated noise pulses, concluded "It is of particular interest to note the inability of the dynamic response 'impulse' to rate the noises, as this response has seriously been considered suitable for the measurement of impulsive noises".

A further British objection to the 'impulse' characteristic was that it is not suitable for assessing impulsive noises for hearing risk purposes where the requirements in the UK had been written in terms of equivalent continuous sound level (Leq) for all types of noise. Thus no British Standard equivalent to IEC 179A was prepared.

Although America was strongly represented on the working group which drafted IEC Publications 123 and 179 and many of the USA proposals were incorporated into the final documents, the revisions of the American standard[13,14] differed in several respects from the international specifications. Sound level meters could be designed to comply with both the IEC/British and the American standards in most respects. However there was one fundamental difference which meant that the sound level meter manufacturer had to offer two versions of a given grade of sound level meter. This was necessary because the overall acoustic performance was specified in the IEC publications in terms of a free-field calibration at a specified angle of incidence for the sound relative to the microphone, usually taken as perpendicular to the diaphragm. There were additionally tolerances on the response for other angles of incidence. These requirements were very precise and, in my view, essential for an acoustics laboratory to check whether a given sound level meter meets the specifications. The American standard was written in terms of the random-incidence response of the microphone and it was usually necessary to slightly adjust the high frequency performance of the sound level meter amplifier or to fit a "random-incidence corrector" to the microphone or to use a "flat random-incidence response" version of the microphone to meet the slightly different American specification. Also the user was told to adopt a different measuring technique to achieve the best practical accuracy when the noise was predominantly from a known direction. With equipment to the IEC and British Standards, the sound should reach the microphone in the direction of calibration marked on the instrument. With the American version, the sound should arrive at the angle of incidence specified by the manufacturer for free field measurement, typically 70^{o} relative to perpendicular incidence. However despite the differences in technical detail, in normal use there were no significant measurement discrepancies between corresponding grades of the IEC and American sound level meters.

Thus about 10 years ago work was started on a consolidated revision of the various IEC sound level meter publications to remove the inconsistencies between the existing specifications, update the performance requirements and above all with the intention of making the new document a truly international standard. In an effort to ensure that the American views were given full consideration, Warren Kundert of GenRad Inc in the USA was invited to be the secretary of the new Working Group, a task which he accepted and carried out thoroughly and effectively.

The new IEC Standard, Publication 651 "Sound level meters"[15] describes in great detail the performance requirements, testing and calibration procedures and the technical information to be provided in the instruction manual. The fundamental parameters are the same as the earlier IEC publications but there are some differences, the most important of which are as follows:

1. Four grades of instrument are now described. All have the same basic characteristics but with differing tolerances.

   Type 0 has been introduced as a laboratory reference standard with the best performance that can be achieved at the current state of the art.

   Type 1 corresponds closely to the IEC 179 (Second edition 1973) precision sound level meter.

   Type 2 is intermediate between Type 1 and Type 3 and is typical of the performance currently achieved in present day general-purpose sound level meters.

   Type 3 is an up-dated version to the IEC 123 "general-purpose" or "industrial grade" sound level meter.

Types 1, 2 and 3 broadly parallel the classifications in American National Standard ANSI S1.4 – 1971, that is :

Type 1	–	Precision
Type 2	–	General Purpose
Type 3	–	Survey

2. Sound level meters which are only used in laboratories where the environment is controlled are not required to meet the full range of ambient temperature and humidity. Such meters are to be marked with the letter "L", for example "Type 0L".

3. Digital readouts and also "discontinuous analogue" displays, for example a column of lamps, are covered by the new standard as well as the conventional meter indication. The trend to meter scales spanning more than 30dB is also recognised. Previously a range change switch was mandatory if the meter scale exceeded 30dB.

4. A test for the stability of the indication with time is added.

5. The "fast" and "slow" responses are called "F" and "S" respectively and a maximum decay time for each is now specified.

6. The "impulse" response of IEC Publication 179A is included as an option and referred to as the "I" detector – indicator characteristic.

7. The optional "Peak" mode from IEC 179A is also specified but with a faster response time. The duration of the test pulse is reduced from 200 microseconds to 100 microseconds (50 microseconds for Type 0).

8. The more complex rectangular pulse and tone burst tests from IEC 179A are now specified for checking the r.m.s. rectifier performance of all sound level meters instead of the previous simpler two-tone test.

Even with the considerable improvements and detailed specification changes, a sound level meter which met the previous standards will, for a modern design, generally give indistinguishable readings from one to the corresponding grade of the new standard.

The British National Committee voted against the latest IEC document firstly because the impulse characteristic was considered to be grossly misleading for reasons previously outlined and secondly because of the change in the test procedure for the r.m.s. rectifier. However now that IEC 651 has been published, it has been decided to issue an identical British Standard 5969 but with a National Foreword to draw attention to the unsuitability of the "I" characteristic for measurements to determine loudness or the risk of hearing impairment of impulsive sounds.

With modern techniques, the complex circuitry required for this type of equipment can be built into a portable, hand-held sound level meter to provide all the facilities of both instruments in one compact housing. Such instruments are now commercially available, for example the Computer Engineering Model 193 which was specially developed to meet this specification and has been supplied in quantity to the H.S.E. for use by their Factory Inspectors.

Personal Noise Dosemeters/Sound Exposure Meters

Many industrial situations require compact instruments which can be attached to the worker and carried around in varying noise conditions to measure sound exposure. A wide variety of these personal noise dosemeters (dosimeters in the USA) have appeared on the market in recent years and thus there is a vital need for standardisation.

An American National Standard Specification for Personal Noise Dosimeters [18] has been published which makes provision for two or more exchange rates, that is the trading of exposure duration for exposure level. The principal exchange rates are 5dB increase in level for halving of the duration used by the Occupational Safety and Health Administration and 3dB which is recommended by the Environmental Protection Agency. The 3dB exchange rate is the "equal-energy" relationship used in the integrating sound level meter.

The American Standard specifies tolerances corresponding to the ANSI Type 2 sound level meter and calls for the A-weighted "slow" response. The measured quantity is given as a percentage of a sound level criterion, for example, 90dB(A), for a reference duration of 8 hours. It should be noted that dosemeters are calibrated in linear units of sound exposure and not logarithmic units related to decibels.

Work on an international standard for dosemeters was started in 1973 using an early draft of the American Standard. Because there is little demand for the 5dB exchange rate outside the USA, only the 3dB exchange rate was retained in the IEC draft. Also the percentage calibration was considered to be unsatisfactory, for example, there could be serious confusion to the user if the criterion level was subsequently changed. Similar difficulties could arise where various countries adopt different criterion levels. Thus calibration in absolute units of sound exposure is proposed in the latest IEC draft.[19] Sound exposure, E, is the time integral of the squared A-weighted sound pressure:

$$E = \int_0^T p_A^2 \, dt$$

where T = measurement duration in hours

t = time in hours

p_A = A-weighted sound pressure in pascals

The USA also voted against the new IEC document primarily because "the freedom to select any angle of incidence, including 0° incidence, for calibration is too broad". It is hoped that the USA too will find some basis, in the interests of truly International standardisation, on which to adopt IEC 651 for the next revision of the American National Standard on sound level meters.

Integrating sound level meters

With the increasing use of the equivalent continuous sound level, Leq or more precisely L_{Aeq}, in many noise codes and standards, high performance measuring systems which integrate the noise with respect to time have been developed to evaluate fluctuating and impulsive noises. In 1971 the National Physical Laboratory placed a contract with Computer Engineering Limited to design and manufacture a "Noise Average Meter" with what, at the time, was an exceptionally wide dynamic range to cover the levels which are frequently encountered in both environmental and industrial noise investigations, in anticipation of the Department of Employment's Code of Practice for reducing the exposure of employed persons to Noise [16]. More recently with the drafting of legislation in this Country the Health and Safety Executive took the initiative and prepared a specification for integrating sound level meters in consultation with equipment manufacturers. This has been used as the basis for a British proposal to the IEC which has now been circulated as a draft international standard [17] for comment.

Four degrees of precision are specified corresponding to the grades of IEC Publication 651 "Sound level meters" for the parameters such as microphone characteristics and frequency weighting which are common to both.

The major feature is the extremely wide pulse factor capability which enables virtually any steady, intermittant, fluctuating or impulsive noise to be measured without overloading the instrument. For Type 1 the pulse factor capability is 63dB for a category "P" ("pulse") instrument, with a dynamic span of 60dB. There is a second category, designated "N", in the IEC draft for integrating instruments intended for environmental and similar noise situations where the ability to respond to short duration pulses is not required. For a Type 1N instrument the pulse factor is only 20dB although the dynamic span is still 60dB. Special test procedures have been developed at the HSE laboratories, for example the pulse factor is checked by super-imposing a short duration tone burst on a continuous signal to simulate an impulsive sound occuring in the presence of background noise. An overload indicator is mandatory so that if the extremely wide range of the instrument is exceeded by the noise being measured, this fact is drawn to the attention of the user.

The unit of sound exposure is the pascal-squared hour. 1 Pa^2h corresponds to 84.95dB(A) for 8 hours. 3.20 Pa^2h is 90dB(A) for 8 hours. As with percentage dose, the sound exposure is a linear unit and to make a distinction between existing dosemeters and instruments to the draft IEC standard, the name "personal sound exposure meter" is proposed.

The accuracy which can be achieved with a sound dosemeter or exposure meter is limited because of the acoustic interference effects which arise through mounting the microphone on the person. Errors of several decibels are typical and the best mounting position for the microphone is on the shoulder.[20] Larger and less predictable errors occur at the breast pocket and, rather surprisingly, larger errors still, up to 10dB(A), with the microphone mounted at the ear. Thus only two grades of precision are included, corresponding to IEC 651 Type 2 and Type 3 sound level meters and as with the American Standard, the IEC draft calls for overall acoustic calibration of the equipment in the absence of the wearer.

The IEC draft on personal sound exposure meters has not yet been accepted as an international standard and some further technical matters have still to be resolved.

Future Work

Proposals that a follow-on specification should be prepared for personal sound exposure meters with a wider dynamic range to respond to impulsive sounds are under consideration and the international work on a head and torso simulator for hearing aids may lead the way to an improved overall acoustical performance of the equipment when mounted on the person.

An IEC working group has been set up to prepare a standard for sound pressure calibrators ("acoustic calibrators") which are now widely used for checking sound level meters and similar measuring instruments.

The recent increasing use of digital filters has meant that the existing IEC standard for band-pass filters,[21] on which the British Standard[22] was based, is being re-examined but it seems likely that it will prove adequate for both analogue and digital designs.

Progress on the design of narrow band real time analysers is still so rapid that standardisation is considered to be premature at the present time. However standards will undoubtedly be required in due course.

Conclusion

International standardisation of instruments for noise measurements is a slow and difficult process. However it is important if acoustic measurements made in different countries are to be compared in a satisfactory manner and it has undoubtedly contributed to the vast improvement in the performance of sound level meters which has been achieved in recent years.

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