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SOUND LEVEL METER CALIBRATION AND VERIFICATION

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1. INTRODUCTION

Requirements for acoustical measurements arise from a very broad range of applications. In most cases a sound level meter or integrating-averaging sound level meter is used as the measuring device. This paper details the current standards relating to the specification of these instruments and discusses the standards at present available on which to base regular testing. In many cases it is important to be able to demonstrate that an instrument is still working to its original specification eg. in court cases such as compensation claims for hearing damage, or for measurements performed under EC Directives. This paper also considers the most appropriate method of testing these instruments for the more common applications.

2. CURRENT INTERNATIONAL STANDARDS

There are currently two main international standards relating to sound level meters. IEC 651 published in 1979 [1] gives the full specification for sound level meters (dual-numbered as BS 5969: 1981), and IEC 804 published in 1985 [2] gives equivalent information for integrating-averaging sound level meters (dual-numbered as BS 6698:1986). These standards are wide-ranging and include acoustical tests, eg. to verify the directivity of the meter, tests to verify the signal processing features of the meter which are normally performed electrically, and also requirements for sensitivity of the meter to various environments, eg. pressure, temperature, humidity, vibration, magnetic fields etc.

The standards specify four Types of meter - Type 0, 1, 2 and 3, the Type number increasing as the tolerances around the centre values are broadened. In the UK, when a new meter is brought on to the market the manufacturer will specify which Type classification the meter has been designed to meet. These IEC standards are also the documents used by countries such as Germany who require an independent authority to verify the claims of the manufacturer and ensure that the meter does meet the specification claimed before it can be marketed. This complete test of a new meter to all the specifications given in the relevant IEC standard is termed a 'pattern evaluation', sometimes known as a type test.

Hence a full test to the relevant IEC standard is clearly very labour-intensive and so expensive, and whilst this cost can be borne by a manufacturer launching a new instrument, it is obviously not practical for all meters to be subjected to such a complete test on a regular basis.

SOUND LEVEL METER CALIBRATION AND VERIFICATION

3. CALIBRATION AND PERIODIC VERIFICATION

There are two tests which can be performed on a meter to verify its accuracy at regular intervals. The first is purely a calibration, and standards laboratories such as the National Physical Laboratory generally offer such a service. The calibration entails measuring the response of the meter relative to true sound pressure level, using a pure-tone sound field. At NPL measurements are normally made over the frequency range 31.5 Hz to 12500 Hz using a plane-wave duct up to 125 Hz and a free-field room as the test facility at higher frequencies. Measurements are performed using the substitution technique and a standard calibrated condenser microphone as reference. Normally one angle of sound incidence is used (generally normal incidence) and the sound field adjusted until a meter reading of 74 dB is obtained at each frequency. The standard calibrated microphone is then substituted in the sound field in place of the meter to determine whether the true level is 74 dB, allowing the response of the meter to be calculated and quoted on a calibration certificate. Clearly there are limitations to this method of test: the meter is tested at only one level for one direction of incident sound and only continuous signals are used. This means that many facilities of the meter are not completely tested and some may not be tested at all.

The alternative is to use a small set of more extensive tests which verify more facilities of the meter, and can be performed on a regular basis to ensure that the meter is still working as it did when it was first manufactured. This is termed a 'periodic verification' test. Now, IEC 651 and IEC 804 do not recommend which of their tests should be performed on a regular basis. So what other standards might meet this need? Until last year there was only one other standard in the UK dealing with the performance of sound level meters. This is BS 3539 'Sound level meters for the measurement of noise emitted by motor vehicles', published in 1986. It describes a very abbreviated set of tests, drawn from IEC 651, for a very specific requirement. BS 3539 applies only to Type 1 instruments which must have A-weighting, time weighting F, and a minimum range of 70-110 dB(A). Meters are normally tested annually, largely electrically, using the signals specified in the subclauses of BS 3539. The extent of the tests is as follows:

- A-weighting (63 Hz to 8000 Hz)
- linearity (70-110 dB(A))
- time weighting F
- r.m.s. accuracy (crest factor 3)

There is an acoustical calibration at 1000 Hz which gives the meter its traceability to national standards, and an acoustical check at 125 Hz. The meter must have an associated sound calibrator. If the meter complies with the tolerances specified in the standard the testing house (the national standards laboratory NPL, or a NAMAS-accredited calibration laboratory) will issue the meter with a certificate stating compliance with the standard.

Some years ago NPL was approached by NAMAS to devise a test to be used to regularly

verify the instruments used by its accredited testing laboratories, who were making measurements under EEC Article 100 directives. NPL decided at the time that the only standard this periodic verification could be based upon was BS 3539, but to add various 'options' from IEC 651 and IEC 804 as required, eg. time weighting S, time averaging etc. This unsatisfactory state of affairs continued for some years until the British Standards Institution set up a working group to write a new British Standard on 'periodic verification' of sound level meters. Further impetus was given to this work as at least one other British Standard, BS 4142 'Method for rating industrial noise affecting mixed residential and industrial areas' published in 1990 effectively referred to a periodic verification test by a NAMAS-accredited laboratory.

The remit of the BSI working group was well defined. It was to draw up a standard with sufficient detail to ensure consistency of testing between different test houses, and the tests should be sufficient to verify the accuracy of the meter at regular intervals. It was not allowed to substantially alter any of the tests in IEC 651 or IEC 804 as these are current standards. The WG used as its basis two documents produced by the International Organization of Legal Metrology (OIML), which is an organization which has an interest in the legal requirements for measuring instruments. These documents, OIML Recommendation R58 [4] which deals with sound level meters and OIML R88 [5] for integrating-averaging meters, suggest a framework of tests drawn from IEC 651 and IEC 804 to be performed for both pattern evaluation, and, of more interest to the WG, for periodic verification. However these documents do not give any detail on how the tests should be performed, so this important aspect was the main task of the WG. From the work of this WG came the new British Standard BS 7580 'The verification of sound level meters' which was published in 1992.

4. BS 7580 - THE VERIFICATION OF SOUND LEVEL METERS

BS 7580 applies to all Types of meter and assumes that the instrument was originally manufactured in accordance with IEC 651 or IEC 804 as appropriate. It has a requirement that the verification be performed at least every two years, unless the particular application of the meter makes it subject to other requirements. The test to BS 7580 may be performed by a national standards laboratory or an accredited laboratory, so the appropriate organizations in the UK are the National Physical Laboratory or a NAMAS-accredited calibration laboratory. A further important point is that all the facilities which a meter possesses and are mentioned in the standard must be tested, and again the meter must have a sound calibrator associated with it. This sound calibrator must have been calibrated within the last year and comply with the international standard on sound calibrators IEC 942:1988 [3] (dual-numbered as BS 7189:1989) in respect of sound pressure level, frequency and total harmonic distortion for the Class of calibrator specified by the manufacturer.

The tests in BS 7580 fall into two groups - those performed electrically and those performed

acoustically. Prior to any measurements the sensitivity of the meter is adjusted using its own calibrated sound calibrator, and then a measurement of self-generated noise is performed with the microphone removed. Various electrical signals as specified in the standard are then applied as a test of the following:

- linearity
- frequency weightings
- time weightings F and S
- peak response
- r.m.s. accuracy
- time weighting I
- time averaging
- pulse range
- sound exposure level
- overload indication

In the case of peak response the WG saw fit to extend the test described for Type 0 meters in IEC 651 to cover all Types of meter, but clearly only Type 0 are required to comply. Similarly the overload indication test was altered slightly to make it more meaningful and ensure that a meter reads correctly up until the overload indication appears. In cases where the tests are not mandated by the IEC standard a meter cannot fail BS 7580 on those clauses alone, but the fact will be noted on the certificate issued. Full details of the test signals applied can be found in the standard, which is available from BSI.

The instrument complete with microphone is then calibrated using a continuous acoustical signal of frequency 1000 Hz at a sound pressure level in the range 73 dB to 125 dB. The sensitivity of the meter is then adjusted, if necessary, so that the meter reads correctly. This acoustical calibration may be performed either in a plane progressive sound field by comparing the response of the instrument with that of a reference microphone substituted at the same position in the sound field, or by application of a standard sound calibrator when corrections for the difference between the free-field and pressure response of the instrument must be applied. It is through this acoustical calibration that traceability of the meter to national standards is established.

Finally the complete instrument is verified acoustically at 125 Hz and 8000 Hz, typical of the frequency range of use, to ensure it is within tolerance and that no microscopic hole exists in the microphone diaphragm. In addition to the two methods mentioned above an electrostatic actuator may be used, and again appropriate corrections must be applied. Finally the meter's own sound calibrator is re-applied and the indication of the instrument recorded. This value should be used to adjust the sensitivity of the meter whenever it is used in future.

All measurement data are then checked against the tolerances given in the standard for the

appropriate Type of meter to determine whether the meter complies with BS 7580, and if this is the case a Certificate is issued stating compliance with the standard. BS 7580 also gives full details of the information to be provided on the Certificate.

5. APPLICATIONS OF BS 7580

How does the publication of BS 7580 affect the typical user of a sound level meter and for what areas of measurement will such a periodic verification test be applicable? The following is a list giving examples of areas and users who will clearly benefit from having a well-defined basis for the verification and calibration of their measuring equipment:

a) NAMAS-accredited laboratories, both those involved in calibration of instruments to agreed uncertainties, and laboratories accredited for testing. For the testing laboratories a requirement for their instrumentation to be verified against BS 7580 will gradually be introduced, replacing the existing test to BS 3539 with appropriate options. NAMAS will only require the meter to be verified every two years in place of the current annual requirement, but the associated sound calibrator will need to be calibrated annually.

b) Measurements under the Noise at Work regulations, which implement the EC directive on noise at work. Here requirements for calibration are somewhat vague. The meter, which is usually a Type 2 should be 'fully checked at least every two years.' As a sound calibrator is also required, BS 7580 now seems the appropriate standard on which to base the tests and this ties in with the guidance issued by the Health & Safety Executive which mentions NAMAS-accredited calibration laboratories.

c) Measurements of motor vehicle noise, which is regulated by EC Directives, and implemented in the UK in the Motor Vehicles (Construction and Use) Regulations. Although BS 3539 is not being withdrawn there is a statement in BS 7580 indicating that a meter which complies with BS 7580 is also deemed to conform to BS 3539.

d) Measurements of noise emission of machinery, where certain types of machinery cannot now be marketed within the EC unless they carry a conformity mark stating their sound power level. Various of the relevant ISO standards require an acoustical and electrical calibration of the measuring equipment every two years and calibration of the associated calibrator annually. In the UK the noise-testing must be performed by a NAMAS-accredited laboratory.

e) Measurements of environmental noise, such as under BS 4142. The latest version of this standard published in 1990, is currently undergoing a minor review, but at present a test of compliance of the complete measuring equipment with the relevant

parts of BS 5969 or BS 6698 performed every two years by a NAMAS-accredited calibration laboratory is required, or the instrumentation must be tested by comparison with a Type 1 reference set which has been so confirmed.

In short, BS 7580 is now the relevant standard whenever periodic verification of a sound level meter or integrating-averaging meter is required.

6. THE FUTURE OF SOUND LEVEL METER TESTING

IEC 651 and IEC 804 are currently in the process of a major revision by an international working group. This revision will produce one combined standard giving full specifications. It will also include details of the tests to be performed for periodic verification, as well as how to perform them, so there will no longer be a need for a standard such as BS 7580.

This paper has dealt largely with periodic verification rather than the initial pattern evaluation tests of a new design of meter to determine its Type. To date there have been no organizations in the UK capable of performing these pattern evaluation tests and it has been necessary for manufacturers to go abroad to have their instruments tested. However the National Physical Laboratory is currently developing its tests and facilities to offer such a service for sound calibrators and sound level meters. OIML have been designing reports to be used by testing houses for reporting measurements from these pattern evaluation tests, and NPL intends to report under this OIML Certificate System.

7. REFERENCES

[1] IEC 651:1979 Sound level meters
[2] IEC 804:1985 Integrating-averaging sound level meters
[3] IEC 942:1988 Sound calibrators
[4] OIML R58:1984 Sound level meters
[5] OIML R88:1989 Integrating-averaging sound level meters