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AN ACOUSTIC CONSULTANTS VIEW

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INTRODUCTION

The publication of BS4142:1990 [1] and more recently BS7580:1992 [2] has raised questions among consultants as to how best to check the performance of instruments which they use for noise measurements - acoustic calibrators and sound level meters. Although some consultants are content to adopt and pay for the preferred method stated in BS4142:1990, that is, verification by a NAMAS accredited laboratory at least every two years, others object on the grounds of cost (now about £400) and down time of their sound level meters (about three weeks). The alternative currently offered in BS4142:1990 clause 4.2, namely by comparison with an instrument which has a NAMAS certificate to Type 1, is vague and inconsistent with suggestions made in the clarification on BS4142 reported by Porter [3], that a multifunction acoustic calibrator be used, which is an absolute calibration. Furthermore, in the two year interval between successive NAMAS verifications, undetected equipment malfunction could occur, requiring a simple checking procedure which could be applied more frequently in-house. Some consultants find that after NAMAS certification of an instrument they are inclined not to risk it in the field and it is thereby consigned to cotton wool in the laboratory.

Current efforts to revise BS4142:1990 include reconsideration not only of the recommended verification procedures but recognition (for which I have not seen the evidence) that the accuracy of type 2 meters would suffice for BS4142 measurement and assessment. In that case the cost of NAMAS verification according to BS7580:1992 might exceed the purchase price of the sound level meter itself.

In this context The Association of Noise Consultants set up a working group to consider the calibration and verification of noise and vibration measurement equipment. Progress has been slow, partly because it is not clear what the working group is trying to achieve but also because it is argued that we should await developments elsewhere, for instance in the proposed revision of BS4142:1990.

The purpose of this paper is to expand on these issues; to consider sound level meter NAMAS certification from the users perspective and to explore alternatives, predominantly with BS4142 measurements and assessments in mind.

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RELIABILITY OF DATA

Valid and consistent measurement results depend on many factors:

a) instrument specification - the accuracy, resolution and stability of the measuring instrument,

b) conformity to specification - verification, calibration and its traceability, reliability of the measuring instrument,

c) appropriate use of instruments - recognition of their limitations, correct application and operation of equipment, avoidance of abuse or damage,

d) Interpretation of readings - error assessment, evaluation and assessment of data.

Specifications for the performance and verification of sound level meters are now in place, though specifications for percentile measurements remain a significant omission. In the list above, the items highlighted are more critical in practice but also more difficult to define and control. As stated in BS5969:1981 [4] clause 2.5, "the method of use has at least as much effect on a measurement as the quality of the instrument itself". Thus, BS4142:1990 devotes more print to guidance on how to use sound level meters than to the assessment of rated noise levels or the calibration of equipment. Clearly, a realistic approach calls for an appropriate balance between the control of equipment quality and the control of its use. Today, the quality of use will always be inferior.

Of those constraints on the validity of measurements which are directly attributable to the measuring instrument itself (ie (a) and (b) above), reliability is the most difficult to define. Currently, for sound level meters the only standardised operational check consists in applying to the instrument at the time of measurement, a single frequency and single amplitude continuous tone from an acoustic calibrator or pistonphone, noting the reading and making an adjustment to the instrument if necessary. Provided the adjustment made (if any) is small and there are no independent contra indications, the apparently rash assumption that the instrument will perform satisfactorily, seems to work in practice as a rule. No doubt the reputation of the manufacturer and the price tag of the instrument have a bearing on the confidence we attach to this assumption. If we are not to rely solely on the operators skill or wish to describe what it entails, we need to explore the common contra indications and their means of identification, together with the circumstances in which the assumption of fitness for purpose fails.

The foreword to BS4142:1990 states that "noise assessment is a skilled operation and should be undertaken only by persons who are competent in the procedures". Operators should be aware of the limitations of their equipment in relation to the measurements they are making. Probably

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Alternatives to full verification are necessary, such as partial verification where only selected functions from the battery of BS7580 tests are selected. More appropriate would be a field test where the indication of the meter to selected real noises or simulated realistic noises, is tested. In this connection, BS4142:1990 currently calls for compliance with the relevant parts of BS6698 or BS5969 but does not say which are the relevant parts. Quite reasonably, we need not be concerned with parts of the instrument our sound doesn't reach, but we need to know which. Prior to the publication of BS7580, laboratories which were NAMAS accredited in this field undertook verification tests to BS3539:1986 which stipulates a limited range of tests appropriate to sound level meters used for the measurement of noise emitted by motor vehicles - Table 1. How do these relate to the relevant parts of BS6698 and BS5969? It seems that the forthcoming revision of BS4142 may call for instrument verification to BS7580:1992, which itself requires that the full complement of its tests be carried out. The danger is that we are beguiled by generally laudable objectives of high accuracy, textual brevity and administrative simplicity without proper consideration being given to the instrument accuracy and reliability required specifically for BS4142 measurement and assessment.

Measurements are subject to systematic and random errors - in the instruments, in the physical variable being measured and in the measurement procedure. To identify and quantify these errors is far from trivial. Verification procedures for sound level meters are appealing in that tolerances for individual functions are already laid down but it is not clear how these relate to deviations from ideal measurements when aggregated over several instrument functions, as would occur in the measurement of real noises. Thus, in what I have called field testing, even with deterministic signals for which the measurement outcome is calculable, we need to devise tolerances which are consistent both with aggregated individual function tolerances and with anticipated requirements for overall measurement accuracy. For instance, in the light of allowable tolerances in the A-weighting and integrating-averaging functions of type 1 and type 2 sound level meters, what maximum deviation from ideal measurements of $L_{Aeq,T}$ can we expect for real noises? What is the expected maximum difference between the two meter readings when measuring this quantity and how does it relate to the accuracy required for BS4142:1990 assessments? How do we calculate the latter?

A WAY FORWARD

Measuring instruments for noise and vibration are increasingly computer orientated, employing A/D converters, digital filters and appropriate software. Perhaps the future for manufacturers is to repair existing equipment and to sell transducers and conditioning amplifiers, leaving signal analysis to their software designers. There are opportunities here to define and demonstrate reliability. Already, digital equipment, for instance printers, come with self-test routines; surely the day is not far off when sound measuring instruments will be supplied together with an optional computer card and floppy disc for self verification, or will themselves contain the necessary test routines and hardware.

In the meantime we could rely largely on the reputation of our instruments and on the skill and experience of operators. If these imponderable qualities will not suffice, what form might a simple field test take? We hear that a technique is being developed [9] for electrically testing the percentile accuracy of noise measuring instruments, using an envelope ramp function for which the theoretical outcome is calculable. Conceivably, the same test could be used at the same time for the equivalent continuous level - Figure 1.

The test should be designed to be suitable for in-house and field testing of sound level meters and take about 5 minutes to run, using either an absolute measurement (preferred) or a comparative test against an instrument already verified. The test signal could be specified with a stated means of generating it by analogue or digital equipment or supplied on tape for replay on a DAT recorder. It should be accompanied by a continuous 1000Hz tone generated by the same means.

The method of applying the signal to the meter should be specified in terms of the signal level and input/output impedences. It may be appropriate to specify a suitable analogue circuit or even to supply the hardware.

Properties of the signal would need to be determined to optimise the test, such as the form (eg a ramp function linear in voltage v, v^2 or $10\log(v^2)$, dynamic range, frequency content and period. To allow the test to be started and ended indeterminately, a minimum test duration should be specified, based on a calculation of the maximum permissible error. Realistic tolerances need to be established for the outcome of the test in relation to the type of meter and the noise measurements for which it will be used.

Testing of the frequency response of the microphone could be done with a multifrequency calibrator, not the multifunction calibrator. A field test for the self noise of the microphone is likely to be less straightforward.

CONCLUSIONS

For the purposes of BS4142, verification of sound level meters by NAMAS laboratories accredited for BS7580:1992 is seen to be worth more on paper than it is in practice. Conceivably, less rigorous but more relevant tests could be devised for day to day checking of sound level meters. Whether these could or should be officially sanctioned, is questionable.

Background work to drafting of British Standards such as BS4142 needs to include an assessment of the required measurement accuracy, which should be reflected realistically in the stipulated quality of instrumentation and

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the commonest stumbling block here is the instrument dynamic range - particularly its self noise, for which there may be no specific indicator on the meter such as that provided for overload. In this connection, a simple operational test for the self noise and frequency response of the microphone, though difficult to devise, would address two more commonly suspected but usually temporary faults.

The question comes down to whether we can identify and quantify the qualities of a skilled operator so as to replace them by a procedure or a machine. As usual, the technological problems are likely to be trivial compared with the psychophysical analysis.

PURPOSES, PRACTICALITIES AND PERCEPTIONS

As a result of the verification clause in BS4142:1990, clients increasingly demand NAMAS verification certificates for sound level meters used by consultants on their projects. Though it is hard to see how either party to this arrangement could really believe that measurement reliability is thereby maintained or improved, both parties are obliged to jump through the bureaucratic hoop.

The appearance of a British Standard for sound level meter verification, its marriage to NAMAS accreditation and the installation of this alliance in BS4142, is not without merit. To the committee member or the town hall clerk issuing contracts, it is perceived as a ready reference to unassailable aspirations. To the hard pressed consultant, following the standard's guidance provides a welcome defence against bellicose barristers. With NAMAS certification thus installed in our perceptions and documentation, third party or self certification, even if it confirmed an instrument as working satisfactorily, would be perceived as second rate.

Where sound level meters are turned round like aircraft at Heathrow, NAMAS certification every two years proves little and is perceived as cash squandered, capital investment lying idle and fee earnings lost. Accidents do happen, meters and microphones get wet or tripods overturned, sometimes with significant short term loss of performance. In time, components fail, become worn, dirty, or corroded. Is it sufficient to keep instrument log books and to rely on experienced staff to detect faults or could a simple test be devised for instruments in day-to-day use, to check with reasonable certainty that they have not suffered a critical malfunction during previous field excursions? Is it not at least plausible that a meter checked today is more likely to be fit for its purpose than one certificated a year ago and subsequently subjected to occasional indignities?

If consultants do not have technical resources to check their meters exhaustively, it may that, all things considered, they do not think it a priority. On the other hand, consultants attached to bodies such as universities, large industry and research establishments, whether as servants to these bodies or offering external services to third parties, enjoy the benefits of extensive laboratories and service facilities where the checking, repair and even the design of instruments is well established. Must these bodies have their sound level meters checked by another laboratory which is NAMAS accredited or be obliged themselves to seek NAMAS accreditation? Surely not, but as BS4142:1990 stands they may have little alternative.

I doubt if consultants believe the accuracy of their measurements would be undermined if their meters were never tested to BS7580:1992. They may be more open minded in respect of an acoustic calibrator; even skilled operators would be slow to discover it was up to 1dB adrift.

From one point of view, BS7580:1992 is a carefully considered document laying down procedures which if carried out by a NAMAS accredited laboratory, will give the highest possible confidence in an instruments performance. But its introduction can also be seen in context as a bureaucratic short cut which avoids the real issues, namely, identification of instrument faults which do occur and those which generally do not, a proper assessment of the instrument and measurement accuracy required for the task in hand, an appreciation of the day to day circumstances in which instruments are used and awareness of the economic, bureaucratic and legal consequences of its introduction.

VERIFICATION -vs- FITNESS FOR PURPOSE

Verification involves checking a limited number of specific functions of an instrument by standardised procedures to determine whether or not these functions meet specification clauses to which the instrument has been built.

What really needs to be checked? Presumably owners will not send equipment for verification unless they are reasonably confident that it will pass, so statistics of failure rates and instrument malfunction from the files of NAMAS accredited laboratories (and NPL) are likely to reveal only those faults which users find difficult to detect - however, knowledge of those would be a step forward.

Assuming that the operator selects the right instrument for the job and is familiar with its controls and application, performance to specification is only one criterion of its fitness for purpose. There may be other, less stringent criteria. For instance, to obtain valid measurements of $L_{Aeq,T}$ the time weightings are not required, or for measurements of percentile levels the integrating-averaging and "S" time weighting functions are not required. At the extreme, a type 1 instrument could be out of alignment to the extent of the type 2 tolerances and with a number of its functions inoperative but still give valid readings for some applications.

its method of test. The preparation of these assessments would be in the best traditions of NPL.

Finally, noise measurement and assessment being a skilled operation, those who do it should ask themselves whether they really want formalised instrument test procedures and if so what the status of these procedures should be.

ACKNOWLEDGEMENTS

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REFERENCES

[1] BS4142:1991 Method for rating industrial noise affecting mixed residential and industrial areas.

[2] BS7580:1992 Specification for the verification of sound level meters.

[3] N PORTER Industrial and residential noise - questions asked at the BSI symposium on BS4142. IoA Acoustics Bulletin, Jan/Feb 1992, p11-13.

[4] BS5969:1981 Specification for sound level meters.

[5] BS6698:1986 Specification for integrating-averaging sound level meters.

[6] BS7189:1989 Specification for sound calibrators.

[7] BS3539:1986 Specification for sound level meters for the measurement of noise emitted by motor vehicles.

[8] A J MYLES Noise measurement standards and their requirements for calibration and verification of measuring instrumentation. IoA Acoustics Bulletin, Nov/Dec 1991, p19-21.

[9] Personal communication from J Sargent, Building Research Establishment, Garston, April 1993.

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Instrument Function	BS7580 1992	BS3539 1986	Multifunction Calibrator
	Electrical	Electrical	Acoustical
self generated noise (electrical)	*		
self generated noise (microphone)			
linearity	*	* limited	* limited
frequency weightings	*	* A	*
time weightings (F & S)	*	* F only	*
peak response	*		} crest } factor
RMS accuracy	*	*	}
time weighting I	*		
time averaging	*		
sound exposure level	*		* dose
percentile levels			
overload indication	*		
	Acoustical	Acoustical	
microphone frequency response			
1000Hz	*	*	* 32Hz-16kHz
125 Hz	*	*	+ 12.5kHz
8000Hz	*		
			+ input freq sweep

TABLE 1 Summary of BS verification tests and testing features of B&K type 4226 Multifunction Acoustic Calibrator.

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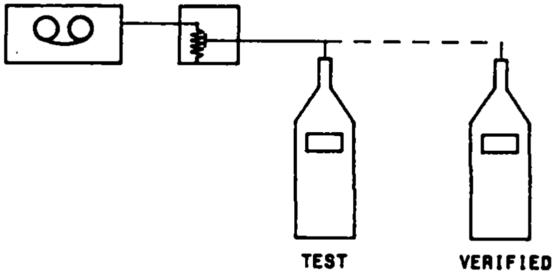

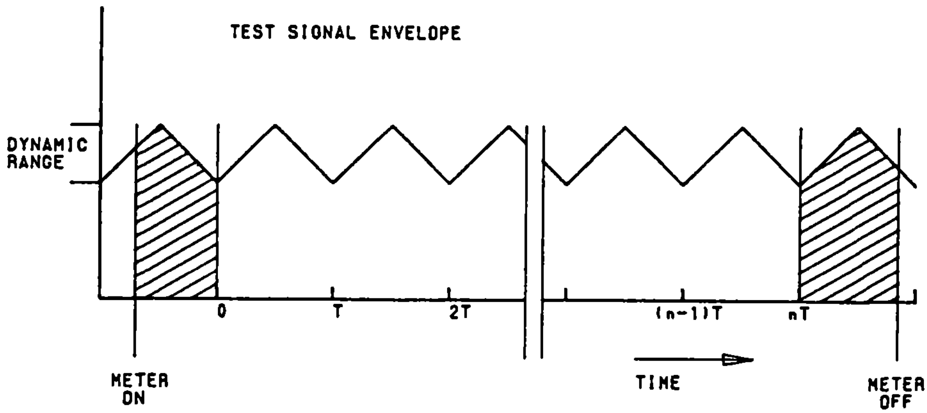

FIGURE 1 Outline electrical field test procedure using a DAT recorder and input circuit to the test sound level meter. In the suggested test signal envelope, the ordinate could be voltage v, v^2 or $\log(v^2)$, as best meets the requirements of the test and the hatched areas represent error time intervals for which likely maximum values should be calculated to determine the minimum required period, nT, of the test.