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DESIGN AND MANUFACTURING CONSIDERATIONS FOR ACOUSTIC INSTRUMENTATION REQUIRING NAMAS CALIBRATION

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1. INTRODUCTION

Until recently, there have been no comprehensive tests documented and nationally agreed for NAMAS traceable calibrations on sound level meters and other acoustic measuring instruments. In the UK, BS3539:1986 [1] gave a very limited set of tests aimed at verifying a sound level meter suitable for measuring vehicle pass-by noise, but with the publication of BS7580:1992 [2] a set of tests aimed at verifying the full range of measurement capabilities changed this situation. CEL Instruments was the first NAMAS laboratory to join the National Physical Laboratory in offering a commercial service calibrating sound level meters to this Standard. Having now gained some experience in this, certain traits in the design of sound level meters and the testing of them have become evident.

If the requirement for the future is for more meters to be calibrated to NAMAS standards, ways must be found to reduce the time-consuming, and therefore expensive, methods necessary to fully test a meter's compliance with the Standards. Whilst the laboratory's methods may be able to be speeded up, the biggest changes are likely to be with the design methods and manufacturing/test facilities used for new models, as easier ways of automatically co-ordinating input signals with instrument readings are made possible.

The wider variety of approaches to instrument design now being taken, where a computer or computing device performs many different calculations with total predictability, also raises the question of exactly what is worth verifying on a periodic basis; something which, as yet, has received little consideration from certifying authorities.

2. NAMAS PERIODIC VERIFICATION

2.1 Sound Level Meters

BS7580:1992 [2] requires many measurements to be made in order to periodically verify a sound level meter. It also states that any feature or function available on a given meter for which a test is given in this Standard must be tested, so the possibility of only testing features required by a given user is not permitted. The majority of measurements made concern the frequency response and signal linearity of each measurement range available tested electrically. Whilst the combination of input frequency and level can be programmed under computer control for a bus controlled generator, for the vast majority of sound level meters currently on sale, there is no way of automatically reading back the answer produced by it. The only solution is to manually transcribe every measurement point either onto paper, and thereafter manually to check that the answers are within the permitted tolerances for that measurement or enter them into a computer which can check the tolerances automatically. Inevitably, this is a slow and time consuming process that is difficult to speed up.

Many meters have some degree of data storage facility, although it is suprising how many cannot output this data until many other conditions have been satisfied, for example that it has finished measuring. As yet, no two manufacturers that I am aware of have used an identical output format when downloading this stored data to a computer, so even if this facility does give a means of correlating the input signal with the measured response, a separate programme would be required for each manufacturer's instruments (and sometimes each product) that the NAMAS laboratory attempts to calibrate. Although a few manufacturers do have this type of programme available for their own internal test functions, only rarely is it available to the end user in a viable form, and the likelihood of it controlling the same equipment for signal input sources as the laboratory is remote.

It must be clear by now that in many cases, each model from a manufacturer needs separate test schedules, a dedicated set of input conditions, a unique set of recordings of the responses and careful checking of compliance with the Standards. All this takes time and effort, both to produce the Procedures to be followed in the first instance, and to document the responses of an actual verification. The sheer number of measurements can be mind-numbing - a meter with a 70 dB dynamic range and 10 measurement ranges could take 80 measurement points just to check its linearity! And then there are the frequency responses, time weightings, acoustic accuracy, accuracy of integration (if fitted) and many other tests. Small wonder that the charge to the user for performing these tests is not cheap.

The task of manually performing this quantity of measurement on a daily basis in itself needs special care. Occasionally in our laboratory we see some items for calibration that bring a smile to the face, such as the meter from a company who thought the sensitivity had fallen a little after using it on a damp day in their factory. It did not occur to them that their product - cement powder - had something to do with this, but concrete microphone diaphragms do not work very well! For the rest, it is a matter of ensuring that the full capabilities of a given meter are understood, documented and tested rigorously.

2.2 Acoustic Calibrators

Calibrating a sound level meter to BS7580:1992 [2] also requires it to be supplied with an acoustic calibrator conforming to IEC942:1988 (BS7189:1989 is equivalent) [3] that has a valid NAMAS or NPL calibration certificate. It is envisaged that this calibrator is the unit to be used for all subsequent field calibrations of the sound level meter and does at least ensure that this calibration level is correct. For many other users, the only item they ever get NAMAS calibrated is their calibrator, often with totally different microphone configurations from those used on their meters, where the value of the NAMAS certificate must be questioned. Here there are far fewer tests to be made unless the calibrator is of a complex multi-level, multi- frequency type, but again, most defy any attempt to automate the verification procedure. Only by the NAMAS laboratory having an automatic reading system connected to the microphone placed in the calibrator's cavity can any significant assistance be gained.

A different problem often arises in verifying calibrators; couplers. Only if the calibrator manufacturer has designed or approved the joining of a given make and type of microphone to the calibrator with a stated method (usually a coupler if not direct) can the NAMAS laboratory actually test the calibrator as the customer uses it. There is often a great temptation by users to believe that any microphone size can be placed into any calibrator cavity by use of as many couplers as is necessary, rather analogous to adapting different sizes of water pipes to mate together with as many adapters as it takes. Refusal of the laboratory to "calibrate" these arrangements is met with incredulity, but with no data to support the method, the level and reliability of the sound pressure produced in these arrangements is totally unknown.

2.3 Verification Procedures

I hope this begins to show that, at present, NAMAS calibration of the basic apparatus used for sound measurement is likely to remain heavily manually-based for some time to come, which in turn is likely to mean time and expense to the owner. This situation need not remain. For the type of user for whom NAMAS certification is important, the quality of the meter owned is likely to be such that, provided the manufacturer has undertaken careful and sensible design, the vast majority of verification measurements can be made automatically in a fraction of the time currently taken. This could prove to be a hidden reduction in the "cost of ownership" of some significance to this group of users. With standards on the more complex acoustic instrumentation like intensity analysers now available, this is a factor worth keeping in focus if NAMAS calibrations are required, and the National Physical Laboratory is already looking into offering a service.

Another aspect becoming increasingly relevant in the verification procedures is to what extent the meter needs all its measurements periodically checked. If, as is now fairly common, many of the displayed parameters available are computed from a single raw data stream by a microprocessor, there is unlikely to be any change in these measurements provided that the original data input remains correct. Remeasuring all these items in minute detail every verification seems unlikely to offer any real benefit to the meter user. If the display device IS a computer, can the laboratory be certain that what it verifies today will be used identically by the user tomorrow? The problem for the laboratory is to know exactly how these measurements are really made before any assessment could be considered for reduced testing even if BS7580 allowed it, which it does not.

3. DESIGN CONSIDERATIONS

If instrumentation is to be made capable of easy and rapid verification, then the manufacturer's design team is going to have to consider this aspect as part of the fundamental requirements of a meter's specification. The only real solution is to offer some way of outputting the parameter to be verified in electronic format capable of being read by a computer using either a simple, manufacturer supplied programme or preferably a well-known proprietary spreadsheet or database package. Some difficulties that will be encountered will involve synchronisation between input and output, and the output format.

As sound level meters still form the main instrument requiring NAMAS calibration at present, the following discussion is primarily aimed at the design of future generations of these items. However, many of the requirements will be equally applicable to a variety of acoustic instrumentation.

3.1 Synchronisation

It is vital for the test laboratory to be certain that any measurement made which involves an element of timing is carried out precisely. Therefore the application of the input source, the starting and stopping of the measurement, and the reading of the answers must be defined to sufficient accuracy to have no error contribution to the measurement uncertainty, or to be very small in comparison with the permitted tolerances. Although some meters already allow external control of some measurement modes, the timing of response to these external commands is often set at a lower priority than the basic measurement tasks of the meter, with delays of often as much as a second in responding to these external signals. If this is known and understood, then the application of the input may be controlled to match, but in most of the meters seen so far, it is a variable and can produce significant differences from measurement to measurement with the laboratory unable to rely on the data.

If a mode is fitted to the meter, where the responses can be synchronised to the applied stimulus, many tests required could be automated; for example, all tests of integration accuracy where bursts of 4kHz sinewaves are repeated at predetermined intervals.

3.2 Range Switching

Although the number of measurement ranges fitted to meters has been falling as the dynamic span of each range has increased, this is an area where there will be differences in almost all designs. Any testing laboratory must check all ranges to ensure that they fully comply with any measurements expected to be made on them. The intrusion of electronic noise or self noise from the microphone (a factor largely overlooked in many measurements) at the bottom end of the lower ranges must be accurately assessed, and the ranges over which the meter is giving accurate readings according to the Standards must be defined and checked against the manufacturer's claims. Yet almost no meter on sale at present has any external electronic means of changing the range setting of the meter!

Many newer designs do not use physical switches to effect the range change. Mostly, this is performed by analogue switches, often controlled by a microprocessor. The means to execute range changing remotely is therefore likely to be fairly simple to add, but seems rarely considered.

The repetition of inputs covering the entire measuring range is significant, as has been mentioned earlier. As all these tests are performed with steady, sinusoidal signals, synchronisation does not present any problems. All that is required is a means to measure the steady r.m.s. level and compare that to the input signal. At present, the approved method for this is to adjust the input until the precise required reading on the instrument is obtained, and then to record the changes from a defined reference point of the input. This often means taking several readings of a given point on the meter before the exact reading/input signal match is obtained. It is therefore essential that an easy way of quickly conveying the meter's reading back to the input signal controller is available, so that the time to close the loop between applied signal and correct reading is short. Instruments that can only output an answer every minute over the bus clearly do not fit this requirement!

3.3 Other Parameter Selection

In addition to the range switching, at least two other parameters could very usefully be available for remote control. These are the selection of the frequency weightings and time constants (weightings) available on this particular meter. All frequency responses of each frequency weighting supplied must be checked at least on the manufacturer's stated reference range, and this is usually performed at all the standard third octave centre frequencies from 31.5Hz to 12.5kHz. A meter with 3 or 4 weightings fitted therefore also consumes quite a few measurements and the ability to select the weighting remotely could mean all of these being done in one pass together with the linearity measurements. The combination of all linearity and frequency weighting tests completed without the need of an operator to intervene would dramatically reduce the time spent testing any sound level meter, and these two items alone would constitute a major reduction in the time taken to test a meter.

Another area of all meters that requires testing is the exponential time constants or weightings supplied. Although the number of tests required here is not as large as for the two areas already mentioned, these are most easily verified with meters that have a Maximum Hold facility. Without this, the timing and synchronisation requirements become severe, and often frustrate almost all methods to measure with any degree of accuracy. If the meter is equipped with a remote control of a reset to the Max. Hold facility and the means to select all weightings externally, then this section of testing can also be speeded up considerably.

Selection of all other required measurement modes to be tested will depend on exactly how many there are and how this information is made available. Integrating sound level meters are really the only other major item that requires significant measurement, and here the synchronisation issue becomes significant. Generalisations about measurements here are difficult as there are many different solutions to the acquisition of integrated data. If the requirements of automatically verifying the basic sound level meter have been fully considered, then it is likely that the operation of the meter in integrating mode will be helpful in speeding up its verification process.

4. MANUFACTURING REQUIREMENTS

It is quite likely that many of the measurements made during a NAMAS verification of the meter are exactly the same as those made when an instrument is tested for the first time at the manufacturers. It is difficult to believe that all these items tested are done by the same manual method as the NAMAS laboratory is forced to use. Clearly the manufacturer has the advantage of choosing at what stage in the manufacturing process these tests are made, and by knowledge of the design principles involved, will be aware of what parameters are likely to be variable and what should be totally fixed. Subsets of the approved tests are therefore almost always used by the manufacturer to give a high degree of probability that a meter fully complies with the Standards.

If the means exist to prove quickly the majority of measurements made by a given design of meter, it seems a pity that these are not available to verifying laboratories. For a NAMAS calibration, it is not usually expected that the meter to be taken apart in any way, so a socket or connection of some description must be provided on the meter to allow access to these measurements if they are otherwise only available internally. Further, if the manufacturer has these tests under computer control, why not make the programme available for bona-fide users to verify the meter's performance?

If a manufacturer is not using these methods, then I would suggest that there are considerable potential time-savings to be had by designing such possibilities in to the meter, and the benefit should be lower prices to the consumer from the efficiency gained. The likelihood of achieving a similar or common set of communication protocols between different manufacturers for all meters is very low, although the increasing use of standard PC packages may achieve some degree of success. With forethought and co-operation, the similarity between manufacturing and test laboratory requirements could be addressed to everyone's advantage.

5. CONCLUSION.

In NAMAS testing a variety of sound level meters, it has been found that some fairly simple additions to most newer designs of meter could dramatically reduce the time to verify a unit. It is unreasonable to expect that the exact methods of improving this situation will be common across a range of manufacturers, but certain features such as linearity and frequency response testing on all ranges would be of great assistance. A means of synchronising an input with a reading would equally be of great assistance.

There is little evidence at present that either manufacturers or users appreciate this fact. Stand-alone meters often have few electrical connections other than an a.c. signal in and out, and instruments which consist in part or in total of a computer based measuring system have the potential to perform as required, but this potential is not realised in a form usable by the laboratory.

This situation can be rectified if thought about at the design stage, and access to the information could benefit the manufacturer, the user and the test laboratory. CEL has considered this in some detail with regard to the NAMAS testing of its own products and the latest generation of real-time sound level analysers, the CEL-573 and CEL-593, packaged in conventional sound level meter cases, have attempted to meet the needs outlined here.

To overcome the problem of needing many connecting sockets on the meter, the appropriate connector was placed on a plug-in module that is available in analogue, serial or parallel digital data formats. With the addition of two small commands to those available for execution over the serial port, an enabling facility has been created which allows for any input signal to be read back digitally within milliseconds of its application, and for measurements to be synchronised to a similar time accuracy.

The meter has up to 63 different combinations of measurement presettable and remembered, many of which are pre-programmed into the meter. If the testing laboratory manually presets a few measurement combinations additional to those already available into the meter before commencing testing, it is possible to access almost all required electrical measurements without the need for operator intervention. This is because the range and pre-set measurement set can be selected from a PC, and all data measured can be transmitted to it with known timing as the computer controls both the starting and stopping of measurement. This facility will soon be available as standard on all new meters of this family and will assist in both manufacturing and NAMAS verifying this complex product to the best Standards available. It will also allow any accredited service or calibration laboratory to perform identical checks on the meter if they follow the CEL procedure using the software provided for the PC.

Although the acoustic tests will still require manual intervention to verify, adoption of this type of method should enable the time-factor of NAMAS verification or just routine calibration checks to be reduced, leading to maintained or lower costs for the user. If other manufacturers follow, then a general improvement in ease of calibration can be expected for the future.

6. REFERENCES.

1. British Standards Institute publication BS3539:1986 "Sound Level Meters for the Measurement of Noise emitted by Motor Vehicles".

2. British Standards Institute publication BS7580:1992 "Specification for the Verification of Sound Level Meters".

3. International Electrotechnical Commission publication IEC942:1988 "Sound Calibrators".