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HOW GOOD IS *YOUR* DECIBEL?

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Most people who make acoustical measurements are familiar with using a sound level calibrator and adjusting the reading on the measuring equipment to the appropriate nominal level. But how accurately is the average sound level meter set up when this is done?

1. SOUND LEVEL CALIBRATORS

These usually consist of a sound source, which may be electrodynamic or electromechanical, and a cavity which connects it to the microphone. They should be used as a field check before, and preferably also after, a sound measurement is made. Calibrators appear to be simple devices which are simple to use, and unfortunately this lulls many people into a false sense of security.

First of all, the basic design and manufacturing quality of the instrument needs to be considered. There are many devices in circulation, some even still on the market, which are of very poor quality. Sound level calibrators should be designed to meet BS 7189 (IEC 942, Ref. 1), and it is as well to purchase one from a reputable company. But even assuming that the design of the calibrator is good, how well are you using it?

1.1 Are you correcting correctly ?

Since sound is in fact a variation in air pressure, the sound pressure level which is produced is dependent on the volume and various properties of the air in the cavity, and within the microphone. The volume will be dependent on the shape and structure of the microphone as well as that of the cavity and any couplers used; and the behaviour of the air will vary with such parameters as temperature, pressure, and humidity. In addition, since this is essentially a closed system, the microphone may not behave in the same way in the sound level calibrator as it does in normal usage, i.e. in a more-or-less free field.

In all but the most expensive of calibrators - and we are talking here in thousands of pounds - most of these changes are not compensated for, and we therefore have to add correction factors to the stated sound pressure level to obtain the true level at the time of use. For general indoor use in the UK the effects of temperature and humidity are relatively small, but appropriate corrections should still be made for:

Air pressure,
Microphone model & couplers,
Free field use.

1.2 Think before you calibrate

A certain amount of common sense is also required. An acoustic calibrator which has been left in a car overnight in winter and is then used to check a sound level meter in a steel foundry cannot be expected to be accurate immediately. It needs time to stabilise. Likewise if you knock your calibrator off a desk it may well no longer give the same output, if any. The treatment which acoustic instrumentation receives

never ceases to amaze us, with even devices such as the B&K pistonphone, probably the most robust of sound level calibrators, being wrecked. It was never intended to be a dual-purpose device, and it really is more cost-effective to go out and buy a conventional hammer. An interesting example of accidental damage was found in our laboratory recently, coincidentally also in relation to a B&K 4220 pistonphone. The visual inspection which is the first stage in our procedure revealed a large piece of mahogany, which had broken off the instrument case, wedged tightly into the acoustic cavity.

1.3 Is your microphone sitting comfortably ?
Another physical factor which can drastically affect the sound level produced is the fitting of it to the microphone. Even if the correct coupler is used, which is essential, there are two common errors in this area. The first is failure to seat the microphone correctly into the coupler, for example by failing to push it past the 'O' ring seals fitted in many instruments. The second, perhaps more common, error is caused by damage to these rings - after all, the dustcap of most microphones is not unlike a miniature cheese grater - which prevents them functioning correctly. It is not unknown for each of these problems to cause an error in excess of 2 dB.

1.4 Check your configuration
Do you use a windshield on your microphone? If so, the manufacturers' instructions should be consulted, because some windshields have an effect at 1 kHz, the most commonly used calibration frequency. Yet another correction factor to be applied! It is even possible that you may need to take into account reflections caused by the body of the sound level meter or any mounting device used. Also, if you use an extension cable between the microphone and the sound level meter, particularly if it is more than two or three metres in length, it is recommended that the calibration be carried out with the cable fitted.

1.5 Where do you start ?
We have now covered the main pitfalls of actually using a sound level calibrator, and compiled an ever-increasing list of corrections to be applied. Assuming that your calibrator is in good condition, that you are using the correct couplers, and that you have taken environmental and microphone considerations into account, the appropriate adjustments can be made. But how do you know the starting figure to which you should add the correction factors? Is it enough simply to take the nominal value quoted in the suppliers' catalogue? The accuracy will, to a large extent, depend upon the manufacturer's integrity and technical expertise. A sound level calibrator designed to BS7189 Class 1 purchased from a reputable manufacturer is likely to have a sound output falling within the requirements of that standard when new. The standard itself allows a spread of 0.6 dB, however, and the level is also likely to change a little with time, even if the instrument is not damaged.

1.6 Outside help
So, you need to have your sound level calibrator calibrated; but who should calibrate it? Obviously you could send it to the National Physical Laboratory, but most end users do not really need this degree of accuracy. Sending it to "a calibration laboratory", however, needs some careful thought. What to you mean by calibration? Does the laboratory to which you send it use the same definition? And above all, do they know what they are doing?

At least two different meanings appear to be attached to the word calibration. The true definition is simply a measurement of the current performance of the instrument in question, and does not imply that at the end of the procedure the instrument will meet its specification. However, many customers believe that calibration also encompasses adjustments and even repair such that the instrument is returned in perfect working order, whatever its state on submission.

1.7 How good is your calibration laboratory ?

Acoustic calibration is a much more complex subject than, say, the calibration of a voltmeter, and the average calibration laboratory simply does not have the expertise or equipment required. Unfortunately this does not stop some of them taking your money for performing a worthless "calibration". An example of this which came to our notice recently illustrates the point. A CEL-284/2 calibrator was returned to us by its owner for repair because the calibration laboratory to which they had submitted it had stated that it was outside specification. It was checked here and found to be well within the permitted tolerances. On further investigation, it was found that the "calibration" had been performed by taking a traceable CEL-177 calibrator, fitting it with a B&K half-inch coupler, using that to set up a Cirrus sound level meter, and finally using that to determine the level of the CEL-284/2. Every step in the measurement chain was flawed, and it is little wonder that the measurement made was in fact almost 9 dB in error. Although this is the worst case which we have seen, there have been numerous others in which incorrect measurement practice has led to errors of up to 3 dB.

1.8 What does it all mean?

How do you decide where to send your calibrator? The magic word "traceable" was used in the above example, and unfortunately this is all too often misunderstood, even deliberately misused. "Traceable to National Standards" simply means that each step in the measurement chain is documented so that it can be followed back until the primary standard - in the UK usually NPL - is reached. The above example was, therefore, a traceable calibration. So we turn to quality, and another misunderstood concept is immediately raised. It is widely thought that if a company has ISO9000 / BS5750 registration, it must be performing the calibration correctly. However, this is a minimum quality standard, and concentrates on the quality system itself. The laboratory in question could have written its own procedure to perform the calibration in the manner described and, provided it always used that procedure, could quite legitimately be registered. BS5750 does not guarantee technical competence, only that the same method is always used.

What should you therefore expect, if you want the calibration to be accurate and meaningful? The laboratory should record, and preferably state on the calibration certificate, the following:

The environmental conditions under which the measurements were made,
The type of microphone and configuration for which the level quoted is valid,
The uncertainty on the measurement, which should be calculated rather than guessed at,
The confidence level with which the results are quoted.

In addition, the laboratory should have a proven record of technical competence in the type of measurement which you require.

Checking that a laboratory meets these criteria is a long and difficult process, and may well be outside the capabilities of many instrumentation users. So why bother? The United Kingdom Accreditation Service, in granting NAMAS accreditation to calibration laboratories, has already done it for you!

1.9 How long does a calibration last ?

A calibration of any device, acoustical or not, and no matter how well performed, can only be taken as correct at the time at which it is carried out. We have seen many calibration certificates which state that, for example, the "calibration is valid for one year"; this statement is meaningless. The calibration laboratory cannot tell what the customer will do to the instrument in the intervening period! Again, purchasing your calibrator from a reputable manufacturer and looking after it will go a long way to ensure

that level drift is not a problem. If your budget will stretch to it, a further check can be made by having two identical devices calibrated and carrying out a periodic comparison between their output levels; if the relative levels are constant, it is unlikely that the absolute level of either calibrator has changed significantly.

1.10 Limitations of the sound level calibrator

Having obtained a valid calibration of your sound level calibrator, made all the necessary corrections, and applied it properly to your sound level meter, what has been achieved? Most calibrators are single level, single frequency devices, so the "calibration" of the measurement device is actually certain for only a single point within the device's range, assuming all the necessary data is known in order to compute the true level on the device being calibrated. How do you know that the rest of the device is accurate? The calibrator cannot tell you. Multi-level, multi-frequency calibrators can provide a considerable increase in points that can be tested, but often the variables of acoustic testing become significant in the accuracy that can be achieved.

2. TYPICAL SOUND LEVEL METER CALIBRATIONS

Whilst it is not always possible to define exactly what requirements are needed to be certain that the device connected to the microphone is displaying the "correct" answers, one of the most common - the sound level meter - has several procedures available that may be selected according to the user's requirements. Unfortunately for the user, modern meters are now complex and make many different measurements, many of which are at differing levels of accuracy. To verify that every aspect of a meter is fully working to specification can be very time consuming, but is the only way of being certain of the meter's performance at any given time. Fortunately, the stability of modern day electronics means that most changes are slow and small, but a full test of all the parameters can yield some surprising problems a year or two after manufacture, and some significant errors after 7 or 8 years, a time which seems to be "still young" to many owners of sound level meters. Listed briefly below are the type of tests that are specified in BS 7580 (Ref. 2) to verify most common aspects of an integrating sound level meter.

3. SUMMARY OF TESTS IN BS 7580

3.1 Performed Electrically

Self generated noise,
Linearity of every measurement range, both integrating and non-integrating,
All frequency weightings from at least 31.5 Hz to 8 kHz,
Time Weightings F and S (and I if fitted),
Peak response, if fitted,
R.M.S. accuracy, including crest factor and tone burst tests,
Time averaging (Leq) for bursts as short as 1 ms for integrating meters,
Pulse range for integrating meters,
Sound exposure level (for integrating meters),
Overload indicator.

3.2 Performed Acoustically

Calibration at 1 kHz,
Measurements at 125 Hz and 8 kHz,
Response to associated calibrator supplied with the meter.

Even this set of tests does not check all performance aspects of a sound level meter; most notably, no environmental effects are considered.

As can be deduced, these are wide ranging tests that can take a considerable time to carry out, especially if the meter has no means of relaying its answers to other test equipment other than by someone reading the display. "Do they all need doing?" is a frequent question raised by users: "surely they don't alter much during the equipment's lifetime?". For many instruments this is true of a large number of the measurements, but almost all meters have some points which are prone to change. The problem for users and testers is that you need a very detailed knowledge of the meter's design before these points become apparent and are almost always different from model to model. The only way to be certain your meter is accurate is to test it fully. With regular checking by a competent laboratory, the interval between checks can be adjusted to suit the degree of change and the accuracy and frequency of use required by the user, although leaving a meter more than 2 years between checking is probably ill-advised.

With the forthcoming introduction of BS 7580 Part 2, the number and complexity of tests for re-verification of Type 2 sound level meters which have initially been verified using the existing standard will be significantly reduced. This means that a fast (and therefore cost-effective) test for cheaper instruments can be made that is likely to highlight any significant errors in measurement, although it does not guarantee that the meter is satisfactory in every aspect of its performance. By using this procedure regularly, at least the major errors that might occur in the meter will be noted, and action taken to correct them, before too many measurements have been made erroneously. These errors often include faults at the bottom end of the measurement range, often caused by high self-noise in the meter, which gives spuriously high readings, and the inverse at the very top of the range, where designs intent on achieving long battery life often struggle to achieve as high a reading as there should be. Damage or dirt on the microphone can alter its frequency response dramatically, and small changes in integration times can noticeably affect the SEL and Leq answers.

Of course, all this checking and calibration can be thrown away if an unsuitable "calibration" laboratory is used (c.f. sound level calibrators) or the user does not carry out the measurements in a sensible way. Mounting the meter on a large bulky tripod often ruins the carefully designed case profile and introduces many acoustic reflections. Similarly, holding the meter near the body alters its directional performance significantly. Proper understanding of the sound field is essential if the measurements made are to be "correct", but an accurate meter is at least a first step along the way.

4. SO HOW GOOD IS *YOUR* DECIBEL ?

There are many factors that influence even a simple reading, and several attempts at quantifying the total errors often result in ±2 dB for the instrumentation and ±3 dB for the user. Do you think your measurements are better than this, and how certain are you of it.

Remember, the ±2 dB is for a good, fully and correctly calibrated unit: what if the meter hasn't been correctly calibrated or checked for years?

REFERENCES:

1) BS7189:1989 British Standard Specification for Sound Calibrators.
2) BS 7580:1992 British Standard Specification for the Verification of Sound Level Meters.