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THE VALIDITY AND ACCURACY OF FIELD MEASUREMENTS

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INTRODUCTION

Carrying out noise and vibration field measurements away from the laboratory requires many decisions to be made by the operators of equipment, including what, where and when to measure and what details need to be recorded and reported. For many types of measurement there are British Standards and Codes of Practice which specify these details but it is important that the persons carrying out measurements understand the reasons for these choices, so that they can adapt to unusual circumstances and are able to carry out and report valid and reliable measurements in situations not covered by Standards and Codes. It is also desirable that the person carrying out the measurements should be able to report on the accuracy and degree of uncertainty in the measured values.

There is no instrument which is foolproof (in the literal sense of the term) and the adage about computers, i.e.. that rubbish in means rubbish out, is applicable. Results of noise measurements taken with even the most sophisticated, accurate and expensive equipment may be useless if the operator does not fully understand how to use the instrument and have a knowledge of acoustic principles sufficient to enable him/her to appreciate its limitations, and to make the necessary decisions about what, how, where and when to measure.

This presentation will review the choices and decisions to be made in carrying out valid and reliable field measurements, and the acoustical and measurement principles underlying them. It will discuss factors affecting the accuracy of field measurements, and illustrate ways in which the measurement uncertainty may be assessed.

THE SELECTION OF EQUIPMENT

The correct choice of equipment can depend upon a number of factors including :

(i) The type of noise and the way in which it is to be measured. Is it for example a steady noise for which the appropriate unit depends on an analysis of the frequency content of the noise, or is it a time-varying noise such as traffic noise, which requires a statistical analysis over a period of time, or an impulsive noise, or one with pure tone components ?

(ii) The accuracy required. Is it for example a precision measurement involving controlled and standardised measurement conditions, or is it a preliminary survey, under field conditions?

(iii) The conditions under which the instrument will be operating. Is it a quick field measurement, requiring a portable and battery operated instrument, or is it a long term survey requiring permanently based semi-automatic mains operated equipment?

There is a very wide variety of equipment in use and because of modern developments in electronics, particularly the introduction of digital techniques, rapid changes have recently occurred and are still taking place in sound measuring instrumentation.

Even the simplest item of equipment, the portable sound level meter, occurs in a bewildering variety of versions, and although they all have certain basic features in common they differ in the detail of their performance, specification and method of use. All manufacturers provide a detailed hand book with their instruments, giving all this information, and a golden rule for anyone making sound measurements should be: the instrument manufacturer's handbook should always be read carefully prior to making measurements with an unfamiliar piece of equipment, and kept safely and readily available for reference thereafter. Equipment should always be operated in accordance with manufacturer's instructions.

MEASUREMENT AIMS

The starting point is to decide on the main purpose or aim of the noise measurement, since this will influence further decisions. As example consider the possible reasons that there could be for needing to measure noise levels produced by a piece of machinery, such as a compressor. These could include :

to compare with noise levels from other, alternative equipment
to compare with manufacturers noise specification
to compare with company's own (i.e. customers) noise specification
to assess the need for, or effect of machine maintenance
to assess need for, and to quantify noise reduction requirements
to diagnose noise sources and mechanisms and specify control methods
to assess the effectiveness of noise control measures
to measure the sound power level of the machine
to assess the noise exposure level of the machine operator
to use as a basis for predicting noise levels at other distances
to use as part of a noise complaint investigation
to use as part of a planning application investigation
to use as part of an environmental impact assessment

Some of these different aims will involve very different measurement procedures - for example in choice of measurement position, type of sound level meter to be used, noise parameter to be measured.

MEASUREMENT DECISIONS TO BE MADE

The choices and checks to be made, the factors and influences to be considered and the information to be noted may include :

Checks - battery condition, calibration, use of windshield, background noise levels.

Choices - type of sound level meter
- type of microphone (free field, pressure response, random incidence)
- position of microphone relative to source or receiver
- height of microphone above ground
- orientation of microphone (frontal or grazing incidence)
- noise parameters) to be measured
- measurement times) and duration(s)

Factors and Influences :

- other noise sources
- background noise, wind generated noise at microphone
- nearby sound reflecting, absorbing or shielding surfaces
- room characteristics (indoors), e.g. size, surface finishes
- sound propagation conditions (outdoors) e.g.. wind, weather, ground type, topography
- type of sound field e.g.. near field, far field, direct or reverberant sound, presence of standing waves

Information :

- all the above information about checks, choices, factors and influences
- manufacturers type numbers, and serial numbers of all equipment
- results of measurements and relevant instrumentation settings
- subjective impressions of the noise e.g. steady, intermittent, impulsive, tonal
- maps and plans showing measurement positions, source a receiver positions, with distances

MEASUREMENT STANDARDS AND CODES OF PRACTICE

In many cases measurement decisions will be based on the operator's knowledge and experience, but there are some situations in which conditions are specified by Standards or Codes, which ensure uniformity of good practice.

Examples of some standardised procedures include :

- measurement method given in Department of Environment publication Calculation of Road Traffic Noise
- measurement method given in Department of Environment publication Calculation of Train Noise
- Aircraft noise, ISO 3891 1978 : Procedure for describing aircraft noise heard on the ground
- Commercial and industrial noise : BS4142 1990
- Construction site noise : BS5228 1984
- General environmental noise : BS7445 1991
- Work-place noise : Noise at Work Regulations Guidance Notes 3 to 8, 1990

THE ACCURACY OF MEASUREMENTS

Every measured value has associated with it a degree of uncertainty, or error. The word error is used here in a specialist, technical sense, and not in its 'everyday' sense, i.e. it does not mean 'mistake'. A statement of the experimental error in a measured quantity is also statement of its accuracy, e.g. reverberation time = 1.6 +/- 0.2 seconds. Accuracy is not the same as precision, which is a statement about the smallest change in a quantity which can be detected. Thus a measurement of a noise level of 86.2 dB(A) from a machine implies that the measuring instrument was capable of a precision of 0.1 dB, but this does not necessarily mean that the measurement is accurate to +/- 0.1 dB, since random fluctuations, or errors might mean that a repeat measurement gave a value one or two dBs higher or lower.

Errors may be of two types - random or systematic. Random errors will show up as fluctuations in the measured value when the measurement is repeated, systematic errors will not. Systematic errors, once detected may either be 'allowed for' or eliminated - as in the case of a calibrator, or sound level meter which is systematically reading 0.3 dB too low.

Errors in the measured value of a noise level, from a machine for example, may arise from a number of sources :

due to the limitation of the accuracy of the sound level meter, and variability in environmental conditions affecting it

due to variability in the way the operator takes the measurement

due to variability in the source of noise

due to variability in environmental conditions affecting noise propagation

due to variability caused by the statistical nature of the quantity being measured e.g. traffic noise

due to limitations in the accuracy of theoretical (or other) assumptions underpinning the measurement (e.g. in the measurement sound power level, or sound intensity level)

Careful measurement procedures can often minimise errors, but if they are of the random type they will never be eliminated completely. The magnitude of random errors is usually estimated from the scatter in results. A common method is to estimate and quote the standard deviation of a group of measurements from the mean value.

Example The sound pressure levels measured in eight different microphone positions in a room during a sound insulation test are given below. Calculate the mean and standard deviation values.

measured levels : 92 dB, 95 dB, 91dB, 96 dB, 90 dB, 92 dB, 95 dB, 93 dB

mean level = (92 + 95 + 91 + 96 + 90 + 92 + 95 + 93)/8 = **93 dB**

deviation from mean : -1 , +2 , -2 , +3 , -3 , -1 , +2 , 0

deviation squared : 1 , 4 , 4 , 9 , 9 , 1 , 4 , 0

mean square deviation = (1 + 4 + 4 + 9 + 9 + 1 + 4 + 0)/8 = 4

standard deviation = root mean square deviation = = **2 dB**

therefore : sound pressure level in room = **93 +/- 2 dB**

If the number of results is large enough, and their scatter about the mean is random, then the usual Gaussian statistics can be applied to interpret the standard deviation in terms of probabilities and confidence limits, e.g.. there will be an 68% probability that any one result will lie within one standard deviation of the mean, and a 95% chance that it lies within two standard deviations of the mean.

When the results are sound pressure levels, in decibels, the question sometimes arises as to whether the mean and standard deviation, should be based on the decibel values, as in the above example, or on the sound pressure-squared values underlying them. This question is discussed, together with other aspects relating to errors in noise measurements, in the book by Yang and Ellison (Machinery Noise Measurement, Clarendon Press, Oxford, 1985).

GRADES OF MEASUREMENT ACCURACY

The measurement uncertainty, or error, in measured values determined using Standard methods are usually given, in terms of a standard deviation in the appropriate British or International Standard. BS4196 describes three different grades of measurement of sound power level, Precision, Engineering and Survey, with three different levels of accuracy.

Any more detailed discussion of accuracy, and measurement errors is beyond the scope of this chapter. The reader should at least be aware that every measured quantity has associated with it a degree of uncertainty, or error which specifies its accuracy. A knowledge of the likely degree of accuracy of measurements is important when assessing the significance of their contribution to the overall result or conclusion. Even when a formal statement of uncertainty is not required the statement of the result should be consistent with its likely accuracy. Thus it may be appropriate to quote a measured sound level only to the nearest decibel, if it is known to vary over a range of a few dB, even though the sound level meter indicates to the nearest 0.1 dB. This is a requirement of BS4142 in particular. The quotation of results to the nearest 0.1 dB may sometimes be justified, when the measurements are very accurate, or as the results of intermediate steps in a calculation, where 'rounding errors' may accumulate, but the statement of a result to more than one decimal place arising from a calculation perhaps, can never be justified, and should avoided.

MEASUREMENT REPORTS

These should contain relevant information in sufficient detail to enable a repeat of the measurements to be carried out, should this be necessary, under, as far as possible, identical conditions. The sort of information to be reported is listed above. It can be grouped as follows :

Basic information : dates, times, locations, name(s) of persons carrying out the measurements
Information about the source(s) of noise
Information about the instrumentation and the noise measurement data
Information about the acoustic environment in which measurements were taken

Many of the British Standards on noise measurements end with sections on the information to be recorded and reported, and give detailed guidance in these specific measurement situations.

Where reports are lengthy or detailed, it may be helpful to the reader if it is split into separate sections, such as :

aims of the measurements
measurement procedures
results of measurements
calculations and analysis of measurement data
discussion of results
conclusions
summary or abstract