NOISE DOSIMETRY : UNDERSTANDING MEASUREMENT PARAMETERS AND PRACTICALITIES

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1 INTRODUCTION

This paper describes the significance of the measurement settings and setup conditions involved in making noise dose measurements. Although most people who regularly make noise dose measurements understand the basic elements involved, details which could improve the integrity of the results are often overlooked.

The effect of different measurement settings on the overall dose measurement will be considered to illustrate the wide variations in dose which can result. The importance of various factors in carrying out noise dose measurement will be discussed with previous research used to illustrate the potential uncertainties which could be introduced.

2 MEASUREMENT RATIONALE

Noise dose measurements are normally conducted out of either a legal obligation to do so or as part of a risk assessment[1]. The legislation or guidelines requiring measurements be made usually stipulate the parameters and conditions under which the measurements should be made.

However, it is becoming increasingly common for measurements to be carried out with more than one set of measurement settings in order to meet multiple requirements, such as local law and global corporate policy. In these situations the overall dose values from the measurements can give significantly different results even when calculated from the same input.

In conducting noise dose measurements it is possible to introduce significant uncertainties as a result of the measurement procedures. It is often the case that situations where the penalties for excessive noise doses are severe take a great deal of care to reduce measurement uncertainties. In these situations research has been carried out to identify potential uncertainties and identify methods for reducing them as far as possible.

3 MEASUREMENT METHODS

3.1 Measurement Uncertainties

In order to ensure that a noise dose measurement is representative for a person, care should be taken to ensure that the measurement uncertainties are kept as low as possible. Studies conducted on the uncertainties associated with noise dosimeters have tended to concentrate mainly on potential errors in the instruments themselves[2]. However, just as important as the correct performance of the instruments is the way in which the measurements are carried out.

3.2 Dosimeter Positioning

Early research into the best position for making a noise dose measurement was carried out by J.A. Redwood at the University of Southampton[3] investigating the errors in noise dose measurements caused by wearing the microphone. This concluded that "easily the best of the microphone positions was on the shoulder, where it was found that in 95% of cases the error should lie between, in round numbers, -1 and +3 dBA. This is acceptable in the context of noise dose measurements". Interestingly, this research also found that positioning the microphone at the ear gave very unpredictable errors of up to +10dB and was therefore not suitable for making dose measurements.

Although this research was carried out using 1 inch microphones, it was repeated in greater detail with ½ inch microphones nearly 20 years later by J.P. Seiler and D.A. Giardino[4]. This research came to the same conclusion as the original; for dose measurements the microphone should be positioned half way between the neck and the shoulder of the subject with the microphone pointing upwards.

Which shoulder the dosimeter is placed on can also have a significant effect on measurements. For example, when a machine operator works sideways on to noisy machinery the microphone should be placed on the shoulder nearest to the source of noise so as to give the worst case dose measurement for that person.

3.3 Calibration

The need for calibration can be split into two main areas : annual calibration and on-site calibration.

Annual calibration is carried out to verify that the dosimeter performance in terms of linearity, frequency response and other parameters is within the tolerances of the applicable standards and that the overall sensitivity of the instrument is correct[5]. This calibration should be carried out to the specifications detailed in either the IEC standard[6] or the ANSI standard[7], whichever is applicable. The calibrator to be used with the dosimeter should also be calibrated annually to verify its performance.

Although most measurement guides recommend that dosimeters be calibrated in the field before making measurements, the importance of a similar post-measurement calibration is often not stressed enough. A post-measurement calibration should be carried out with the same calibrator as was used for the pre-measurement calibration. The main purpose of a post-measurement calibration is to verify the integrity of the measurement by ensuring that the acoustic sensitivity of the dosimeter has not changed during the course of the measurement. This is an important check as dose measurements are frequently made in industrial environments where the dosimeter may be subjected to occasional mechanical damage. The most likely damage that this will cause is to the microphone diaphragm which would very likely lead to a loss of sensitivity, and possibly other effects in the frequency response. A post-measurement calibration gives a simple check to eliminate this potential source of measurement error.

3.4 Measurement Period

Most noise dose measurement standards specify a working shift as the length of time over which the measurement is made for dose assessment purposes. However, a degree of common sense must be applied to this requirement to ensure that significant information is not excluded. For example, in some mining situations, workers may be exposed to high noise levels while being transported to and from working sites in lifts or vehicles. Although this time may not be considered part of the miners' working shift, it should be included in the dose measurement as it is still an exposure to noise due to their working environment.

3.5 Measurement Integrity

In situations where measurements may be required as evidence in a legal context, it is imperative to ensure that the dosimeter has not been tampered with in any way during the course of the measurement. Therefore it is sometimes required that the subjects of the dose measurements are supervised throughout the measurement to eliminate tampering as a source of measurement error.

4 MEASUREMENT PARAMETERS

4.1 Dose Measurement Settings

Settings for noise dose measurements are specified as a combination of the following parameters :

- Exchange Rate (in dB)
- Threshold (in dB)
- Time Weighting (Fast / Slow / None)
- Criterion Level (in dB)
- Criterion Time (in Hours)

The measurements will then, depending on the settings, yield one or more of the following results :

- Dose (in %)
- Estimated Dose (in %)
- L_{Aeq} / L_{Avg} (in dB)
- TWA (in dB)
- $L_{EX,}$ 8h (in dB)
- L_{AE} (in dB)
- Exposure (in Pa^2 Hours)
- Estimated Exposure (in Pa^2 Hours)

All of these values are essentially an expression of the energy contained in the measurement normalised in different ways using either different units, different time references or different exchange rates.

The parameters used for setting up dosimeters for making measurements are usually dictated by the local legislation or guidelines which apply. Some examples of these settings are shown in Figure 1 below.

Figure 1: Standard Noise Dose Measurement Settings

Standard	**Exchange Rate Q**	**Criterion Level dB**	**Criterion Time (hours)**	**Threshold dB**	**Time Weighting**
ISO	3	85	8	None	None
MSHA	5	90	8	90	Slow
OSHA	5	90	8	80	Slow

4.2 Effects of Variations in Measurement Settings

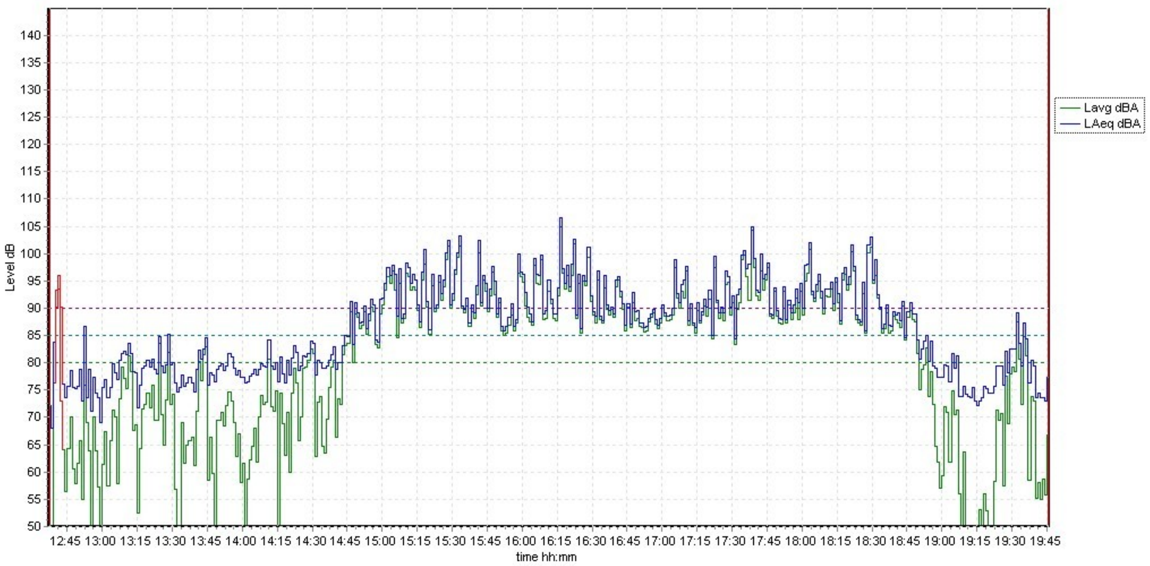
Variations in measurement settings can give widely varying results when applied to identical input data. This is illustrated in Figure 2 which shows two simultaneous measurement results made on the same dosimeter, one channel with ISO settings (most commonly used in Europe) and one channel with OSHA settings (most commonly used in the US).

Figure 2: Overall Measurement Results

Measurement Duration – 7:08:22							
OSHA Settings				**ISO Settings**			
L_{Avg}	**88.9 dB(A)**	Criterion Level	**90 dB**	L_{Aeq}	**92.6 dB(A)**	Criterion Level	**85 dB**
TWA	**88.1 dB(A)**	Criterion Time	**8 h**	L_{Ex}, 8h	**92.1 dB(A)**	Criterion Time	**8 h**
Dose	**75%**	Threshold	**80 dB**	Dose	**511%**	Threshold	**None**
Est. Dose	**83%**	Exchange Rate	**5 dB**	Est. Dose	**573%**	Exchange Rate	**3 dB**
		Time Weighting	**Slow**	L_{AE}	**136.5 dB**	Time Weighting	**None**
				Exposure	**5.1 Pa²h**		
				Est. Exposure	**5.8 Pa²h**		

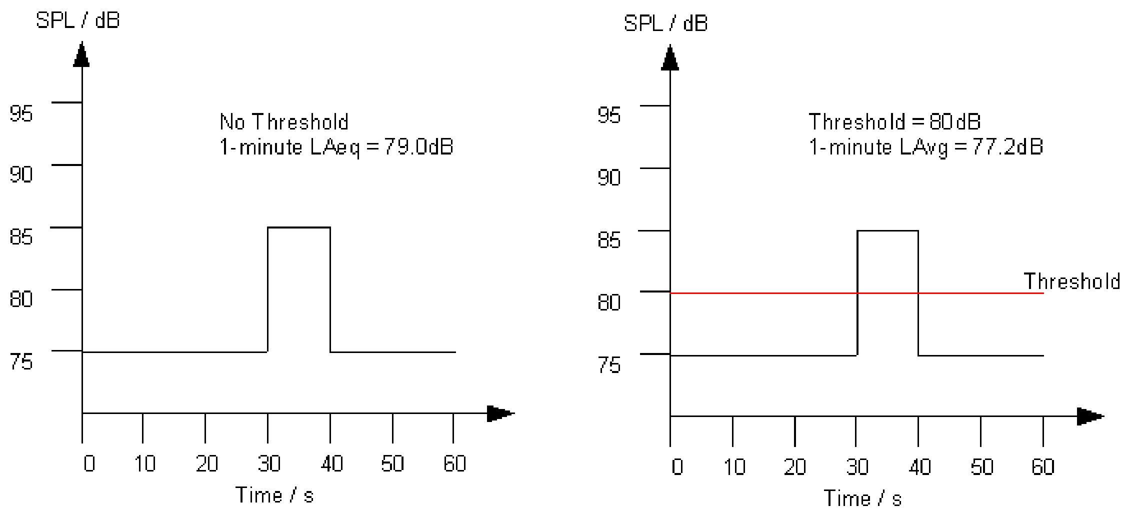
The difference in the overall dose percentages of 75% for the OSHA settings and 511% for the ISO settings can be explained by a combination of the differences in the measurement settings. Figure 3 shows a 1-minute time history of these two measurements and gives further clues as to the effect the measurement settings are having on the overall dose values.

Figure 3: Comparison of Time Histories for ISO (Blue) and OSHA (Green) Measurement Settings



Perhaps the most obvious effect when comparing the two sets of time-history data is that of the threshold on the 1-minute values for the OSHA settings. Although at high level the 1-minute values for ISO and OSHA settings are almost identical, at lower levels the OSHA values drop off sharply as samples below 80dBA are excluded. An example of why these 1-minute time history values drop off so sharply when the sound pressure level varies around the threshold level is illustrated in Figure 4.

Figure 4: Effect of Threshold on 1-minute Measurements



The effect of the threshold on noise dose measurements has been researched in some detail[8] and concluded that if the results were to be correlated with sound level meter measurements or tape recorded data then a threshold of either 20dB below the lowest sound level being measured, or no threshold should be used. This research also stresses caution in comparing measurements made with dissimilar settings, for example with dosimeter and sound level meter measurements.

The other very significant measurement setting is that of the difference in the criterion levels used to calculate the doses. It is possible to recalculate the dose percentage for the ISO settings changing the criterion level to 90dB which results in a dose of 162%, still some way above the 75% for the OSHA settings with the same criterion time and level.

The exchange rate will also have an effect on the overall dose values. The exact nature of its effect is difficult to quantify as it will depend on the nature of the noise being measured. Likewise the time-weighting will cause some differences in the dose values although the nature of those differences will depend on the noise source.

4.3 Interpretation of Measurement Results

Once a measurement has been made, the legislation or guidelines it was made to comply with will normally give action levels at which preventative action should be taken. As almost every standard differs in both the measurement settings and action levels it is extremely difficult to meaningfully compare measurements made to different standards. This is particularly true where the measurement settings include differences in threshold settings or exchange rates.

The use of measurement settings which include threshold settings or non-Q3 exchange rates tends to give more weight to constant high level noise rather than impulsive noise when compared to measurements made with ISO settings. Therefore the most important factor when interpreting noise dose results is to do so in the context of the measurement settings.

5 CONCLUSIONS

Previous research into the methods of carrying out noise dose measurements has identified several potential sources of uncertainty and the following guidance is a summary of the findings :

- Ensure the dosimeter microphone is positioned half way between the neck and the end of the shoulder of the subject, pointing upwards.
- Place the dosimeter on the shoulder likely to be subject to the highest noise levels if applicable.
- Ensure that the dosimeter is calibrated annually.
- Carry out pre and post measurement calibrations on the dosimeter to ensure that it has not been damaged during the measurement
- Make sure that the measurement period includes all relevant data, even if this extends beyond the subject's working shift.

The settings used when carrying out a noise dose measurement have been shown to have a significant effect on the resulting overall noise dose. Great care should be taken when comparing noise dose measurements with different settings as they can give extremely misleading results.

6 REFERENCES

1. 'Controlling noise at work' HSE Guidance on Regulations, 2005
2. Dennis A. Giardino and John P. Seiler 'Uncertainties associated with noise dosimeters in mining', JASA v100, No 3, p1571-1576 (September 1996)
3. R.A. Redwood 'Investigation of the Errors in Noise Dose Measurements Caused by Wearing the Microphone', Masters Thesis, University of Southampton, Faculty of Engineering and Applied Sciences, Institute of Sound and Vibration Research, 1977.
4. Dennis A. Giardino and John P. Seiler 'Interaction of Body-Worn Measurement Microphones with the Undisturbed Sound Field', JASA, v100, No 4, p2672 (October 1996)
5. John P. Seiler and Dennis A. Giardino 'Calibration of Acoustical Instruments for Noise Exposure Measurements', Sound and Vibration 2-5 (March 1996).
6. 'Electroacoustics – Specifications for personal sound exposure meters' IEC 61252:1993
7. 'Specification for Personal Noise Dosimeters' ANSI S1.25-1991
8. Dennis A. Giardino and John P. Seiler 'The Effect of Threshold on Noise Dosimeter Measurements and Interpretation of Their Results', MSHA Informational Report IR1224, 1994