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A practical comparison of occupational noise standards

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ABSTRACT

The use of digital signal processing in noise measurement instruments has dramatically increased the measurement capabilities of even the simplest sound level meters and noise dosimeters. There are often a wide range of frequency and time weightings available as well as a selection of thresholds, exchange rates, criterion times and criterion levels. In many modern instruments, the results of a measurement are presented to the user automatically and this can often result in confusion as to the correct value or parameter to report, especially when the metrics appear to be very similar. In the case of occupational noise exposure, this can result in the under or over reporting of values when there is a need to provide data under a range of different or multiple standards. This paper describes a review and a comparison of a range of different occupational noise standards using real-world noise sources. The review demonstrates the differences in how the same physical noise exposure is reported under these different regulations, how often similar standards can produce significantly different outcomes and suggests ways in which users can be informed about the nature of the noise measurement data that they are presented with.

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1. INTRODUCTION

Modern noise measurement instruments have the capability to record and display noise levels using a wide range of different parameters, many of these simultaneously.

It is not unusual for a modern sound level meter that meets the latest standards (7) to be able to measure A, C and Z frequency weightings and Fast, Slow and Impulse time weightings simultaneously alongside the measurement of Peak sound pressure levels.

Multiple integrators may also be available, each of which can be independently configured in terms of frequency weighting, time weighting, exchange rate, threshold, criterion level and criterion time.

Users may have been familiar with seeing parameters such as SEL on their sound level meters are can now be faced with the same information displayed as L_{AE} (7) and although these metrics may be identical, for the less experienced user this can cause confusion and introduce a lack of confidence in their measurements.

Many of these parameters are presented to the user automatically and whilst the more experienced user may fully understand the differences between these parameters, the majority of noise measurements, and in particular occupational noise measurements, are carried out by users for whom making noise measurements may not be a common practice.

This can often result in some confusion as to the correct value or parameter to report, especially when the metrics appear to be very similar.

In the case of occupational noise exposure, this can result in the under or over reporting of values when there is a need to provide data under new, different or multiple standards.

In addition to this, many users are unaware that once the data has been processed by the instrument, in many cases it is not possible to recalculate the values against different standards or guidelines.

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2. Measuring to multiple noise exposure standards

Although many users will be measuring against a single occupational noise standard (UK Noise at Work Regulations (8), OSHA HC/PEL (3), ISO 1999:1990 (5) etc), it is becoming increasingly common for users to measure and assess the same employees' noise exposure against multiple standards.

As an example, an EU-based company operating in a region where the OSHA standard is used may require data to report back to the head office in terms of the European Physical Agents (Noise) Directive (2), whilst at the same time reporting measurements against the OSHA standard for local compliance.

The noise exposure measurements would need to be made with the equipment configured to measure using the OSHA and EU standard integrators simultaneously to allow for this reporting.

The equipment used to make the measurements should be capable of measuring and recording the noise data against both of these standards at the same time.

A second example would be where measurements are mandated in accordance with OSHA but where measurements are also being made against recommendations such as NIOSH and ACGIH.

This may require three different sets of measurement data to be gathered each with its own specific requirements in terms of the exposure limits and configuration of the measurement equipment.

3. Noise exposure standards around the world

The need to measure, assess and control occupational noise levels as a way of reducing the risk of both long and short term damage to hearing is one that is common to all countries where occupational health is deemed to be a priority. To the casual observer it may appear that in these regions the standards, guidelines and regulations that are being used would be the same, if not very similar.

However, although there are only a few core parameters that can differ between these regulations, this can produce a myriad of differing requirements and standards.

A review of noise exposure standards (1) noted that there were 14 different regulations in Canada with some provinces using a 5dB Exchange Rate and a 90dB Criterion Level, some using a 5dB Exchange Rate with an 85dB Criterion Level and some using a 3dB Exchange Rate with a 90dB Criterion Level.

In the US, the US military services require standards that are more stringent than those required by OSHA. Both the US Air Force and the US Army both use an 85dBA permissible exposure limit and a 3dB exchange rate.

The American Conference of Governmental Industrial Hygienists (ACGIH) has established exposure guidelines for occupational exposure to noise in their Threshold Limit Values (TLVs). These guidelines are based on a 3dB exchange rate as opposed to the 5dB mandated by OSHA (3) but the use of Slow time weighting and an 80dB threshold remain.

Similarly, the National Institute for Occupational Safety and Health (NIOSH) recommends the use of a 3dB exchange rate, also retaining the use of a Slow time weighting and an 80dB threshold (6).

The table below shows examples of different standards in terms of the Criterion Level, Exchange Rate (Q), Threshold Level and Time weighting for some common occupational noise standards.

Table 1 – Example integrator configurations

Name	EU	OSHA HC	OSHA PEL	NIOSH
Exchange Rate	3dB	5dB	5dB	3dB
Time Weighting	None	Slow	Slow	Slow
Frequency Weighting	dB(A)	dB(A)	dB(A)	dB(A)
Threshold	None	80dB	90dB	80dB
Criterion Time	8 hrs	8 hrs	8 hrs	8 hrs
Criterion Level	85dB	90dB	90dB	85dB

The EU data above refers to the requirements of 2003/10/EC (2).

Although this paper has referenced the overall noise exposure parameters as a way of showing the potential differences that can occur when different standards or guidelines are used, many regulations also require the measurement of peak sound pressure as a method of assessing the risk of hearing damage from short, high level noise sources.

The measurement of peak sound pressure levels is often unfamiliar to users and there may be an assumption that an instrument that reports the peak sound pressure does so in line with the regulations or guidelines under which they are operating. The use of different terminology such as Peak, L_{CPeak}, MaxPeak and so on also introduce further levels on uncertainty to the user.

The 2005 Control of Noise at Work Regulations, currently in force in the UK, and the corresponding EU Directive 2003/10/EC require that peak sound pressure levels are measured using C-weighting.

However, there are some regions in the world where the use of A-weighting for peak measurements is used and there are some regions where reference is made to the use of Linear weighting for peak measurements. Users should be aware of these differences and ensure that their equipment does meet any specific requirements.

In addition to this, there are examples of where the standards for instrumentation have been amended, updated or replaced whilst references to instrumentation in the measurements standards have not. The reverse of this also occurs, an example being a requirement in a published measurement standard that a sound level meter should meet IEC 61672-3 whilst that part of the standard was still in the draft stage.

4. Differences in terminology and misconfiguration of measurement equipment

One area where misreporting of noise measurements may occur is in the terminology used by these different standards.

In the UK, the 2005 Control of Noise at Work Regulations describes the Daily Personal Noise Exposure as the $L_{EP,d}$.

In many European countries the same noise exposure will be referred to as the $L_{EX,8h}$ as defined in ISO 1999:1990. Both of these functions are the same, differing only in the terminology used to describe them as can be seen below.

$$L_{EP,d} = L_{EX,8h} = L_{Aeq,T_e} + 10\, log_{10}\left(\frac{T_e}{T_o}\right)$$

where

T_e is the duration of the person's working day
T_0 is 28,800 seconds (8 hours)
$L_{Aeq,Te}$ is the equivalent continuous A-weighted sound pressure level

Many users of noise measurement instruments do so infrequently and may not have an understanding of how these two metrics are the same.

A more significant problem arises when some changes have been made to the configuration of the instrument which has resulted in the data being reported using terminology which may be completely unfamiliar to the user.

A UK user could expect to see the equivalent continuous A-weighted sound pressure level reported as the L_{eq}, L_{Aeq} or $L_{Aeq,t}$ and the daily personal noise exposure level reported as the $L_{EP,d}$ (or possibly the $L_{EX,8h}$).

However, by applying a threshold, time weighting or exchange rate other than 3dB would, and should, change these parameters to L_{AVG} and TWA respectively. Doing so would not only change fundamentally the method used in the integration of the noise exposure but also the metrics reported by the equipment.

5. A practical comparison of the noise exposure standards

To demonstrate how what may appear to be simple differences in the configuration of noise measurement equipment can produce significant differences in the reported noise levels, the following sections show two examples of noise measurements made using a number of different integrator settings.

The first uses a synthesized noise source whereas the second shows data from a real-world measurement.

5.1 Example 1 – 5 simultaneous integrators

The measurement instruments used in the tests were 2 Cirrus Research CR:171C Class 1 Sound Level Meters. These instruments allow three independent integrators, each with different configurations, to be run simultaneously. In each test, the first integrator was set to the ISO standard to provide a reference point. The ISO standard uses a 3dB exchange rate, no time weighting and no threshold.

To ensure that the signals processed by both instrument were the same, the microphone capsules were removed and the signals inputted electrically via an 18pF dummy microphone adaptor. Both sound level meters were calibrated electrically and acoustically before and after each measurement to ensure consistency.

The signal fed into the instruments was a 1 hour & 12 minute audio file created by combining a number of different noise sources. These sources were made in real-world workplaces and were chosen to demonstrate the effects of time weighting, exchange rate and threshold levels. The file was played into the instruments from a 44.1 kHz 16 bit audio file.

The measurement duration was fixed at 8 hours using the preset timer function in the instrument and the audio file set to repeat throughout the 8 hour measurement. Both instruments were started at the same time using remote control.

The integrators in each instrument were set to the following settings and were named ISO, OSHA HC, OSHA PEL, NIOSH & DOD USN.

5.2 Integrator configurations

The three integrators in each sound level meter were configured as follows:

Instrument 1 Serial Number # G056346

Table 2 – Integrator configuration 1

Integrator	1	2	3
Name	ISO	OSHA HC	OSHA PEL
Exchange Rate	3dB	5dB	5dB
Time Weighting	None	Slow	Slow
Frequency Weighting	dB(A)	dB(A)	dB(A)
Threshold	None	80dB	90dB
Criterion Time	8 hrs	8 hrs	8 hrs
Criterion Level	85dB	90dB	90dB

Instrument 2 Serial Number # G061297

Table 3 – Integrator configuration 2

Integrator	1	2	3

Name	ISO	NIOSH/ACGIH	DOD USN
Exchange Rate	3dB	3dB	5dB
Time Weighting	None	Slow	Slow
Frequency Weighting	dB(A)	dB(A)	dB(A)
Threshold	None	80dB	90dB
Criterion Time	8 hrs	8 hrs	8 hrs
Criterion Level	85dB	85dB	85dB

The 5th integrator named DOD USN was included to demonstrate the effect of the 4dB exchange rate. For each integrator, the primary measurement data was recorded as the measurement duration and the $L_{Aeq,t}$ or L_{AVG}.

L_{AVG} is presented as the integrated noise value where the integrator has any configuration other than a 3dB exchange rate, no time weighting and no threshold.

Additional data was recorded for each integrator including a 1 second time history, maximum fast time-weighted sound level and peak sound pressure.

5.3 Measurement results

The measurements were repeated 5 times with the same configurations and input signals. The repeated measurements presented results within 0.01dB for the primary noise parameter. The logarithmic average of each measurement was taken and is shown below in the results.

To remove the effect of rounding errors within the sound level meter, the % Dose values were calculated manually using Microsoft Excel for each $L_{Aeq,t}$ or L_{AVG} value in accordance with the Criterion Time and Criterion Levels for each integrator.

The calculated % Dose value is presented as the primary result with the measurement duration and the $L_{Aeq,t}$ or L_{AVG}.

Table 4 Measurement results

Integrator	Name	% Dose	LAeq,t/LAVG
1	ISO	270%	89.3dB(A)
2	OSHA HC	73%	87.8dB(A)
3	OSHA PEL	50%	85.0dB(A)
4	NIOSH/ACGIH	272%	89.4dB(A)
5	DOD USN	185%	88.6dB(A)

This practical comparison shows that for the same physical noise, the noise exposure values reported are significantly different for a range of different occupational noise exposure standards.

The noise exposure, in terms of the sound pressure to which a worker in this environment would be exposed, is the same for all of the different integrators.

The lowest % Dose value (The OSHA PEL) gives the noise exposure as 50% whereas the highest (The NIOSH setting) gives the same noise exposure as 272%, a clear demonstration of how what may appear to be simple differences in the configuration of the integrators can produce significantly different results.

5.4 Example 2 Noise dosimeter measurements at an American football game

In 2006, a series of measurements were made at American football games using the Cirrus Research plc CR:110A doseBadge noise dosimeter.

The purpose of these measurements was not to assess the effectiveness of occupational noise programs but to gather some example measurement data that could be used to demonstrate the potential differences between the UK and OSHA standards.

The measurements were made with a dual channel Cirrus Research CR:110A doseBadge dosimeter, calibrated in accordance with the manufacturers recommendations.

In the measurement shown below (5th November 2006, San Diego Chargers vs Cleveland Browns, Chargers Stadium, San Diego), the measurements was made over 7 hours and 8 minutes and covered the time from arrival of the fans at the stadium prior to the game, through the game itself and during the exit from the stadium.

5.5 Instrument Configuration

The two integrators in the instruments were configured as detailed in the table below:

Table 5 – Instrument configuration

Channel	Exchange Rate	Threshold	Time Weighting	Criterion Level	Criterion Time
1	3dB	None	None	80dB	8 hrs
2	5dB	80dB	Slow	90dB	8 hrs

5.6 Measurement results

Table 6 – Measurement results

Channel	LAeq,t/LAVG	LEP,d/TWA	% Dose
1	92.6dB(A)	92.1dB(A)	511%
2	88.9dB(A)	88.1dB(A)	75%

The table above shows the overall measurement data for the measurements gathered using the two different integrator configurations.

In the lead up to the game which covered the first 2 hours of the measurement, the noise levels were typically below 80dB and so the threshold applied by channel 2 was effective in reducing the overall noise exposure. All of the noise exposure during this period was integrated by channel 1.

During the game the noise levels were between 80dB(A) and 105dB(A) and so both channels were integrating similar data. However when a touchdown was scored by the home team, a pyrotechnic cannon was fired.

The impulsive nature of this noise was affected by the slow time weighting applied to channel 2 which reduced the impact of these events. Again, channel 1 was not affected by any time weighting and so all of the noise energy was integrated into the final result.

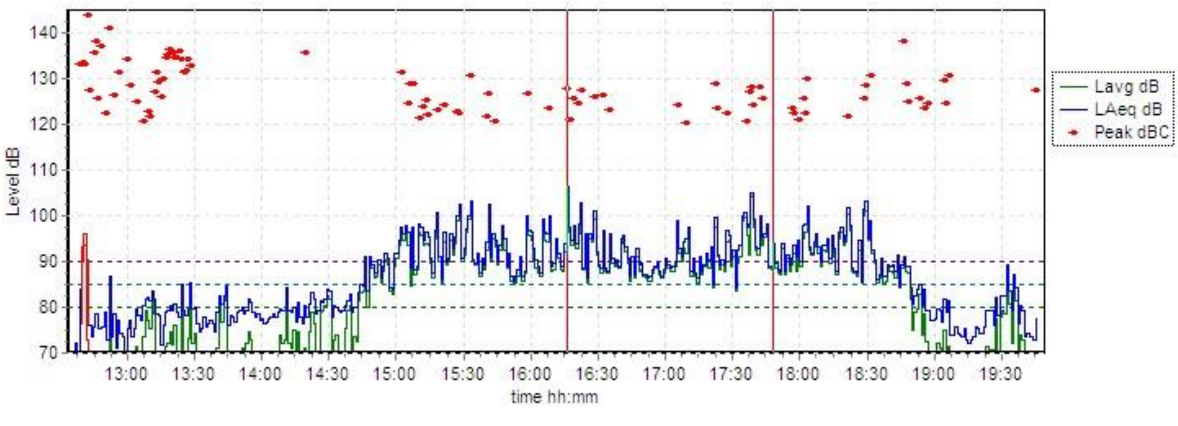

Figure 1 – Detailed time history data for channels 1 & 2

The most significant difference between these two different configurations is in the reporting of the % Dose value.

Although the noise source was the same for both channels, the channel 1 configuration reported an exposure of 511% whereas the configuration for channel 2 reported the same noise levels as a noise dose of 75%.

This is a clear demonstration of how the measurement of the same noise under two different occupational noise standards can produce dramatically different results. Although the noise source for these two values or 75% and 511% are the same, the effects of the differing time weightings, threshold levels, exchange rates and criterion levels combine to provide two hugely differing outcomes.

Neither of these measurements could be considered to be wrong or inaccurate but are simply the outcome of the use of occupational noise standards whose origins and configurations are very different.

6. CONCLUSIONS

In the examples measurements described above, the differences in the reported noise exposure levels between the different integrators are created by the use of one or a combination of differing exchange rates, time weightings and threshold levels.

In most modern instruments that are designed for the measurement occupational noise, each of these parameters can often be adjusted independently of each other allowing the user to select them according to the regulations and guidelines to which they are working.

Many manufacturers will provide quick settings or setups to allow the user to choose but in many cases the user will still be able to adjust and change the parameters within these recommended configurations.

How much effect each of these will have upon the noise measurements being made will depend largely upon the nature of the noise itself under assessment.

From the two examples detailed above, we can conclude the following.

6.1 Exchange Rate

The use of different exchange rates is most significant where the reported noise exposure is given in terms of the % Dose. The Leq and Lavg values for all 5 measurements in example 1 differ by 4.5dB whereas the % Dose values differ by a factor of 5.

In areas where the regulations follow or are influenced by those of OSHA, the use of the % Dose metric is quite widespread but the increasing use of guidelines such as those produced by NIOSH (6) and the ACGIH alongside those of OSHA does have the potential for confusion, especially when the noise metrics being reported appear to be the same, ie L_{AVG} and TWA.

The exchange rate is a parameter that is often misunderstood by users as it can be difficult to explain in simple terms.

6.2 Time Weighting

If the noise source under investigation contains impulsive content, such as a power press or hammering, the use of Slow Time Weighting can have a significant effect.

This use of slow time weighting effectively slows the instruments ability to react to fast changing noise levels and results in a lower noise exposure being reported.

This effect is most visible in the noise dosimeter measurements in example 2 where the effect of the pyrotechnic cannon was reduced by between 4dB and 6dB when the slow time weighting in the OSHA integrator was used.

The ISO setting integrated all of the noise energy into the measurement data, resulting in a higher final figure. The effect of applying a time weighting to the noise before it is integrated becomes even more apparent in measurements where a noise profile or time history graph is presented. The effect of the slow time weighting upon 1 second noise profile samples is quite visible where the noise contains impulsive content.

6.3 Threshold Level

The use of different threshold levels has an effect where the noise source is below the threshold for a large proportion of the measurement.

The most significant effect of the threshold setting is shown example 1 where in the OSHA PEL setting where threshold is set to 90dB. In this case, all noise levels below 90dB are discarded and are not included in the final integrated noise figure.

It is not uncommon to see measurements being made without a threshold being applied where one is required or conversely measurements being made with a threshold where none should be used.

The use of a threshold to exclude all noise below a certain level is one that surprises many users who are working under regulations such as the UK Noise at Work Regulations, especially when examples are used where a constant noise level of 79dB would be reported a zero under the OSHA standards against 79dB under the UK regulations.

6.4 Recommendations and comments

A user may reasonably expect that the equipment supplied to them meets the specific requirements for their country or territory and in many situations it will do so. The manufacturer or their representative will be able to advise the user before purchase and to support them afterwards to ensure that they are getting the correct information and that their equipment is correctly configured.

However, so called grey imports and the ability to purchase equipment across international boundaries via the internet has inevitably increased the chance that the equipment may not be correctly configured “out of the box”.

This effect of this can often been seen when there is a tender raised for the purchase of noise measurement equipment and this tender is picked up by a number of different purchasing companies who have little if any knowledge of noise measurement.

An example of this is a technical point in a tender for a noise dosimeter that called for the measurement of “Slow Leq”. Unfortunately, there was no channel available to discuss the requirement with the end user customer and so it was not possible to determine if this was an error and the need was to measure L_{eq} (L_{Aeq} or $L_{Aeq,t}$) or whether the noise exposure should indeed be measured with Slow Time Weighting and therefore be referred to as L_{AVG}.

Noise measurement equipment has advanced to a point where it has often become possible to configure it to meet any number of different standards simultaneously and for what may be considered advanced users this can be an advantage, allowing comparisons between regulations and standards to be carried out quickly and easily.

However, the majority of users of sound level meters and noise dosimeters are not experts and often need support and training to ensure that they can make effective noise measurements.

Users should be able to ensure that the settings provided “out of the box” are those needed for their specific application and reporting requirements and it should be clear to the user how their equipment has been configured so that they can verify that it meets the requirements of the regulations under which they are working.

Users should also be able to access up to date and accurate information about the standards against which they are measuring and reporting noise exposures, and should be able to demonstrate that the equipment has been correctly configured to meet these needs.

We should not forget that for most users, carrying out noise measurements is just one part, and possibly a small part, of the process of managing the risk of noise induced hearing loss and creating a healthy working environment and that providing equipment that is both accurate, simple to use and easily understood should be the highest priority for instrumentation manufacturers.

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