Selection of Hearing Protection

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There are many aspects to noise within the workplace, from conducting a risk assessment to noise control measures, but at some point within the process it is likely that it will be necessary to issue Personal Protective Equipment (PPE) to at least some employees.

A noise survey will determine just who needs ear protection. The survey should list employees and their exposure, not a map of the factory, then compare their exposure to the relevant action levels to determine who needs to wear the protection.

There are two main types of exposure that need to be measured or calculated: the $L_{EX,8h}$, which is the daily noise exposure (or average over a week if daily variation in exposure occurs) and L_{Cpeak}, which addresses protection from instantaneous damage to hearing when the peak noise is measured. The action levels have acceptable values for both these parameters. Note that within the UK, the $L_{EX,8h}$ is known as the $L_{EP,d}$, but they both have the same meaning. A good quality sound level meter or dose meter will be able to calculate these values, but care must be taken with the $L_{EX,8h}$ to ensure that the correct exposure time for the noise is inserted into the instrument, taking into account work patterns and breaks. A brief summary of when hearing protection needs to be worn relative to these action levels is:

Below the first action levels

Below an $L_{EX,8h}$ of 80dB(A) or L_{Cpeak} of 135dB(C) hearing protection does not have to be worn.

Between the first and second action levels

With an $L_{EX,8h}$ of between 80dB(A) and 85dB(A) and an L_{Cpeak} of 135dB(C) and 137dB(C) hearing protection should be made available to employees who ask for it but it is not compulsory to wear.

Above the second action levels

With and $L_{EX,8h}$ over 85dB(A) or an L_{Cpeak} of 137dB(C) employees must wear the hearing protection provided and employers will need to provide training on correct use.

The EU directive also introduces the concept of exposure limit values at the ear, taking into account the attenuation of the hearing protection, which cannot be exceeded. The exposure limit values correspond to an $L_{EX,8h}$ of 87dB(A) or an L_{Cpeak} of 140dB(C).

Selecting the correct hearing protection is essential. There are many factors to be considered - chiefly the fact that any PPE is only effective if it is worn.

The same is true of hearing protection. There is no point buying the most expensive ear muff that attenuates the noise by, say, 30dB(A) if the employee has to remove the muffs for two hours of an eight hour shift because they are uncomfortable. That will only reduce the daily noise exposure by 6dB(A) instead of 30dB(A).

There are three main types of protection: earplugs, earmuffs and semi-inserts, each with individual benefits, and there are many factors affecting their choice.

Use with other PPE

The interaction of hearing protection with other PPE that may need to be worn is an important factor. An employee wearing prescription or safety glasses will not obtain an adequate fit from a standard ear muff, so plugs or perhaps semi-inserts become the better option - although special glasses with a flat side to obtain a better fit are available, should earmuffs be necessary.

The use of hardhats with earmuffs can still be an issue. If the employee constantly needs to wear them both together a hard hat with built in hearing defenders should be considered. However, this may not be the best option because this type of hearing muff does not give quite the same protection as regular hearing muffs.

Communication

Communication can be a big issue with PPE and it all comes down to the attenuation that the protector will provide. If a protector is provided with too little attenuation, not enough protection will be given. To go to the other extreme, however, simply 'buying the best' and providing too much attenuation generates associated issues.

Too much reduction of the noise can instil a feeling of isolation that is detrimental, as employees may need to remove their PPE in order to communicate with colleagues. The subsequent exposure to noise will therefore far outweigh the benefits a high attenuation hearing protector would have provided.

Another major problem with over attenuation of a hearing protector is that of safety. There is an inherent danger in providing too much protection because of listening out for safety warnings such as fire alarms and sirens from reversing vehicles. A general rule of thumb is to not provide so much protection as to reduce the level at the ear to below 70dB(A) as this would be over protection, but aim for a level of 75-80dB(A) at the ear. See below for how to calculate the noise levels at the ear after taking into account the hearing protection.

The environment and individual

Other individual preferences such as hair and jewellery affect the choice of hearing protection. Long hair that flows over the ears will cause an inadequate fit of an earmuff and hence a significant education in the effectiveness of the protection, while earrings will cause a comfort problem, so plugs or semi inserts are an alternative.

The working environment also has an effect on the choice of protector: hot humid conditions make earmuffs uncomfortable to wear, while dusty environments cause problems with hygiene, especially with plugs. In this case it is especially important to keep the hands clean when inserting the plugs as they could cause an ear infection. It is advisable to ascertain from an employee any history of ear problems such as irritation or earache, in which case the use of earmuffs that fit over the outer ear is preferable.

The predicted attenuation

This is where we enter into the 'dreaded' world of logarithms. There are three methods for predicting the overall attenuation that a hearing protector will give, and each rises slightly in the amount of mathematics required.

The methods for calculating the effectiveness of hearing protection are:

• SNR

• HML

• Octave band

In terms of accuracy in predicting the attenuation, the SNR method is the least accurate and the octave band is the most accurate, and hence is the preferred method. However, it does require a little more calculation.

Any catalogue with hearing protection will list values corresponding to these three methods, which should look something like this:

Frequency (Hz)	Mean Attenuation (dB)	Standard Deviation (dB)	Assumed Protection Value (APV in dB)
63	21.2	7.3	13.8
125	22.3	5.7	16.5
250	26.4	6.2	20.2
500	29.3	6.1	23.1
1000	29.3	5.4	23.8
2000	34.6	3.6	31.0
4000	41.3	5.4	35.9
8000	41.6	7.1	34.5

H=31dB M=25dB L=22dB SNR=28dB

This data is for a standard disposable earplug. Protection is better at higher frequencies, which is the case with most hearing protection. The effectiveness of a protector at various frequencies varies between PPE, so it is necessary to match the frequency of the noise produced to the noise the employee is exposed to.

Generally, earmuffs provide better protection at higher frequencies above about 250Hz, but earplugs are on average slightly better at lower frequencies.

All the three methods describe 'frequency weightings' of either 'C' or 'A'. This is the way a sound level meter converts the decibel value it measures, which is all the frequencies of the noise evenly, and converts them into a value to represent how the human ear hears the noise.

Essentially the ear does not hear low or high frequencies very well, but actually exaggerates noise roughly between 1000Hz to 4000Hz. The ear does this because most of our speech takes place at these frequencies. The 'A' weighted scale is shown below in the 'Octave band method' description.

The SNR method

The Single Number Rating (SNR) method is the simplest form of calculation, but does not take into account the frequency content of the noise in any depth. To do this, simply take the SNR value quoted for the hearing protector away from the 'C' weighted sound pressure level which needs to be measured for the employee in question.

The dB value at the ear (LA') is calculated by:

$L_A' = L_C - SNR$

The value of LC is a measured value of the sound pressure level. It can be difficult to get an idea of this fluctuating value on the screen of a sound level meter, so it is highly recommended that you get an instrument that provides an averaged result call Leq.

So if the LC was measured and found to be 105dB(C) our worked example would be:

$L_A' = 105 - 28 = 77dB(A)$

This value is rounded to the nearest whole number, which is the recommended way for decibel values once the calculation is complete. This result means this protector would be adequate if worn in the correct way.

The HML method

This method requires a sound level meter that will measure both the 'A' weighted and the 'C' weighted sound pressure level or average level (Leq). Take a 'C' weighted measurement of the sound pressure and an 'A' weighted measurement also. Then if:

$L_C - L_A$ is less than or equal to than 2:

$$PNR = M - \frac{(H - M)}{4} \times (L_C - L_A - 2)$$

the LC - LA is greater than 2:

$$PNR = M - \frac{(M - L)}{8} \times (L_C - L_A - 2)$$

where PNR is the predicted noise reduction provided by the hearing protector and H, M and L are the values provided by the PPE catalogue. The HML values stand for high, medium and low. This is therefore the value for the attenuation at high, medium and low frequencies.

There are two formulas because by taking two values of the sound pressure with different frequency weightings (L_C and L_A) then this is giving an indication of the frequencies of noise the employee is exposed to. That is why in the two formulas different values are used from the high, medium and low combination.

For example, for measured values of L_C = 105dB(C) and an L_A = 102dB(A), from our example earplug the results would be:

L_C - L_A is greater than 2 so:

$$PNR = 25 - \frac{(25-22)}{8} \times (105 - 102 - 2) = 24.6dB = 25dB$$

This would make the value at the ear:

L_A' = 102 - 25 = 77dB(A)

The result is exactly the same as for the SNR method.

The Octave Band method

This method requires the use of an octave band sound level meter to take the measurements. To do the final calculations a calculator with the Log function is required. The use of this method is considered the most accurate way of measuring effectiveness of hearing protectors because it is looking at the actual frequencies of noise that are present for the employee.

The table shows an example measurement taken from a sound level meter for a different employee.

Octave band centre frequency (Hz)	63	125	250	500	1000	2000	4000	8000
Sound pressure level (dB)	92	93	95	95	96	98	96	94

So for the hearing protector in question:

Octave band centre frequency (Hz)	63	125	250	500	1000	2000	4000	8000
Assumed protection Value APV (dB)	13.8	16.5	20.2	23.1	23.8	31.0	35.9	34.5
A-Weighting Factors	-26.2	-16.1	-8.6	-3.2	0.0	1.2	1.0	-1.1

The A-weighting factors are standard as shown above. Taking these values from each other will give the A-weighted value at the ear for each frequency. For example at the 63Hz octave band.

L_A' = 92 – 13.8 – 26.2 = 52dB(A)

Octave band centre frequency (Hz)	63	125	250	500	1000	2000	4000	8000
L_A' (dB)	52.0	60.4	66.2	68.7	72.2	68.2	61.1	58.4

In order to add these together a formula is required to work out the overall SPL at the ear taking into account of the hearing protection. This formula is:

Sound Pressure Level (SPL) = 10 log (10L1/10 + 10L2/10 +….10Ln/10)

Simply insert the values for each frequency in to obtain the result:

L_A’= 10 log (105.2 + 106.04 + 106.62 + 106.87 + 107.22 + 106.82 + 106.11 +105.84) = 75.8dB(A) = 76dB(A)

Although this was for a different noise source than for the first two examples, it still shows that the protector would be adequate. Note: within the UK it is recommended to take off 4dB from the calculated effectiveness to take into account real world factors. Useful calculators for hearing protection calculation can be found at:

http://www.hse.gov.uk/noise/