Application Note 1

Practical Approaches to Hearing Protection Device (HPD) Selection

INTRODUCTION

The proper selection of hearing protection devices (HPDs) for workers can be a difficult, challenging and sometimes even a misleading task. The objective is to insure optimal hearing safety without screening out important noises like alarms, voices of co-workers and other communications that are critical to the safe performance of work. Often times companies provide workers with HPD's that attenuate noise much more than necessary for an effective program. One common result of this overprotection is the worker does not use the HPD when required because he/she feels isolated when too much sound is removed. Once it is established that workers need to wear HPDs, the best-practice methods described here can be used to select those devices that are more consistent with the stated objective. These methods require determining the noise levels present in the workplace at different frequencies within the human hearing range and then choosing the most appropriate HPDs based on that information. Once a complex and time consuming task, frequency analysis of hazardous noise has been greatly simplified by recent advancements in handheld real-time frequency analysis technology.

HEARING PROTECTION RATING METHODS

We will review least different ways that ear plugs, foam inserts, ear muffs and other HPDs may be rated by manufacturers for noise reduction effectiveness. Noise Reduction Ratings (NRRs) is a rating system that provides a single reduction rating number in decibels (dB). Single Number Methods are considered the simplest of methods for a user to implement. However, with simplification comes compromise. Recognizing the shortcomings of single number ratings requires a general understanding of how these numbers are determined. The process for NRR's is explained below. Table 1 provides a supporting example.

Line A. Manufacturer or independent laboratory exposes the hearing protector to a noise source that is comprised of 100 dB noise levels across a defined set of octave band center frequencies (pink noise) within the hearing range.

Lines B & C. Corrections for C-Weighting are applied to the 100 dB levels to obtain the unprotected C-weighted noise levels for each center frequency.

Line C. The log sum of the C-weighted noise levels is calculated, producing a single-number unprotected C-weighted noise level.

Lines D & E. Corrections for A-weighting are applied to the 100 dB levels to obtain the unprotected A-weighted noise levels for each center frequency.

Line F. The average attentuation achieved by the HPD is then determined through measurement for a set of specific defined frequencies.

Line G. The standard deviation of the average attentuations determined in Line F are also determined at each frequency.

Line H. Two standards deviations are computed.

Line I. Line F minus Line H yields APVs in dB for each center frequency.

Line J. Line E minus Line I yields the protected A-weighted noise level for each center frequency. The log sum of the A-weighted noise levels from Line J is calculated, producing a single-number protected A-weighted noise level.

Line K. The log sum of Line C minus the log sum of Line J yields the NRR.

TABLE 1 - Computation of the NRR

Octave band center Frequency, Hz	125	250	500	1000	2000	3000	4000	6000	8000	Log Sum
A. Assumed pink noise (dB)	100	100	100	100	100		100		100	
B. C weighted corrections (dB)	-0.2	0	0	0	-0.2		-0.8		-3	
C. Unprotected ear C-weighted level	99.8	100	100	100	99.8		99.2		97	**107.9**
D. A Weighted corrections (dB)	-16.1	-8.6	-3.2	0	1.2		1.0		-1.1	
E. Unprotected ear A-weighted level	83.9	91.4	96.8	100	101.2		101		98.9	
F. Average attenuation at each frequency (example)	21	22	23	29	41	43	47	41	36	
	21	22	23	29	41		45*		38.5*	
G. Std. deviation in dB at each frequency (example)	3.7	3.3	3.8	4.7	3.3	3.3	3.4	6.1	6.5	
	x2	x2	x2	x2	x2					
H. Two standard deviations	7.4	6.6	7.6	9.4	6.6		6.7**		12.6**	
I. Complete APV-98 in dB at each frequency. (line F - line H) (APV = Average Protection Value)	13.6	15.4	15.4	19.6	34.4		38.3		25.9	
J. Protected ear A-weighted level, (average attenuation minus two std. deviations develops the A-weighted levels (line E - line I))	70.3	76.0	81.4	80.4	66.8		62.7		73.0	**85.1**
K. NRR is unprotected ear "C" level (line C) minus protected ear "A" level (line J) minus 3 dB										**19.8**

*Average attenuation at 3000 and 4000 Hz and at 6000 and 8000 Hz

**Summed standard deviation for 3000 and 4000 Hz and 6000 and 8000 Hz.

Source: NIOSH Hearing Protector Compendium

The single number is effectively an approximation of the dB reduction achieved across the entire range of center frequencies, which is analogous to a "broad-band" measurement of sound pressure levels (SPL) in a work area using a traditional handheld sound level meter. What the NRR numbers do not provide is adequate information to understand noise reduction at each of the center frequencies. The actual attenuation at each center frequency is likely to be higher or lower than the NRR. In practice, hazardous noise levels are often limited to or dominant at select frequencies and almost never exist at equal levels across a continuous span of frequencies. In real-life applications, it is therefore possible that the actual noise reduction performance of the HPD at some frequencies will be more or less than the single number indicates. When this occurs, the result can be either a failure to adequately reduce some noise levels, the introduction of new safety risks associated with unnecessary compromises in communications, or both.

The NRR also gives high weighting attention to low frequency attenuation, while neglecting high frequency performance. This is because in the calculations to compute NRR A- weighting factors get deducted from the initial 100 dB constant level. And since the A-weighting scale falls off below 1000 Hz, the NRR discounts much of the noise that would be present below 1000 Hz. This too, may or may not fit the "real world" situation.

Application of the NRR is further clouded by different recommended deratings of it by different agencies (see Table 2). The EPA uses a straight forward approach using the unprotected sound level minus the HPD NRR to yield the protected sound level. For example, if the overall sound is 95 dB and the NRR of the HPD is 25 dB, the EPA interpretation is that the sound present at the ear is 70 dB. OSHA has probably the most complicated interpretation and lengthy derating scheme. If the sound measurements were made with the dB(A) scale the recommended derating factor is the sound level minus the HPD NRR less 7 dB and then divided by two. In the example above that would have resulted in an interpretation of the sound present at the ear of 86 dB. If the measurements were made with the dB(C) scale the recommended derating factor is the sound level minus the HPD NRR divided by two. In the example above that would have resulted in an interpretation of the sound present at the ear of 82.5 dB. To add one more agency, NIOSH recommends the following: 1) For earmuffs deduct 25% from the manufacturer's NRR. 2.) For formable earplugs deduct 50% from the NRR. 3) For all other earplugs deduct 70%. NIOSH further states that for dB(A) measurements simply deduct 7 dB from the NRR for all protection devices.

TABLE 2 - Application of NRR

(Assume a measured sound level exposure of 95 dB in all examples. Assume an HPD that has NRR of 25 dB).

Method	Formula	Example	
EPA	$L_{measured}$ - NRR = L_{HPD}	95 dB - 25 dB	= 70 dB
OSHA	If A-weighted measurements: $L_{measured}$ - (NRR - 7 dB)/2 = L_{HPD}	95 dB(A) - (25 dB - 7 dB) /2	= 86 dB(A)
	If C-weighted measurements: $L_{measured}$ - (NRR / 2) = L_{HPD}	95 dB(C) - (25 dB / 2)	= 82.5 dB(C)
NIOSH	If C-weighted measurements: If Ear Muffs: $L_{measured}$ - NRR x 0.75) = L_{HPD}	95 dB(C) - (25 dB x 0.75)	= 76.25 dB(C)
	If Foam Ear Plugs: $L_{measured}$ - NRR x 0.50) = L_{HPD}	95 dB(C) - (25 dB x 0.50)	= 82.5 dB(C)
	If All Other Ear Plugs: $L_{measured}$ - NRR x 0.30) = L_{HPD}	95 dB(C) - (25 dB x 0.30)	= 87.5 dB(C)
	If A-weighted measurements:	95 dB(A) - (25 dB - 7 dB)	= 77 dB(A)

$L_{measured}$ is the unprotected noise exposure level before the HPD. L_{HPD} is the calculated protected noise level.

The SNR method is the European version of the NRR method. However, there are three differences from the NRR method to be aware of, two technical and one regulatory. The SNR applies one standard deviation, instead of two as in the NRR calculation. This results in only a 84% coverage factor versus a 98% coverage-factor when using the NRR method. And the SNR method does not deduct 3 dB from the final calculation as does the NRR method. From a regulatory standpoint, because of the European CE mark requirements [since 1995] there must be a certified CE test report performed after July 1995 attesting to the SNR for it to be sold in Europe. But here again, because the SNR works off the same basic principles as the NRR it has the same disadvantages of being low frequency weighted and assuming a constant 100dB sound level exposure.

A third single number system encountered primarily in Canada is really an A, B, and C class rating system. It is based on CSA Standard Z94.2-1994 Hearing Protection Devices – Performance, Selection, Care, and Use. It states the A class is equivalent to an NRR of 24+; the B class to NRR's of 17-24; and the C class to NRR's of < 17.

The final two methods we will discuss account for reduction ratings as a function of frequency. The first and more data intensive of these methods is the Octave Band (OB) method that breaks the reduction rating down into eight values that report the attenuation at the following eight frequencies between 63 Hz and 8 KHz: 63, 125, 250, 500, 1000, 2000, 4000, and 8000. You may recall that in the discussion above, the APVs were determined in order to arrive at the NRRs and SNRs. Applying APV using the OB method is the most precise of all five methods discussed here. There is a fifth method that falls in between the APVs and NRRs/SNRs in terms of precision and complexity. It is called the High Medium Low (HML) method. HML provides aggregate attenuation values similar to the NRR method, but across broader groups of frequencies than the more precise APV method. HML provides values that rate the HPD's attenuation capability at high, medium and low frequencies. The HML Method is defined in ISO 4869-2, which specifies the frequency bands as follows: High is above 2 kHz; Medium is between 500 Hz and 2 kHz; Low is below 500 Hz. HML provides a better estimate of actual performance than the single number methods by

Ttable 3 summarizes the five methods discussed into key advantages and disadvantages.

TABLE 3 - HPD Rating System Advantages/Disadvantages

Method	Key Advantage	Key Disadvantages
NRR	Simple one number method	May over-protect or under-protect
SNR	Simple one number method	Same as NRR
CSA Class	Simple one number method	Same as NRR
OB	Most accurate in specific applications	Requires more data
HML	Balance between accuracy of APV and simplicity of NRR, SNR & CSA methods	Less accurate than APV method

Example Application

Process changes in a manufacturing facility have necessitated the retesting of worker noise exposures. Noise dosimeter studies indicate that some workers in the facility now need to wear HPDs, where previously they were not required. Real-time frequency analysis using the Quest Technologies model SoundPro® DLX Hand-Held Sound Level Meter and Real-Time Frequency Analyzer has identified that the noise levels the workers are exposed to are 20 dB higher than acceptable at 4000 Hz. Using the EPA method of applying the NRR, it would appear the quick and easy solution is to provide an HPD that has an NRR of 20 to protect the workers. However, looking at the HML data for an HPD with an NRR of 20, it is discovered that the H or high frequency attenuation is 30 dB, certainly overprotection at this 4000 Hz frequency. Looking at additional data on other HPDs from the same manufacturer, two other HPD's are identified that have H components of 21 and 19. They also have corresponding NRR's of 16 and 8 respectively, which means using the NRR method they would not have been considered for use. Either of the latter two HPDs are actually a better fit for this application, but evaluating them on the basis of their NRR alone eliminates them as possible solutions.

ANALYZING SOUND TO APPLY THE OB OR HML METHODS

Frequency based measurement is, of course, the only way to analyze a sound signal to be able to apply the APV or HML values. Using the SoundPro DLX from Quest, this task is easier, more accurate, and faster than with traditional octave band analyzers that step through the frequency spectrum one octave at a time. The SoundPro DLX makes the HML and OB methods practical approaches for hearing protector selection in real world applications.

Measurement is really quite simple. The instrument must be set up for linear response, called Z weighting. This insures that sound pressure levels are treated equally at all frequencies and not weighted. The OB and HML methods do not apply weighting such as A or C weighting in their unprotected noise measurements. The instrument is then put in the run mode and a sample taken of sufficient duration to ensure a representative sample has been captured. Sequencing from octave to octave is no longer required as the SoundPro DLX captures all octave bands at once.

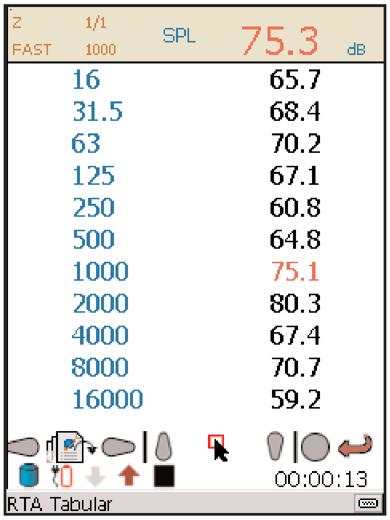


Figure 1
Frequencies in Real-Time
(Numerically)

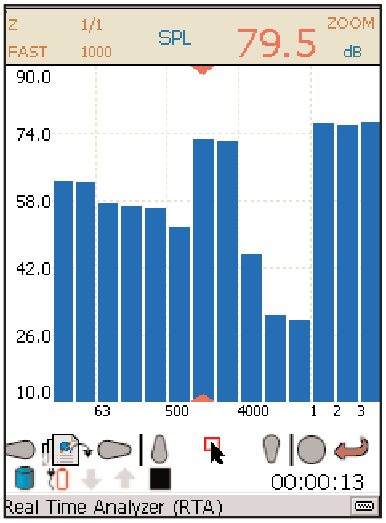
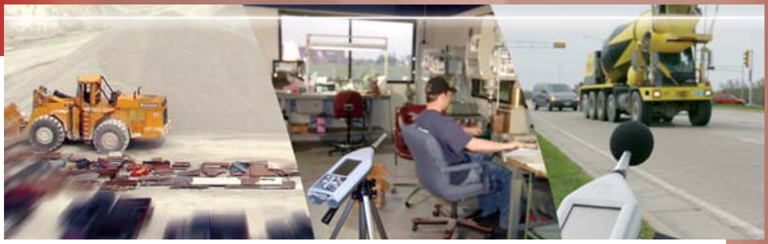


Figure 2
Frequencies in Real-Time
(Graphically)

Measurement data (see Figure 1& 2) is used to determine the necessary attenuation needed from an HPD at each center frequency in order to provide optimal worker protection. This requires looking for noise levels that are above the regulatory agency action level at the eight frequencies specified by the OB method or in the three frequency bands defined in the HML method. This evaluation can also be performed in QuestSuite® Professional II (QSPII), the supporting software for the SoundPro DLX.



CONCLUSION

As is evident from the material presented, the NRR and the closely related SNR and CSA Class methods have some inherent disadvantages in helping a user pick the best HPD for a given application. Single number methods all assume a constant sound level across the whole frequency spectrum and are heavily weighted to lower frequency components. Certainly one could argue that sound levels are not constant in real world applications and understanding and protecting workers from inside levels at all frequencies within the hearing range is important. It is also clear from the examples cited that relying on single-number or letter protection systems could result in under/over protection. Therefore those methods that address determining protection factors at application-specific frequencies are better methods that allow tailoring the protection to the specific hazard level. The APV method with its eight data points and the simpler HML method are methods that more accurately determine protection levels required and provided for worker safety. The complexities associated with obtaining in the measurement information necessary to apply the OB and HML methods are overcome by using the Quest Technologies model SoundPro DLX Hand-Held Sound Level Meter and Real-Time Frequency Analyzer.

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