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FILTER SELECTION TO ADAPT EARPLUG PERFORMANCES TO SOUND EXPOSURE

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1. INTRODUCTION

For hearing protection to be made effective, the research needs established by NIOSH [1] (National Institute for Occupational Safety and Health) are to find a way for workers to be individually fitted and to offer them increased comfort and the ability to hear speech and warning signals.

To address these individual fit and comfort issues, a new concept has been developed; a re-usable earplug that is custom-fitted using silicon injection- and field tested for attenuation on the worker [2].

The ability to hear speech and warning signals can be partially addressed by adapting the earplug attenuation to the actual noise exposure of the worker [3]. This proposed adaptation is based on a set of acoustic filters that could be placed into the earplug's sound-bore to lead to a protected exposure level between 70 to 85 dBA.

2. INDUSTRIAL NOISE EXPOSURE LEVELS IN CANADA

Based on the data published by Statistics Canada [4] the number of workers in various industrial areas is identified. The corresponding noise exposure is then determined from compilation of published data in the areas of construction , refined petroleum and plastic [6], forestry [7, 8], food, beverages & machinery [9-11], printing and textile [12], transports [13, 14], and other areas [15].

Exposure Levels	Number of Workers	Relative Weight
85 - 90	140,000	6.2%
90 - 95	793,300	35.3%
95 - 100	701,000	31.2%
>100	612,000	27.2%
Total	2,246,300	100.0%

Table 1: Summary of exposure levels and number of workers exposed in Canada's workplaces

3. PROTECTION OUTCOME OF FILTERED EARPLUGS

3.1. Attenuation Data of Filtered Earplugs

The attenuation of custom earplugs filtered with a set of 9 elements (Full-Block, 4700 Ω, 3300 Ω, 2200 Ω, 1000 Ω, 680 Ω, 330 Ω and 0 Ω dampers) has been measured per octave bands -from 125 to 8000 Hz - on an Artificial Test Fixture (ATF).

3.2. Protection Outcome of Filtered Earplugs for Typical Industrial Noises

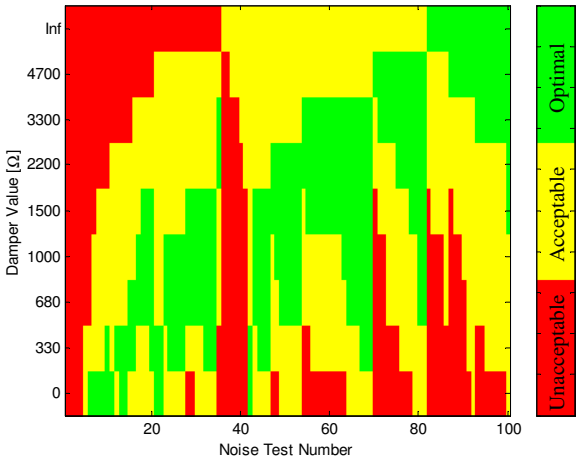

Figure 1: Protection outcome for the different filters on 100 typical industrial noise spectrums ("Unacceptable" are protected sound exposure levels below 70 or above 85 dBA; "Acceptable" are between 70 and 75 dBA or between 80 and 85 dBA; "Optimal" are between 75 and 80 dBA).

From published typical industrial octave-band spectra [16] and the measured filtered earplug attenuations we can compute the protected exposure levels according to the *Octave Band Procedure*; the resulting Protection Outcome –as defined by CSA[3]- is presented in Figure 1.

For 89 of the 100 industrial noises, at least one appropriate filtered earplug could be found that leads to an *optimal* protection (versus 96 for merged *optimal* and *acceptable* protection outcomes).

4. SELECTION OF FILTERED EARPLUG FOR ADEQUATE PROTECTION

Damper Value [Ω]	%	85-90	90-95	95-100	>100	Weighted Mean
	∞	0.0	2.0	40.7	35.0	22.9
	4700	0.0	10.0	59.3	25.0	28.8
	3300	0.0	32.0	59.3	20.0	35.2
	2200	0.0	38.0	33.3	20.0	29.3
	1500	33.3	56.0	29.6	20.0	36.5
	1000	33.3	50.0	25.9	10.0	30.5
	680	33.3	50.0	25.9	10.0	30.5
	330	0.0	38.0	11.1	5.0	18.2
	0	33.3	16.0	7.4	0.0	10.0
Optimal Situation		66.7	100.0	100.0	50.0	**84.2**

Table 2: Percentage of optimal protection for the 9 different filters when the exposure levels are between 85 and 100 dBA and more.

The percentages of optimal protection are calculated in Table 2 for every filtered earplug for noise exposure levels from 85 to 100 dBA and more. The *relative weight* (see Table 1) of each of those noise exposure classes is used to compute the *Weighted Mean* percentage that reflects the usefulness of the corresponding filter to correctly protect workers in Canada's industrial workplaces. The *Optimal Situation* line reflects the percentage of noise cases where at least one filter provides an optimal protection. A global coverage of 84.2% is obtained with the set of 9 filters. Since the protection of some filters overlap, a similar computation could be applied to a subset of filters. For example, it is possible to find among the 512 ($512=9^2$) possible subsets, 2 subsets of only 6 filters that give the same 84.2% *optimal* coverage. When also including *acceptable* protection, the global coverage increases to 94.6% and can be easily obtained with 12 subsets of only 3 filters.

5. CONCLUSION

This study has demonstrated that it was possible to filter a custom earplug to provide an adequate protection in most of Canada's industrial workplaces. The use of a reduced set of simple acoustic filters avoids most of the over-protection situations (uncomfortable and dangerous because speech and warning signals can not be heard) and under-protection (dangerous because of the over-exposure).

6. ACKNOWLEDGEMENTS

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