ATTENUATIONS FROM HEARING PROTECTORS AND THE ABC CLASSIFICATION SYSTEM

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SUMMARY

This paper evaluates the accuracy of the CSA ABC class system for rating hearing protectors. The noise level of the protected ear of twelve protectors (six Class A and six Class B) subjected to twelve noises were calculated. It was shown that there is large variation among sound levels from both protector classes as well as overlaps, resulting mostly in overprotection. It is recommended that the ABC system be changed to some other rating system used by the international community.

SOMMAIRE

Cet article s'intéresse â l'adéquacité de la classification ABC dans l'ACNOR pour l'évaluation des protecteurs auditifs. Le niveau de pression acoustique atteignant l'oreille protégée par douze protecteurs différents (six de classe A et six de classe B) soumis à douze bruits différents est calculé. Les résultats démontrent une dispersion importante des niveaux de pression acoustique ainsi que des chevauchements pour les deux classes de protecteurs, résultent principalement en une "sur-protection". Il est recommandé que le système ABC soit écarté au profit d'un autre système d'évaluation utilisée par la communauté internationale.

1.0 OBJECTIVE

The ABC Classification system in the CSA Standard for hearing protectors[1] has been under discussion for many years within the CSA Committee as well as among the Canadian scientific community, manufacturers and users. The fact that Canada is the only place in the world where this system is used has been often pointed out. Also, the ease and simplicity in using the NRR[2] as a simplified substitute to the NIOSH "long" method[3] has been debated.

This paper intends to bring a different approach to this discussion by examining the intrinsic value of the ABC system. To this effect, sound level of the protected ear, resulting from the use of twelve protectors (six Class A and six Class B) in twelve different noises was calculated. Accuracy of the system was examined by analyzing overlaps and spreads of sound levels of the protected ear when using Class A and B protectors. The adequacy of using a particular class of protector for a given noise was also tested for the noises used in the study.

2.0 INTRODUCTION

2.1 Background

Protectors are intended to reduce the sound level that reaches the tympanic membrane of the ear of a person exposed to noise ("sound level of the protected ear"). Consequently, the sound attenuation is one of the most important parameters of a protector. The almost universally accepted ANSI method[5] (similar to the ISO one[6]) allows for the measurement of the protector's sound attenuation at each one of the measurement frequencies, 125 Hz through 8000 Hz. It also provides a mean for assessing the variability between and within test subjects using the standard deviation of the measured attenuations.

Results from the measurement of the attenuation of protectors are used to:

(a) determine if a protector is appropriate for a given noise by calculating the sound level of the protected ear, and

(b) compare protectors.

A variety of methods allow for the calculation of the sound level of the protected ear, using attenuation values measured in laboratories around the world. It is well known that those attenuations are higher than these obtained in real world situations. Because all classification methods use the same source of information, (laboratory measured attenuations), the same criticism regarding non-realistic results applies to all and everyone of the prediction methods.

2.2 The ABC Classification System

The CSA Standard on hearing protectors provides details on how to classify a protector into Class A, B or C according to the attenuation measured as per the ANSI Standard. No provisions are made for using the standard deviation of the measurements.

The CSA classification system was originated as an attempt to set performance requirements for plugs and muffs. It was incorporated in the CSA Standard Z94.2-1965[4]. Later, the system was modified following a proposal by Berger[8]. The attenuation of the hearing protectors was reduced to reflect their performance in real life situations. To that effect, Class A protectors were derated by 4 dB, Class B by ten and Class C by eight. To simpligy the derating and in a somehow arbitrary manner, no difference was made between derating of plugs and muffs.

2.3 Use of the Measured Attenuation

Attenuation results are used in one of the following ways:

(a) To calculate the sound level of the protected ear. This is the approach taken by the international community using the NIOSH "long" method[3], the NRR[4] and the HML[7] Method.

This approach has the advantage of allowing for the calculations of the sound level of the protected ear. In some instances it takes into account the entire spectrum of the ambient noise (NIOSH "long" method). In some others (NRR) it only uses the C-Weighted sound level of the noise. Finally, the HML method uses both A and C-weighted sound levels.

(b) To divide protectors in classes according to the mean attenuation at the measured frequencies. Use of a given class of protector depends on the time weighted average sound level the person is exposed to. This method is only used in Canada in the CSA Standard.

One advantage of this method is of being procedural: no calculations are needed to determine the class of the protector to be used.

3.0 MATERIAL

Twelve different noises (No. 1 through No. 12) and twelve protectors (A through L) were used in this study. Some of the noises are real (measured in real life situations), while other are shaped artificially. Details of the noises are presented in Table 1, Figure 1 and Figure 2. They were chosen so that to cover a wide variety of spectra. Details of the twelve protectors (six Class A and six Class B), their attenuations and CSA classes are presented in Table 2. All data are those supplied by manufacturers.

TABLE 1

NOISES USED IN THE STUDY

No.	Type of Noise	Sound Levels, dB*									
					Octave Band Centre Frequencies, Hz						
		A	Lin	C	125	250	500	1000	2000	4000	8000
1	Air chisel chipping	109.4	110.1	109.4	90	98	104	102	100	103	104
2	-4 dB/oct	99.3	107.2	107.1	105	101	97	93	89	85	81
3	Air compressor	100.2	102.7	102.5	65	100	91	93	93	94	89
4	Chemical reactor	92.9	94.4	94.3	82	87	88	90	86	76	66
5	+4 dB/oct	111.9	112.2	110.4	86	90	94	98	102	106	110
6	Bell shape	95.4	96.1	95.9	82	86	90	90	90	86	82
7	Blower	94.8	95.8	95.7	86	87	88	90	90	84	72
8	Feeding pump	92.8	94.9	94.8	82	89	90	87	86	83	75
9	Wood chipper	102.8	106.5	106.4	97	102	102	95	95	91	85
10	Clarifier	94.4	94.5	94.3	78	82	87	88	90	86	78
11	Compressor	99.5	100.1	99.9	81	90	93	96	93	88	86
12	Grinder	103.5	102.5	102.0	64	72	81	85	101	95	92

* Octave band levels were rounded to the nearest dB; A, C and Lin levels were obtained by calculation and were rounded to the nearest tenth of dB.

Since the objective of this paper is to compare treatment of laboratory data, no allowance is made here to compensate for the difference between laboratory and real life attenuation results.

TABLE 2

LIST OF HEARING PROTECTORS USED IN THIS STUDY

Letter	Manufacturer	Model	Type	Attenuation - 2 Standard Deviations, dB							CSA Class
				125	250	500	1000	2000	4000	8000	
A	Willson Prod. Division	Sound Band	Semi-insert	16.4	12.8	12.4	12.8	23.4	25.6	36.8	B
B	Bilsom International Inc	Prop-O-Plast	Plug	15.4	17.8	18.2	18.0	26.2	33.0	27.6	B
C	Mine Safety Appliances Company	Noise-foe Mark IV	Muff	7.2	12.2	18.6	31.0	29.6	36.4	29.6	A
D	American Optical Company	1720	Muff	12.0	17.0	26.6	39.3	39.1	43.4	32.3	A
E	Cabot S.C. Safety Corp.	E-A-R	Plug	23.6	26.0	26.2	32.2	34.4	39.6	36.4	A
F	Mine Safety Appliances Company	Ear De-fender	Plug	10.4	8.2	11.0	15.2	18.8	15.2	7.6	B
G	Safety Supply Canada	204	Muff	7.2	13.2	20.5	31.2	33.4	35.8	32.5	B
H	Glendale Optical Company	GN901	Muff	8.8	14.8	25.6	31.2	33.8	37.0	27.6	A
I	Peltor	H9A	Muff	10.6	11.0	20.3	28.4	32.9	35.9	29.3	B
J	North	Com-Fit	Plug	15.1	20.5	25.1	27.4	33.8	42.1	40.8	A
K	Cabot S.C. Safety Corp.	Ultra Fit	Plug	27.5	28.7	32.1	28.9	26.5	29.6	39.4	A
L	Peltor	H9P3e	Cap. Muff	9.9	12.5	20.9	25.4	32.5	33.6	30.5	B

4.0 METHOD AND RESULTS

Sound levels of the protected ear, in dBA, were calculated for each of the one hundred and forty-four combination protector/noise, using the NIOSH "long" method. They are presented in Table 3. The Table also shows the CSA class of each protector and the sound level in dBA of each noise. As an example, when wearing Protector I (Class B) while exposed to the Noise 9 (SL=102.8 dBA), the noise level of the protected ear will be 84.2 dBA, while it will be 70.9 dBA, when exposed to Noise 12 (103.5 dBA).

TABLE 3

SOUND LEVELS OF THE PROTECTED EAR

Protectors		Noises (3)												
		No.	1	2	3	4	5	6	7	8	9	10	11	12
Letter (1)	Class (2)	SL dBA	109.4	99.3	100.2	92.9	111.9	95.4	94.8	92.8	102.8	94.4	99.5	103.5
C	A		84.4	84.6	79.9	70.2	81.8	71.2	61.6	69.2	84.3	68.5	74.6	73.4
D	A		77.9	79.5	74.8	63.9	77.6	64.4	63.1	62.0	78.4	61.3	67.8	65.0
E	A		77.2	71.8	68.8	62.3	75.8	63.9	62.4	62.8	74.5	61.9	67.9	68.5
H	A		80.8	82.3	77.1	66.7	82.2	67.2	66.1	65.0	80.6	64.5	70.9	70.1
J	A		79.2	77.1	72.8	65.7	75.4	66.5	64.8	65.5	77.4	64.3	71.0	69.1
K	A		79.4	70.2	71.5	64.4	80.8	67.1	66.9	64.0	73.5	66.5	71.0	76.2
A	B		92.3	85.5	83.7	78.8	88.2	79.6	77.7	79.0	88.7	77.4	84.6	80.3
B	B		87.2	80.9	78.6	73.6	85.2	74.4	72.7	73.8	83.3	72.4	79.4	77.0
F	B		97.7	88.0	87.4	78.7	101.9	81.2	81.3	80.6	90.7	79.2	85.2	87.5
G	B		82.8	84.1	78.8	68.9	79.6	69.6	68.0	67.6	83.0	66.7	73.1	70.1
I	B		83.8	83.6	80.8	70.2	81.7	70.6	69.4	68.7	84.2	67.7	74.4	70.9
L	B		83.6	83.1	87.6	70.0	81.4	70.5	69.2	69.0	83.2	67.9	74.7	71.4

Note: Sound levels were calculated using the NIOSH "long" method

(1) From Table 2
(2) As per CSA Standard
(3) From Table 1

Protectors were further divided into two groups according to their CSA class: one group contains six Class A protectors and the other six Class B protectors. For each noise and class of protectors, the maximum and minimum sound levels of the protected ear, as well as their ranges were calculated. Maximums, minimums and ranges are shown in Table 4. The graph in Figure 3 shows the maximum and minimum values, while the graph in Figure 4 shows their ranges. Figure 5 shows the overlap existing between the maximum SL using a protector Class A and the minimum SL using a Class B.

5.0 DISCUSSION

It is accepted that the best prediction of the sound level of the protected ear is obtained by using the NIOSH "long" method. It has also been shown, that no large differences appear between results from using the above method or anyone of the NRR and the HML methods. [9] [10]

As mentioned at the beginning, the ABC is a procedural method. As such, it implies that the use of a given type of protector, ensures a "safe" sound level of the protected ear, without having to confirm it through calculation of the noise level of the protected ear. As per the CSA Standard, a Class A protector is to be used in sound levels up to 105 dBA and a Class B up to 95 dBA. There is an implicit assumption that a Class A protector has a 10 dBA higher attenuation than a Class B.

Data in Table 4, Figure 3 and Figure 4 show that there is a wide variation among the sound levels of the protected ear among protectors of the same class. Depending of the noise involved, their range varies between 5.3 and 14.4 dBA for Class A protectors and between 7.1 dBA and 22.3 dBA for Class B protectors.

The examination of Table 3 and Figure 3 shows that there is also a large overlap between sound levels of the protected ear using Classes A and B protectors. In almost all cases, the maximum sound level of the protected ear using a Class A protectors results in a higher sound level than the lower sound level using a Class B protector, meaning that a Class A protector is not always better than a Class B. Differences ranging between -1 dBA and +6 dBA are shown in the graph of Figure 5.

The wide variation of sound levels of the protected ear and their overlap leads us to the conclusion that there is no clear difference between sound levels of the protected ear using protectors of Class A and Class B. Therefore, there cannot be a safe guideline as to when to wear what.

TABLE 4

SOUND LEVELS OF THE PROTECTED EAR

(maximum, minimum and ranges)

Protectors Class	SL	Noises											
		No.	1	2	3	4	5	6	7	8	9	10	11	12
		SL, dBA	109.4	99.3	100.2	92.9	111.9	95.4	94.8	92.8	102.8	94.4	99.5	103.5
A	Min		77.2	70.2	68.8	62.3	75.4	63.9	61.6	62.0	73.5	61.3	67.8	65.0
	Max		84.4	84.6	79.9	70.2	82.2	71.2	66.9	69.2	84.3	68.5	74.6	76.2
	Range		7.2	14.4	11.1	7.9	6.8	7.3	5.3	7.2	10.8	7.2	6.8	11.2
B	Min		82.8	80.9	78.6	68.9	79.6	69.6	68.0	67.6	83.2	66.7	73.1	70.1
	Max		97.7	88.0	87.6	78.8	101.9	81.2	81.3	80.6	90.7	79.2	85.2	87.5
	Range		14.9	7.1	9.0	9.9	22.3	11.6	13.3	13.0	7.5	12.5	12.1	17.4

Finally, the validity of Table 1.A of the Standard was tested against the sound levels of the protected ear calculated in Table 3. To account for the derating of 4 dB (Class A protectors) and 10 dB (Class B protectors), Table 5 was developed, where those levels were added to the levels in Table 3. Next step was to see how many protectors of each Class reduce the sound level of the protected ear to 85 dB for each one of the twelve noises. Table 6 shows the result. In this table, the first row lists noise numbers and the second their levels in dBA. Next row contains the Class of protector to be used for that noise as per Table 1.A of the Standard. The following two rows show the number of protectors from this study that will satisfy the requirement of reducing the noise level of the protected ear to the required 85 dBA (or less).

Table 6 shows that, for instance, for noise No. 1 (SL=109.4 dBA), the CSA requirement is for a combination of a plug and a muff. However five of the six Class A protectors will be sufficient by themselves without being used in combination. Therefore the CSA recommendation will result in overprotection.

In the case of noise No. 2 only four of the six Class A protectors will provide the required reduction.

The last row of the table summarizes the findings:

(a) in only one case (noise No. 3) all six Class A are adequate and none of the Class B could be used. Therefore, the Class system works.

(b) in six cases (noises No. 2, 4, 7, 8, 9 and 10) not all protectors of the assigned classes are adequate, and

(c) in five cases (noises No. 1, 5, 6, 11 and 12) protectors of a lower class will also be sufficient.

Therefore, in one out of twelve cases, the Class system works correctly.

6.0 CONCLUSIONS

As stated before, the conclusions of this study apply only to:

(a) protectors and noises studies here, and
(b) to attenuations provided by manufacturers. No derating for real life situations has been done.

The CSA Standard ABC classification and selection method is supposed to insure a proper protection of wearer's hearing by dividing protectors into Classes A, B and C and indicating the maximum sound level the person should be exposed to. Those maximum levels are:

105 dBA for protectors Class A
95 dBA for protectors Class B, and
89 dBA for protectors Class C.

The obvious implication is that the attenuations from protectors Class A are at least 10 dBA higher than those of Class B and 16 dB than those of Class C.

Results from this study show that this is not the case and that there are large variations and overlaps between sound levels of the protected ear when wearing either Class A or Class B protectors. There is a basic inconsistency in the results of assigning a particular Class of protector for a given noise, as hown in Table 6.

The conclusion is that the Class ABC system is not a reliable one and should be replaced by other method (or methods, as done by the ISO), developed on a more scientific basis and recognized by the scientific community.
The conclusion is that the Class ABC system is not a reliable one and should be replaced by other method (or methods, as done by the ISO), developed on a more scientific basis and recognized by the scientific community.

REFERENCES

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TABLE 5

SOUND LEVELS OF THE PROTECTED EAR

Protectors		Noises												
		No.	1	2	3	4	5	6	7	8	9	10	11	12
Letter	Class	SL dBA	109.4	99.3	100.2	92.9	111.9	95.4	94.8	92.8	102.8	94.4	99.5	103.5
C	A		88.4	88.6	83.9	74.2	85.8	75.2	65.6	73.2	88.3	72.5	78.6	77.4
D	A		81.9	83.5	78.8	67.9	81.6	68.4	67.1	66.0	82.4	65.3	71.8	69.0
E	A		81.2	75.8	72.8	66.3	79.8	67.9	66.4	66.8	78.5	65.9	71.9	72.5
H	A		84.8	86.3	81.1	70.7	86.2	71.2	70.1	69.0	84.6	69.4	74.9	74.1
J	A		83.2	81.1	76.8	69.7	79.4	70.5	68.8	69.5	81.4	68.3	75.0	73.1
K	A		83.4	74.2	75.5	68.4	84.8	71.1	70.9	68.0	77.5	70.5	75.0	80.2
A	B		102.3	95.5	93.7	88.8	98.2	89.6	87.7	89.0	98.7	87.4	94.6	90.3
B	B		97.2	90.9	88.6	83.6	95.2	84.4	82.7	83.8	93.3	82.4	89.4	87.0
F	B		107.7	98.0	97.4	88.7	111.9	91.2	91.3	90.6	100.7	89.2	95.2	97.5
G	B		92.8	94.1	88.8	78.9	89.6	79.6	78.0	77.6	93.0	76.7	83.1	80.1
I	B		93.8	93.6	90.8	80.2	91.7	80.6	79.4	78.7	94.2	77.7	84.4	80.9
L	B		93.6	93.1	97.6	80.0	91.4	80.5	79.2	79.0	93.2	77.9	84.7	81.4

Note: Sound levels were calculated following the procedure in the NIOSH "long" method and then 4 dB were added to all Class A protectors and 10 dB to all Class B protectors.

TABLE 6

PROTECTOR'S CLASS AS PER THE CSA STANDARD

NOISE NUMBER		1	2	3	4	5	6	7	8	9	10	11	12
SL, dBA		109.4	99.3	100.2	92.9	111.9	95.4	94.8	92.8	102.8	94.4	99.5	103.5
CLASS AS PER THE CSA STANDARD		A plug + A or B muff	A	A	B	A plug + A or B muff	A	B	B	A	B	A	A
NUMBER OF PROTEC-TORS	Class A	5	4	6	N/A	4	6	N/A	N/A	5	N/A	6	6
	Class B	0	0	0	4	0	4	4	4	0	4	3	3
CORRECT CLASS ASSIGNED		NO		YES	NO	NO	NO	NO	NO	NO	NO	NO	NO

Figure 1

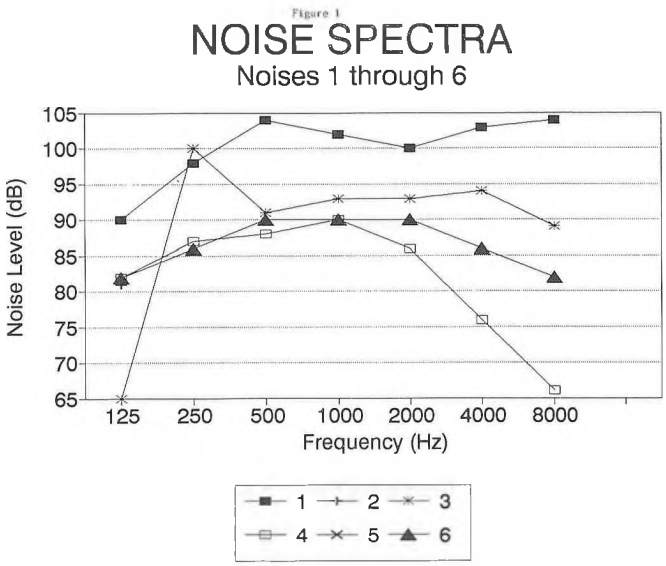

Figure 2

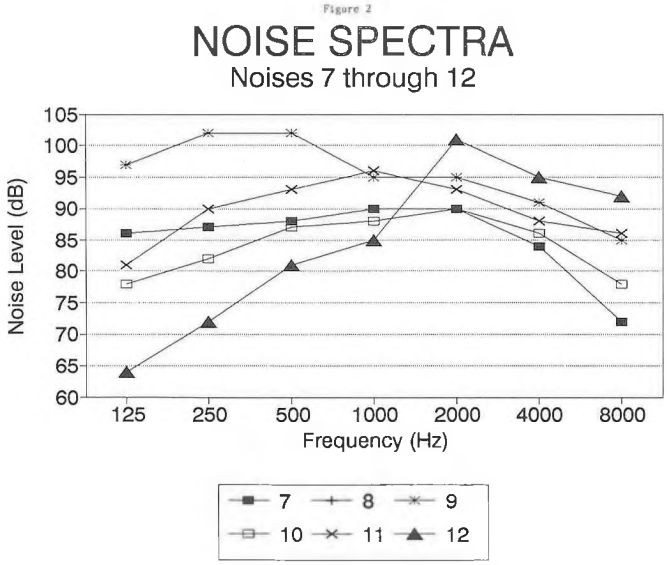

Figure 3

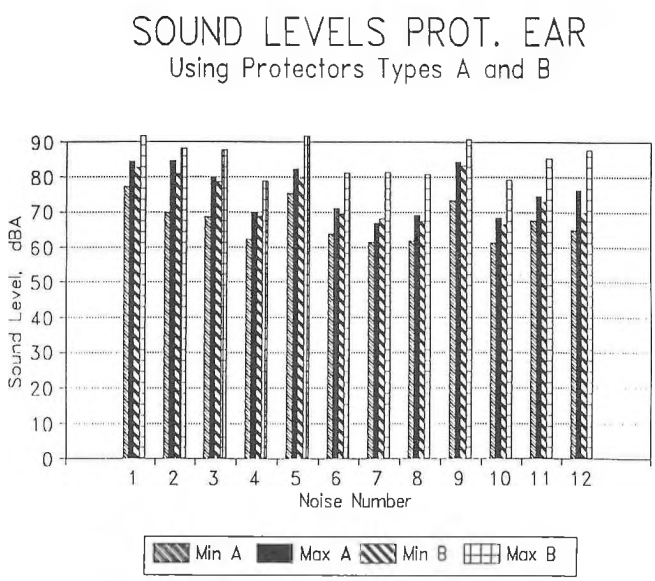

Figure 4

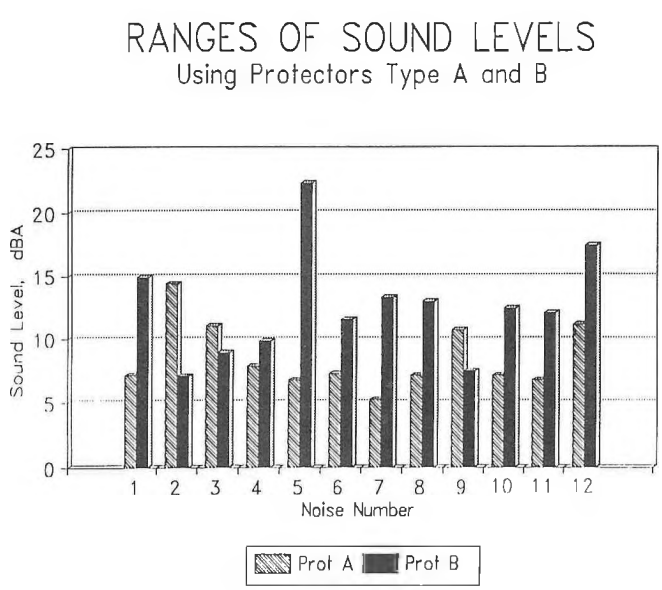

Figure 5