AN OVERVIEW OF THE DIFFERENCES BETWEEN JURISDICTIONAL HEARING PROTECTION DEVICE ATTENUATION SCHEMES AND THE EFFECTIVENESS OF EARPLUG FIT TESTING

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About Me

- Graduated from UBC in 2022
  - *MSc. Occupational and Environmental Hygiene (OEH)*
  - *BSc. in Cell/Molecular Biology*

- NorthStar Occupational Hygiene and Safety
  - *Consulting firm primarily based in Calgary*
  - *Exposure assessments*
  - *Turnaround support*
  - *Personal exposure monitoring*

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Presentation Overview

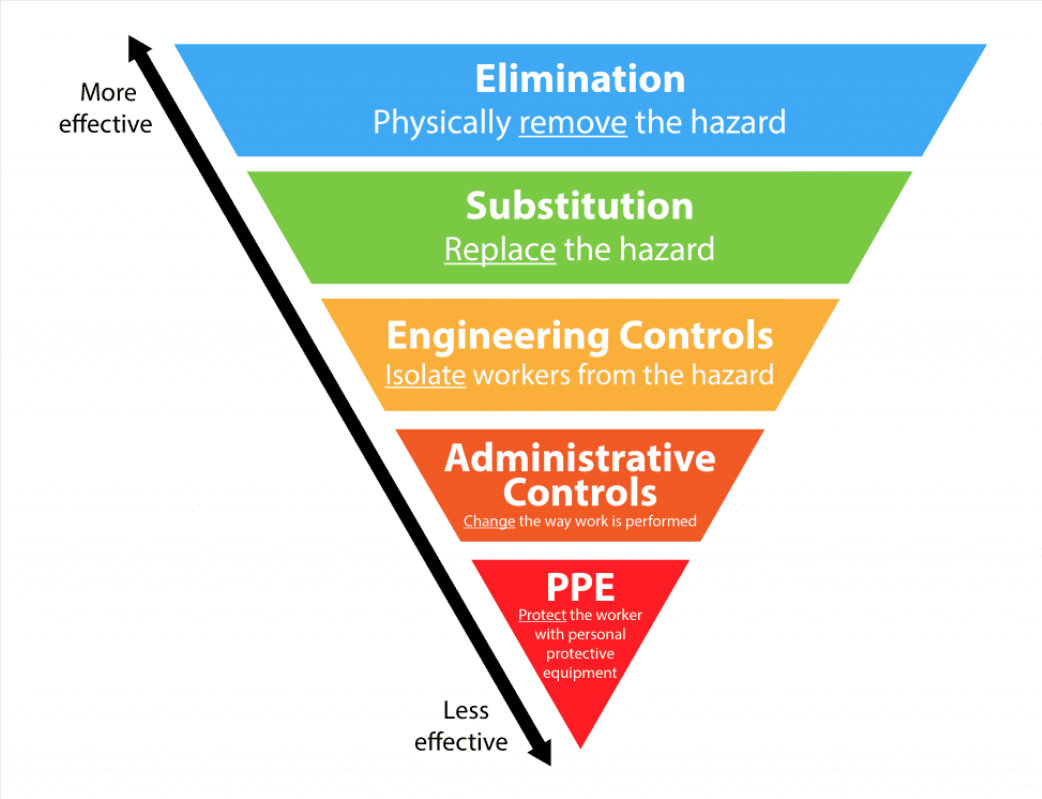
- HPD General Info
- New Legislation
- Quantitative Fit Testing
- What's on the Earplug box?
- Determination of Attenuation Values
- Experimental Study
- Take Home Points

What are hearing protection devices?

- Devices that attenuate noise exposure
  - Attenuation
    - CSA Standard defines it as - “the reduction in sound pressure level incident upon the ear due to the application of a hearing protector or, specifically, the change in hearing threshold level that results when a hearing protector is worn.”

When and where are HPD's required?

- In situations/areas where noise cannot be reduced by other means
- Personnel who are exposed to ≥85dBA of noise for ≥8 hours or ≥115dBA
  - *Schedule 3 Table 1 in Alberta OHS Code*
- How to know if they are required?
  - *Noise exposure assessment required if sound levels are 82dBA, reduced from 85dBA*
  - *Proactive approach*



Why are HPD’s required?

- Protect from noise induced hearing loss (NIHL)
- Health effects:
  - *Hearing loss*
  - *Tinnitus – ringing in ears*
  - *Hyperacusis – Increased sensitivity to sound*
  - *Communication difficulties*
  - *Sleep disturbance – fatigue, irritability*
  - *Cardiovascular problems*
  - *Cognitive impairment – Increased risk for dementia*

HPD selection

- Comfortable
- Properly worn
- Compatible with other PPE
- **Attenuation capabilities**
  - *Overprotection*
- **Fit testing to confirm**

NEW HEARING PROTECTION REGULATIONS IN ALBERTA – MARCH 31, 2023

New HPD Regulations – March 31, 2023

- Alberta OHS Code states:

Hearing protection

222 An employer must ensure that hearing protection devices used and worn by workers at a work site or work area

(a) meet the requirements of CSA Standard Z94.2-14 (R2019), *Hearing protection devices — Performance, selection, care, and use*, and

(b) are fit tested in accordance with CSA Standard Z94.2-14 (R2019), *Hearing protection devices — Performance, selection, care, and use*.

AR 191/2021 s222;242/2022

CSA Standard Z94.2-14 (R2019)

11.2.2

The proper fitting technique for the selected HPD, as recommended by the manufacturer, shall first be demonstrated and then be practiced by the individual under close supervision. It is important to stress that individual, not group, training is necessary to ensure the best fit of hearing protectors. Of great value in this regard is the use of FAES (see Clause 13).

- FAES – Field Attenuation Estimation System – Quantitative Fit Testing

CSA Standard Z94.2-14 (R2019)

11.2.2

The proper fitting technique for the selected HPD, as recommended by the manufacturer, shall first be demonstrated and then be practiced by the individual under close supervision. It is important to stress that individual, not group, training is necessary to ensure the best fit of hearing protectors. Of great value in this regard is the use of FAES (see Clause 13).

- Does not explicitly state “fit testing”

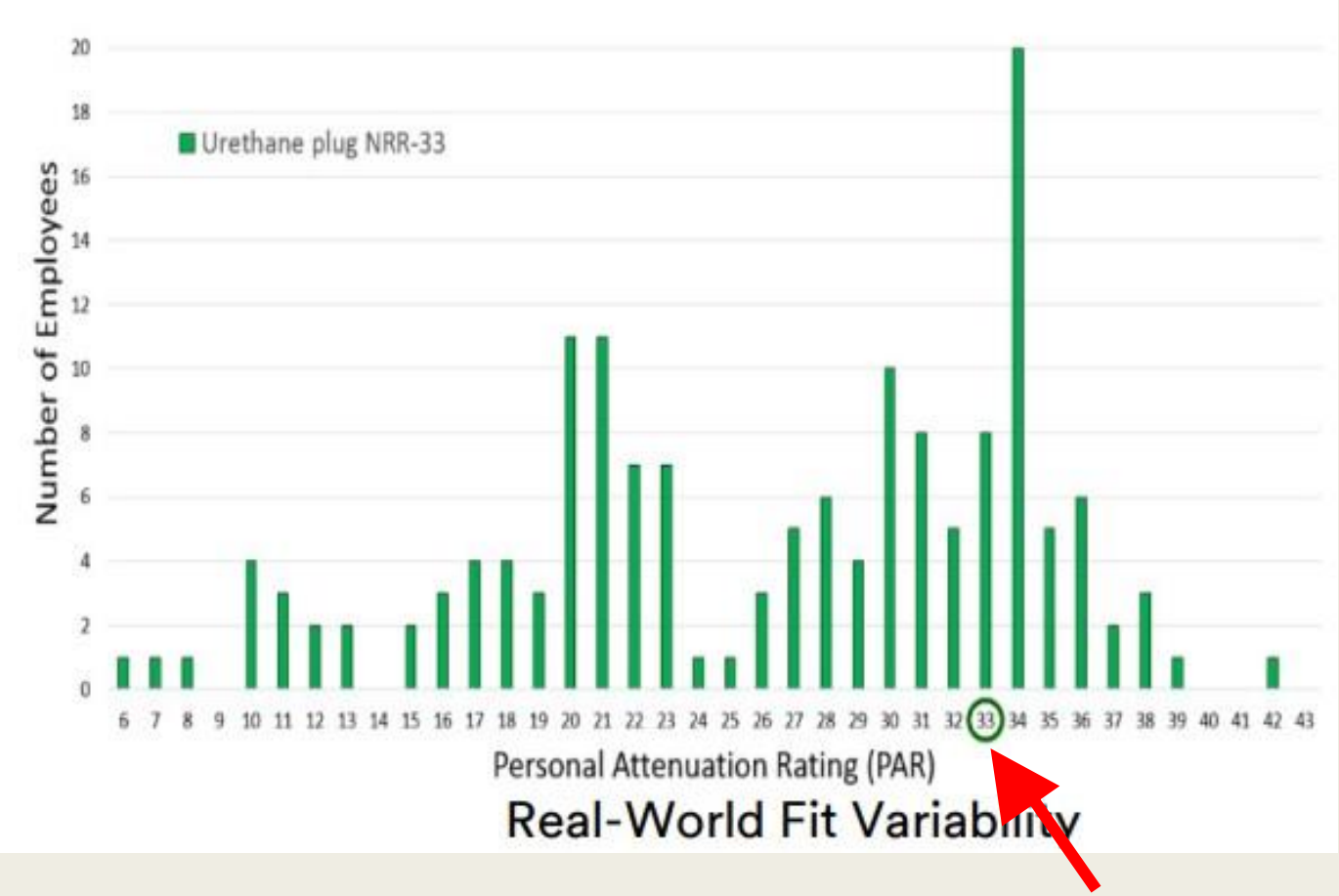
Change highlights: Noise exposure – Part 16 in the OHS Code

OHS information for work site parties and service providers

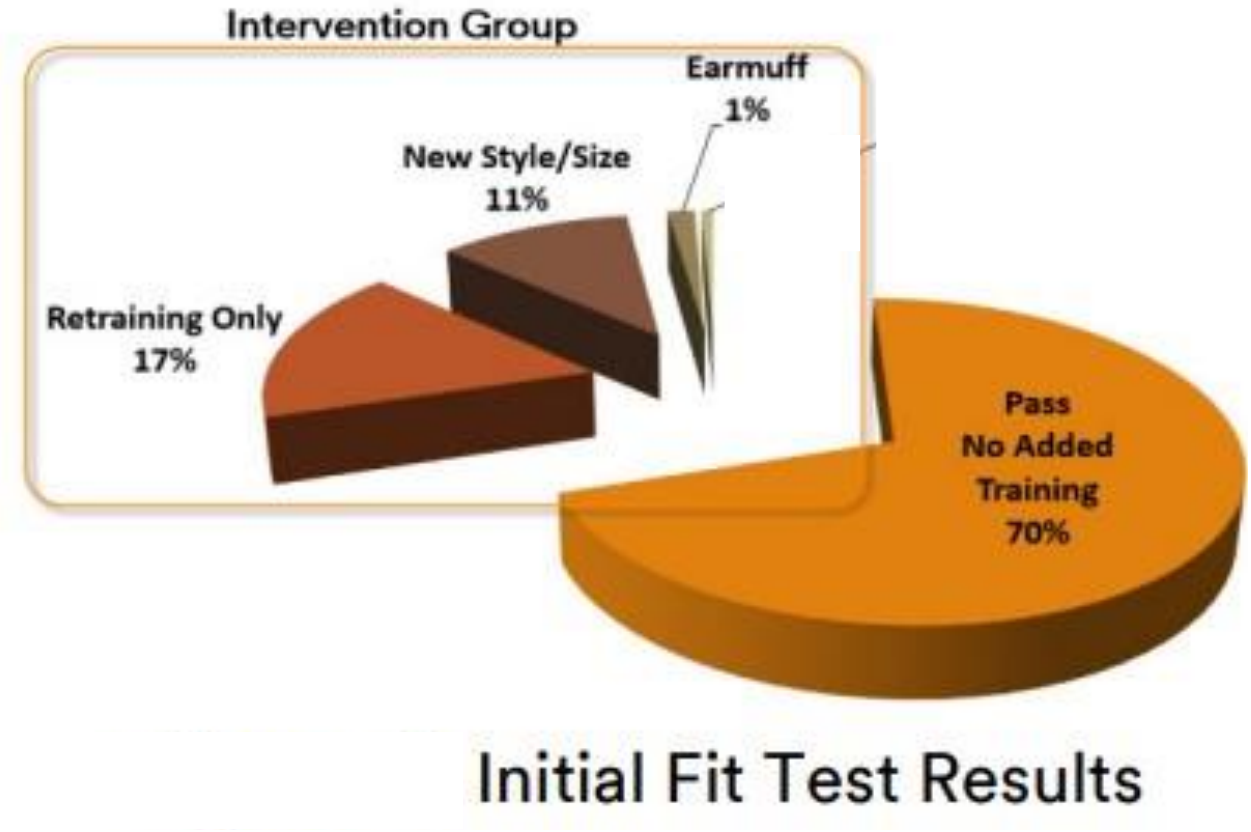
- Qualitative or Quantitative Fit Testing required for all personnel who use HPD's
- Suggested Qualitative methods to check fit:
  - *Use fingers, mirror or ask co-worker to ensure full earplug insertion*
  - *Listen to surrounding noises*
  - *Cup hands over ears*
  - *Talk out loud – hollow sound*
- Quantitative methods are "preferred standard"
  - *Objective*
    - Provides quantifiable evidence

Why is fit testing important? Doesn't the package state the attenuation?

- NRR provides attenuation in ideal conditions
  - *Does not account for:*
    - Anatomical differences
    - Improper usage
    - Interference with other safety equipment



- 150 subjects
- Stated NRR of 33
- 46 achieved ≥NRR
- 104 did not achieve it
- 19 achieved <50%



Why is fit testing important?

Quantitative methods

- Three primary methods
  - *REAT – Real Ear Attenuation at Threshold*
  - *F-MIRE – Field Microphone in Real Ear*
  - *Loudness Balance*

REAT - Real-Ear Attenuation at Threshold

- Gold Standard for determining attenuation
- Used by HPD manufacturers
- Laboratory setting
- Various frequencies
- Unoccluded ears vs. occluded ears
- Difference = “Real world” attenuation

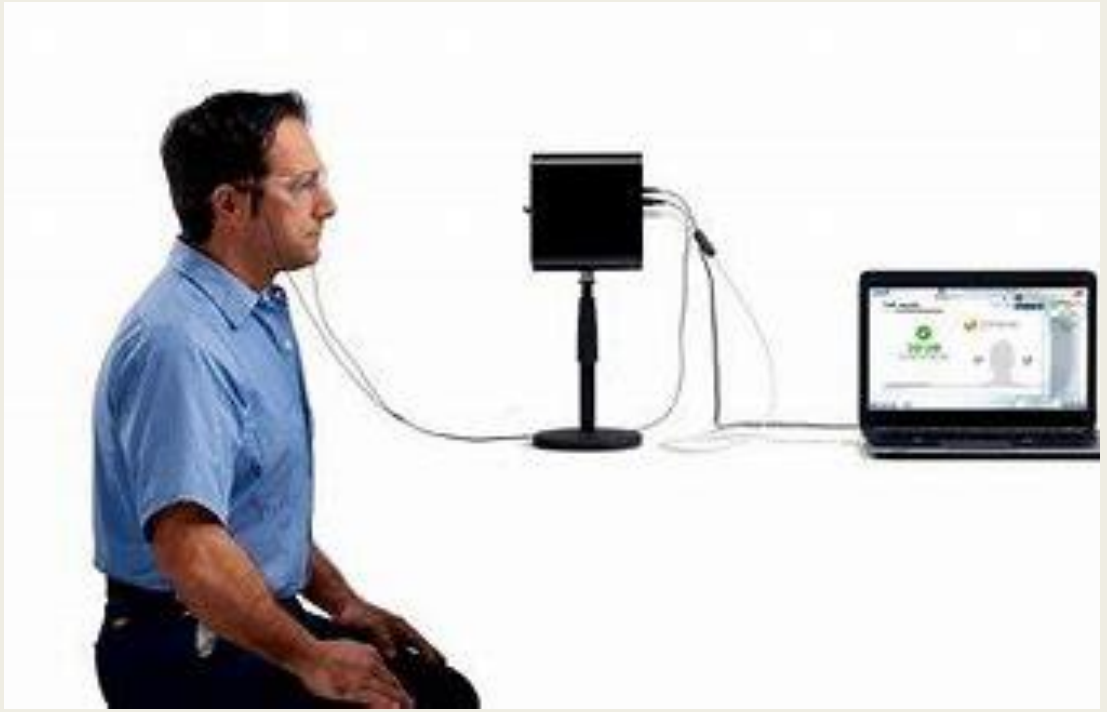
Tested according to ANSI S.3.19-1974

Attenuation data

Frequency Hz	125	250	500	1000	2000	3150	4000	6300	8000	NRR
Mean Attenuation, dB	36.8	38.0	40.4	41.1	40.1	44.4	48.5	46.4	45.8	32 dB
Standard Deviation, dB	4.0	4.5	5.5	4.0	2.7	4.5	4.1	5.4	5.2	

F-MIRE - Field Microphone in Real Ear

- Microphone inside ear/behind HPD
- Another microphone outside ear
- Provides a binaural PAR
- 3M EARFit Dual-Ear Validation System



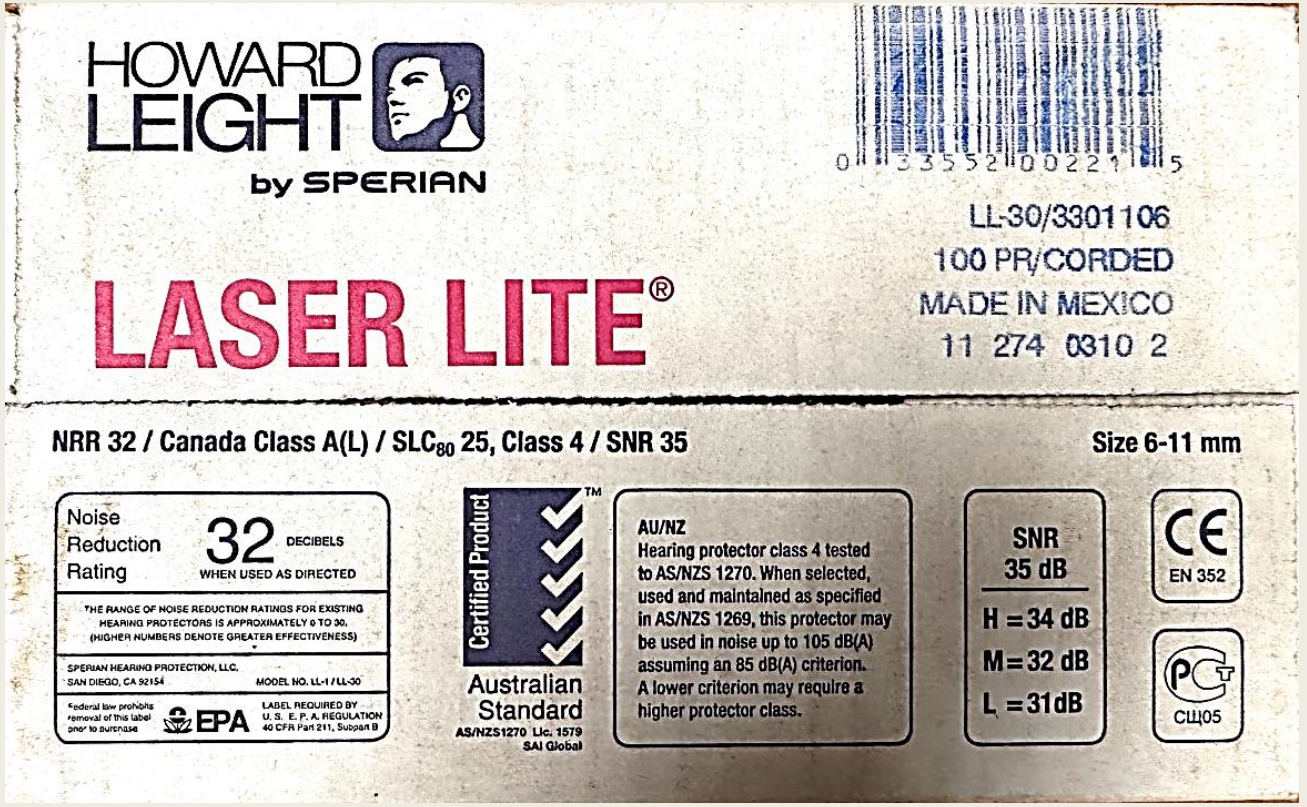
Loudness Balance

- Match loudness of tone between both ears
- Unoccluded ears, one earplug, both earplugs
- Various frequencies
- Difference is the PAR

- Honeywell Howard Leight Veripro Fit Testing System
- Come get fit tested at our booth!

- Provides a Personal Attenuation Rating – PAR
  - *Single number real-world attenuation value*
  - *Individual's Anatomy + Particular HPD + Fit Technique*
  - *May vary every time HPD is fitted*

Manufacturer-determined attenuation

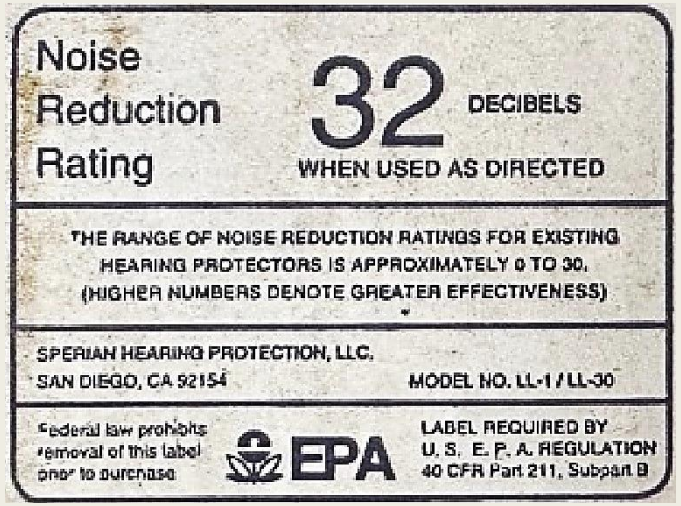


Manufacturer-determined attenuation

- Manufacturer's attenuation values are overestimates
  - *Subtract from measured noise levels*
  - *NRR and SNR - De-rating*
- Each country/jurisdiction has their own attenuation scheme(s) and determination method(s)

NRR – Noise Reduction Rating

- Developed by Environmental Protection Agency (EPA) in 1970s
- Single number that represents noise reduction
- Higher NRR = Better protection
- Used in Canada and US



Worker's noise exposure = Measured workplace noise levels – derated NRR (CSA)

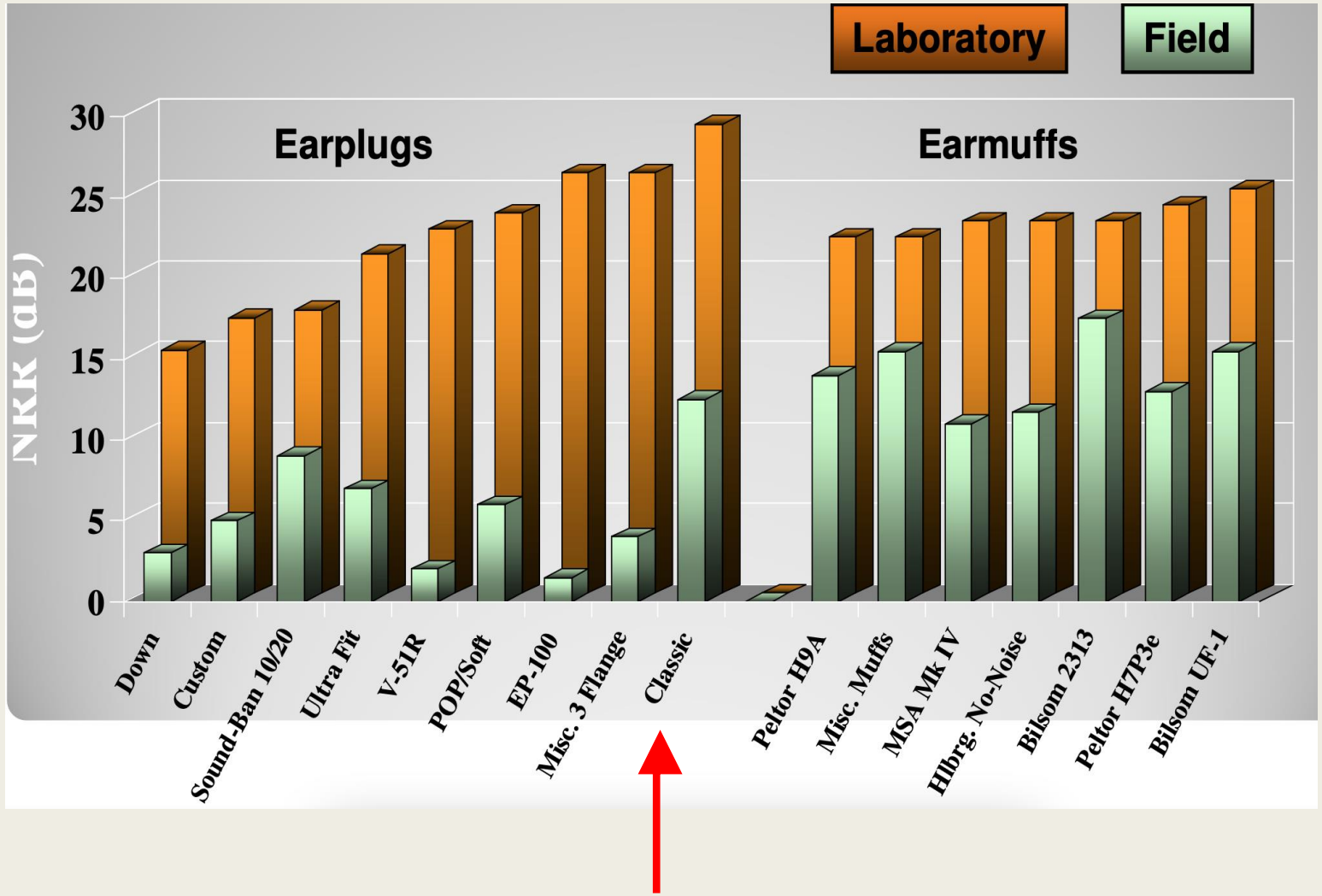
= 102dBA – [(50% of 32dB) -3dB]

= 89dBA **Not sufficient!**

NRR derating

Example NRR	Owner of De-rating Scheme	Workplace Measurement	De-rating Equation	De-rated NRR
32dB	OSHA & 3M	dB(A)	(NRR-7)/2	12.5
		dB(C)	NRR/2	16
	NIOSH	Either	NRR/2	16
	CSA	dB(A)	(NRR/2)-3	13
		dB(C)	NRR/2	16

Lab vs. Field NRR (PAR)



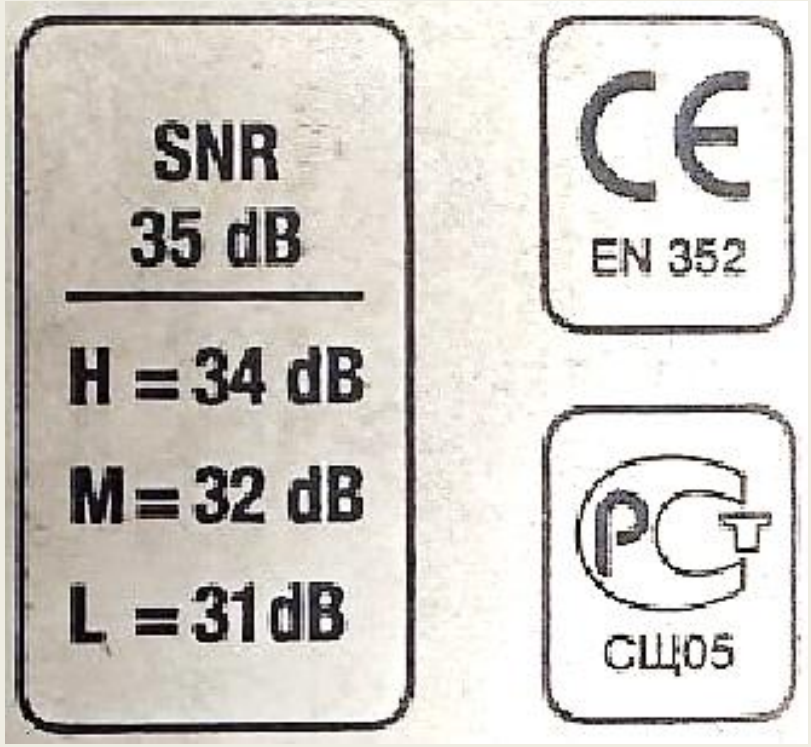
Canadian class system
A, B, C, A(L), B(L)

- Loosely based on NRR; >24 – Class A, 24-17 – Class B, <17 – Class C
- L designation - Minimum attenuation of 20dB @125Hz
- Can also use below table from CSA Standard – Has been de-rated

	Minimum attenuation, dB		
Frequency, Hz	**Class A**	**Class B**	**Class C**
125	10(1)	5(1)	None
250	18	12	None
500	26	16	None
1000	31	21	11
2000	33	23	13
3150	33	23	13
4000	31	21	11
6300	33	23	13
8000	33	23	13

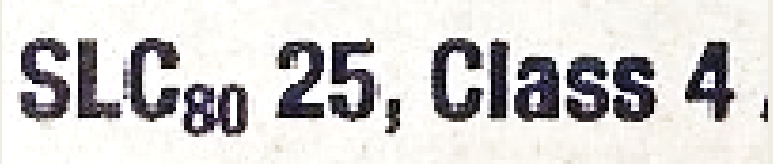
SNR - Single Number Rating

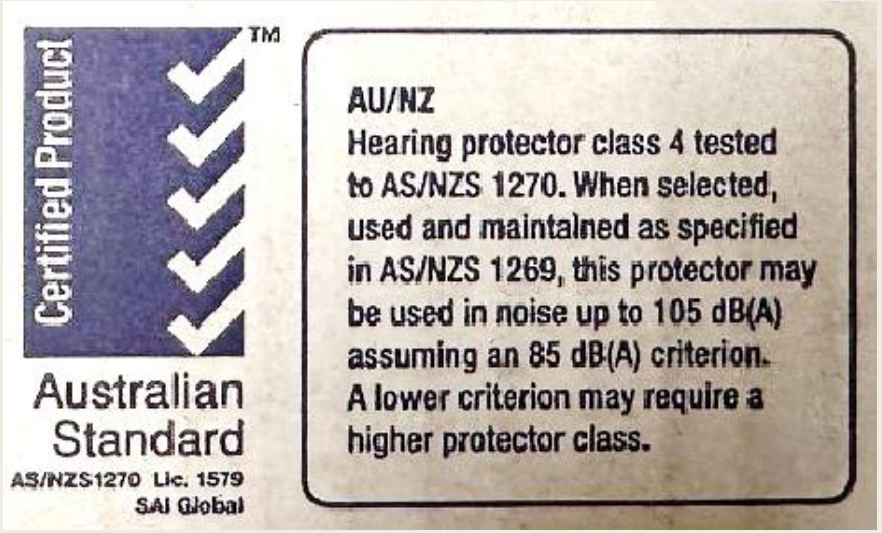
- Single number that represents noise reduction
- Higher SNR = Better protection
- Used in European Union
- HML values: Attenuation at high, medium and low frequencies
- Subtract 4bB to derate



SLC_{80} – Sound Level Conversion

- Rating is achievable by 80% of users
- Used in Australia and New Zealand
- Rounded down to nearest multiple of 5 – No derating
- Used to determine AUS Classes: 1-5

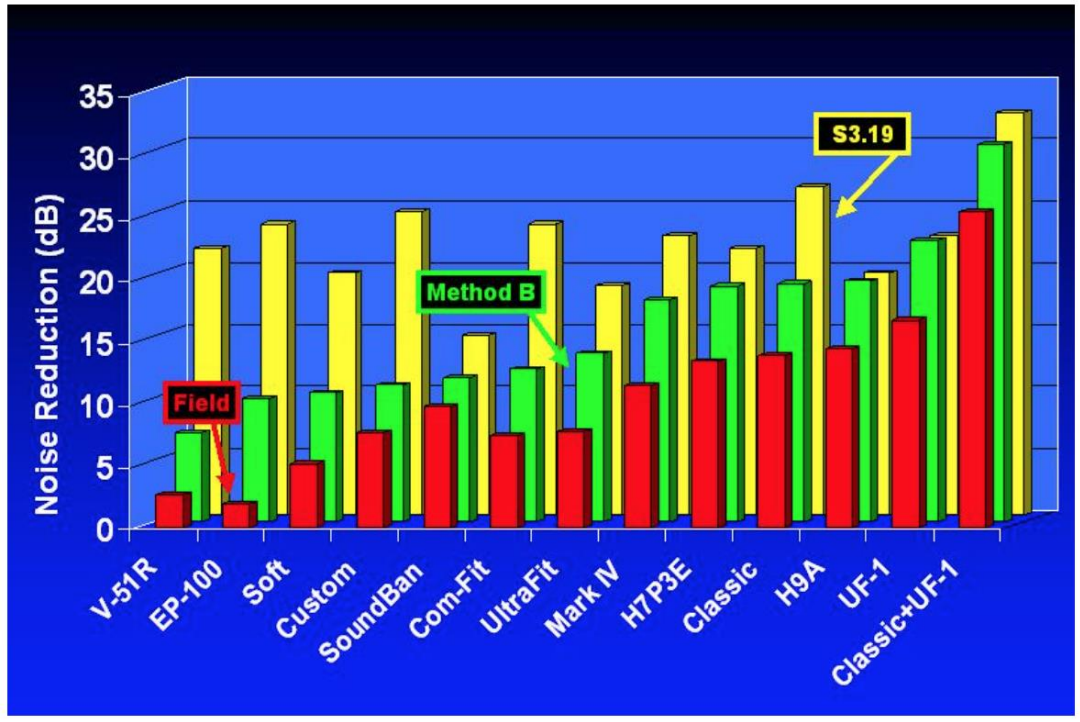


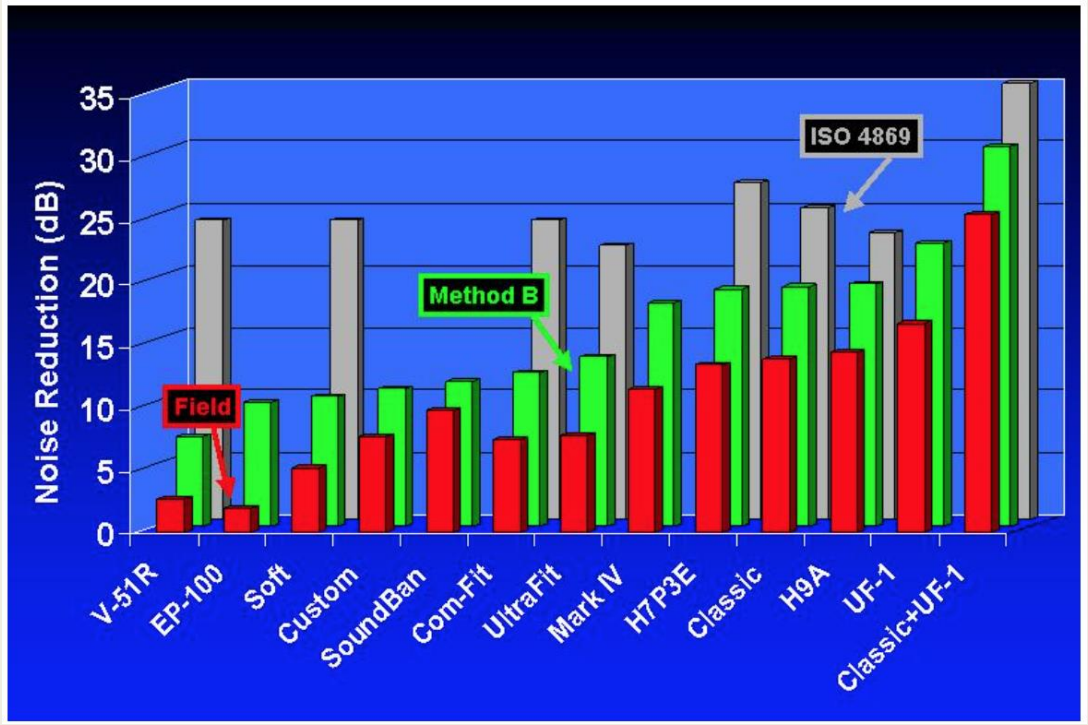


Determination of attenuation values

AVS	Definition	Testing Standard	Jurisdiction(s)
NRR	Noise Reduction Rating	ANSI/ASA S12.6-2008 ANSI S3.19-1974	US and Canada
CSA Class	A, A(L), B, B(L), or C	CSA Z94.2: 2014 (R2019)	Canada
SNR	Single Number Rating	EN352-2:2002 ISO 4869	EU
SLC_{80}	Sound Level Conversion (80%)	AS/NZS 1270: 2014	Australia & New Zealand
AUS Class	Class 1-5		

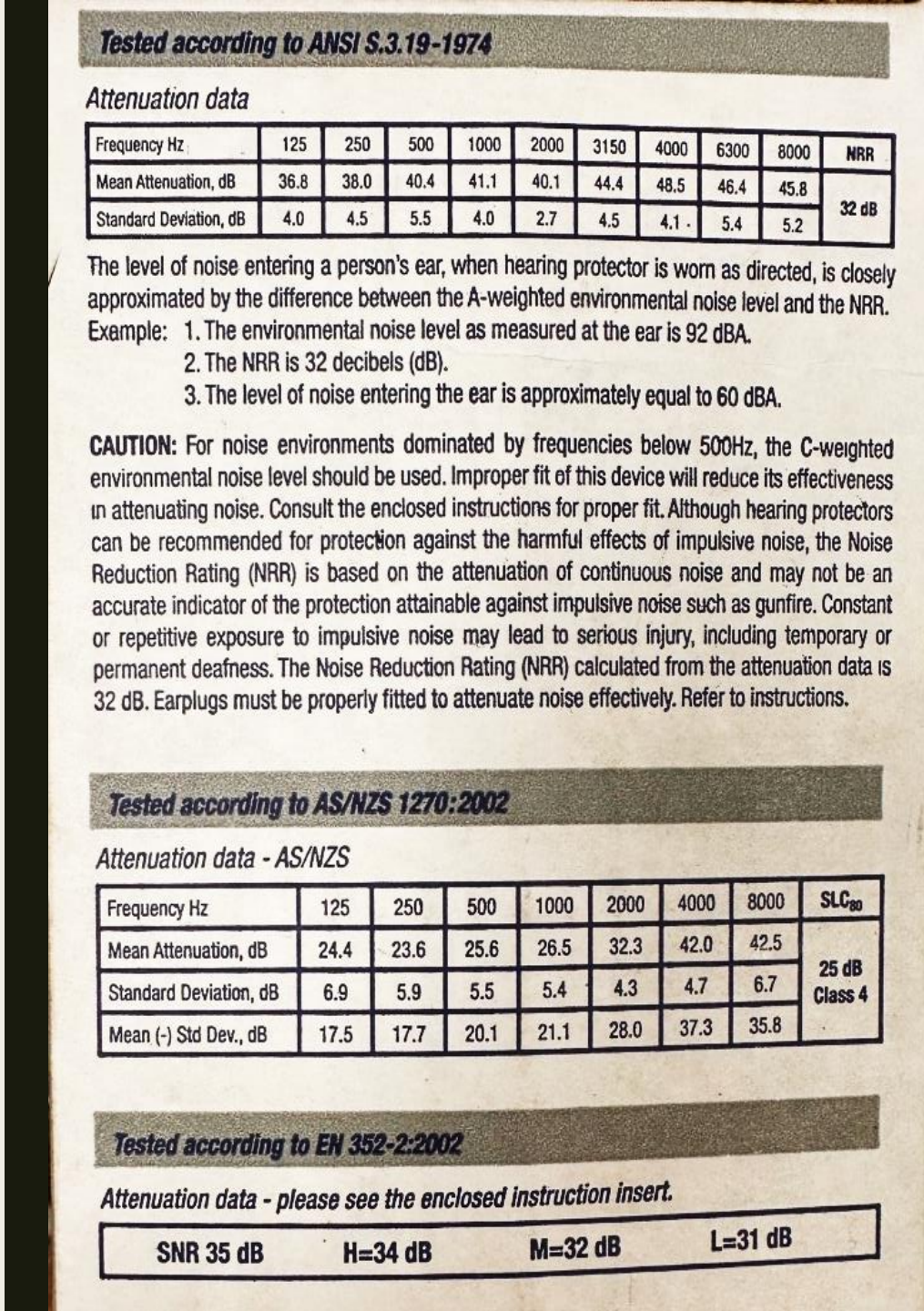
Method/standards comparison





What causes these jurisdictional differences?

- *Each testing method is slightly different*
  1. 10, 16, or 20 subjects - REAT
  2. Subject-fit vs. Experimenter-fit
     - *EF = Higher attenuation*
     - *Example: Attenuation @125Hz*
       - ANSI S.3.19-1974 – 36.8dB
       - AS/NZS 1270:2002 – 24.4dB
  3. Attenuation calculations
     - *Further explanation in following section*



Tested according to ANSI S.3.19-1974

Attenuation data

Frequency Hz	125	250	500	1000	2000	3150	4000	6300	8000	NRR
Mean Attenuation, dB	36.8	38.0	40.4	41.1	40.1	44.4	48.5	46.4	45.8	32 dB
Standard Deviation, dB	4.0	4.5	5.5	4.0	2.7	4.5	4.1	5.4	5.2	

The level of noise entering a person's ear, when hearing protector is worn as directed, is closely approximated by the difference between the A-weighted environmental noise level and the NRR.
Example: 1. The environmental noise level as measured at the ear is 92 dBA.
2. The NRR is 32 decibels (dB).
3. The level of noise entering the ear is approximately equal to 60 dBA.

CAUTION: For noise environments dominated by frequencies below 500Hz, the C-weighted environmental noise level should be used. Improper fit of this device will reduce its effectiveness in attenuating noise. Consult the enclosed instructions for proper fit. Although hearing protectors can be recommended for protection against the harmful effects of impulsive noise, the Noise Reduction Rating (NRR) is based on the attenuation of continuous noise and may not be an accurate indicator of the protection attainable against impulsive noise such as gunfire. Constant or repetitive exposure to impulsive noise may lead to serious injury, including temporary or permanent deafness. The Noise Reduction Rating (NRR) calculated from the attenuation data is 32 dB. Earplugs must be properly fitted to attenuate noise effectively. Refer to instructions.

Tested according to AS/NZS 1270:2002

Attenuation data - AS/NZS

Frequency Hz	125	250	500	1000	2000	4000	8000	SLC_{80}
Mean Attenuation, dB	24.4	23.6	25.6	26.5	32.3	42.0	42.5	25 dB Class 4
Standard Deviation, dB	6.9	5.9	5.5	5.4	4.3	4.7	6.7	
Mean (-) Std Dev., dB	17.5	17.7	20.1	21.1	28.0	37.3	35.8	

Tested according to EN 352-2:2002

Attenuation data - please see the enclosed instruction insert.

SNR 35 dB	H=34 dB	M=32 dB	L=31 dB

Methods - Summary

AVS	Number of Test Subjects: Tests per Subject	Fit (Subject/Experimenter)	Standard Deviations Subtracted	Percentage of Users Protected
NRR	10:3	Experimenter	-2	98%
SNR	10:3	Subject	-1	84%
SLC_{80}	20:3	Subject	-0.84	80%
AUS Class				

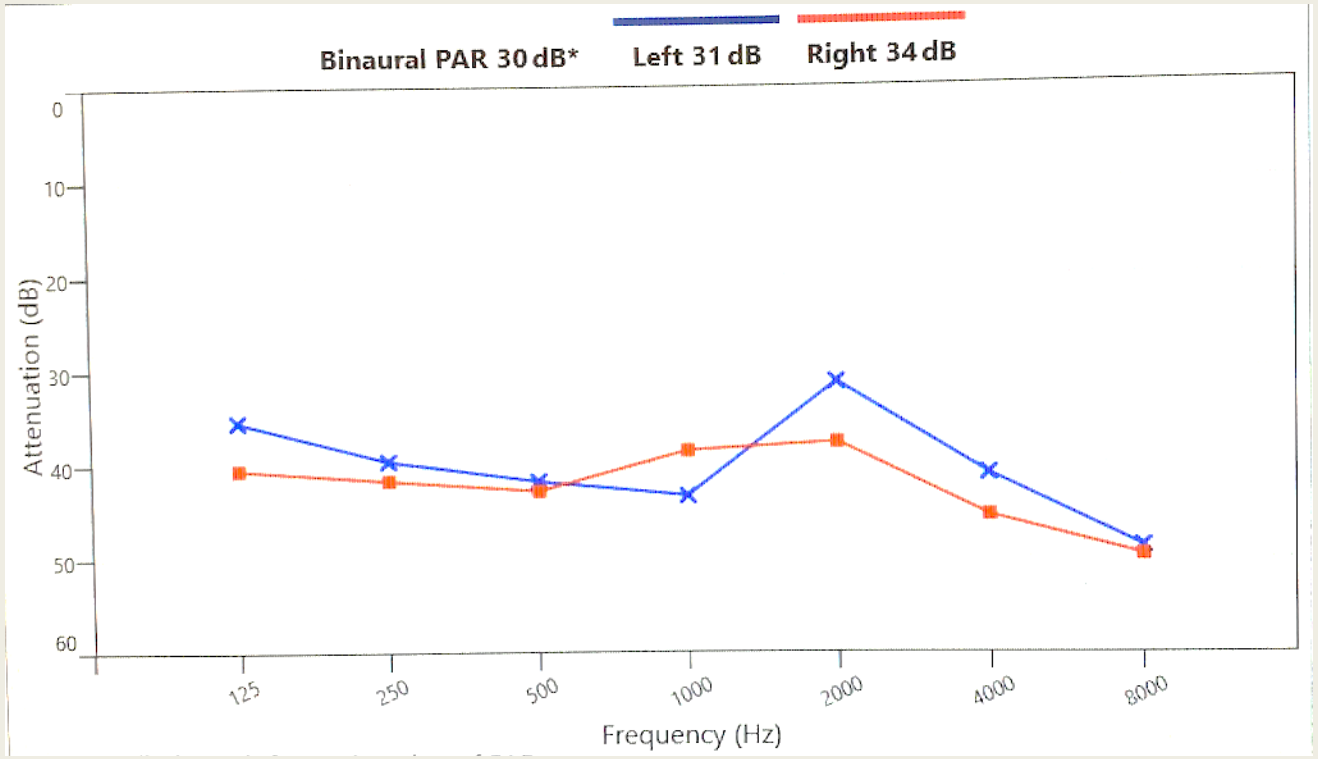
Which method provides the most “real-world” attenuation estimate?

Based on these differences: MSc. OEH Experimental set-up

- 20 test subjects
- Probed 3M Classic earplugs used with 3M E-A-Rfit Dual Ear Validation System.
  - *Used instead of REAT - availability*
  - *How does it work?*
- Subject-fit x3, Experimenter-fit x3
  - *Video shown to “train” subjects*

Data Collection: Output of EARfit system

- Attenuation values
  - Transcribed into Excel
  - Averaged for each frequency
  - SD calculated
  - xSD subtracted
  - All frequency values logarithmically summed



Data analysis

$$AV = L_{background} - A - 10log_{10}\left[\sum_{f=125Hz}^{8000Hz} 10^{0.1(L_{af}-APV_f)}\right]$$

- $L_{background}$ = Pink noise total energy
- A = Spectral uncertainty adjustment
- dBC to dBA adjustment

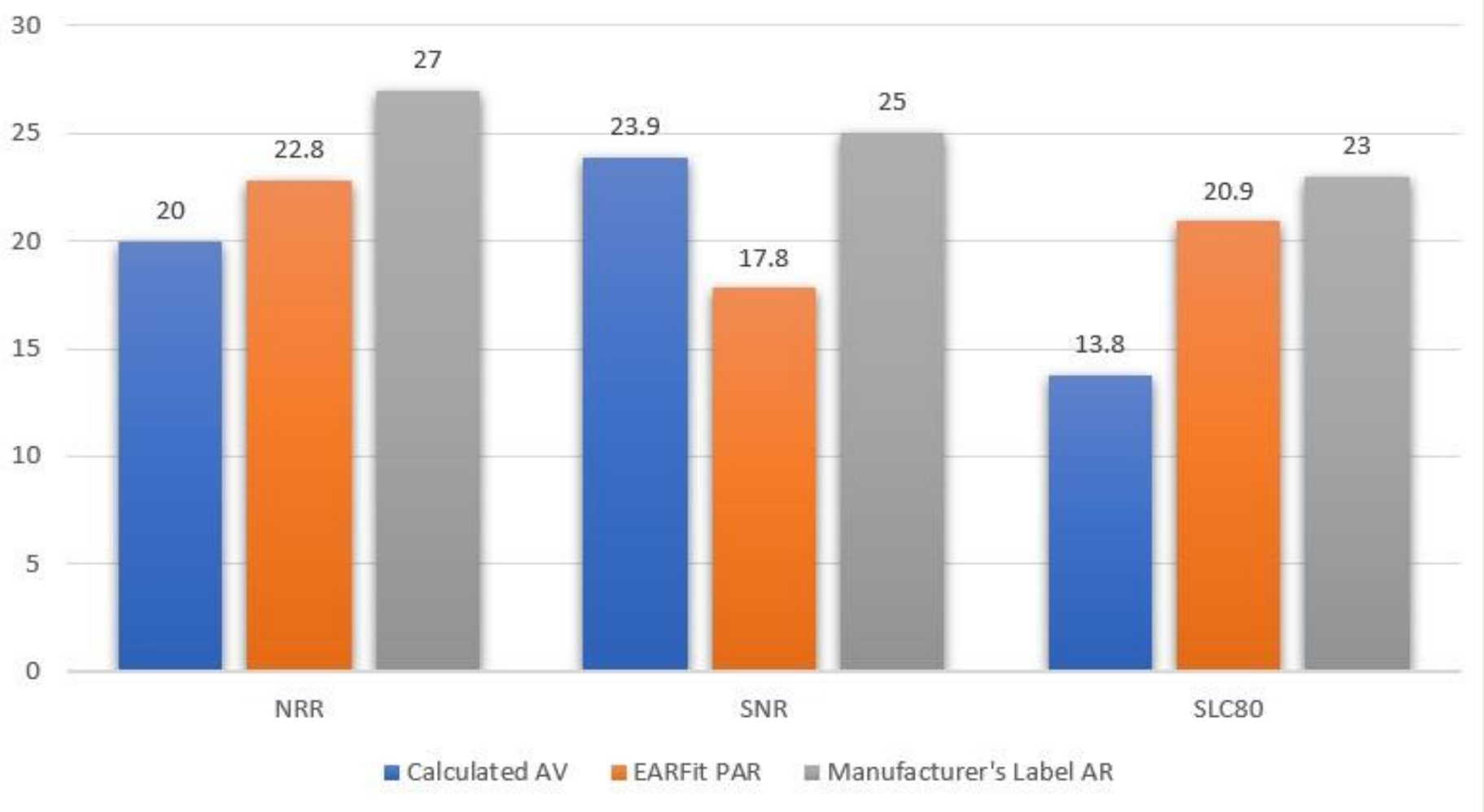
AV	$L_{background}$	A	dBC to dBA
NRR	107.9dBC	3	-2
SNR	100dBC	0	-3
SLC_{80} AUS Class	85dBA	0	0

Comparison of PAR's to CAR's

- Needed something to compare calculated values to
- Personal Attenuation Rating – to simulate "field" ratings
  - *EARFit calculated individual trial values at various frequencies*
  - *Logarithmically averaged and summed*
- Difference between PAR and calculated attenuation ratings

Which method was most accurate?

Results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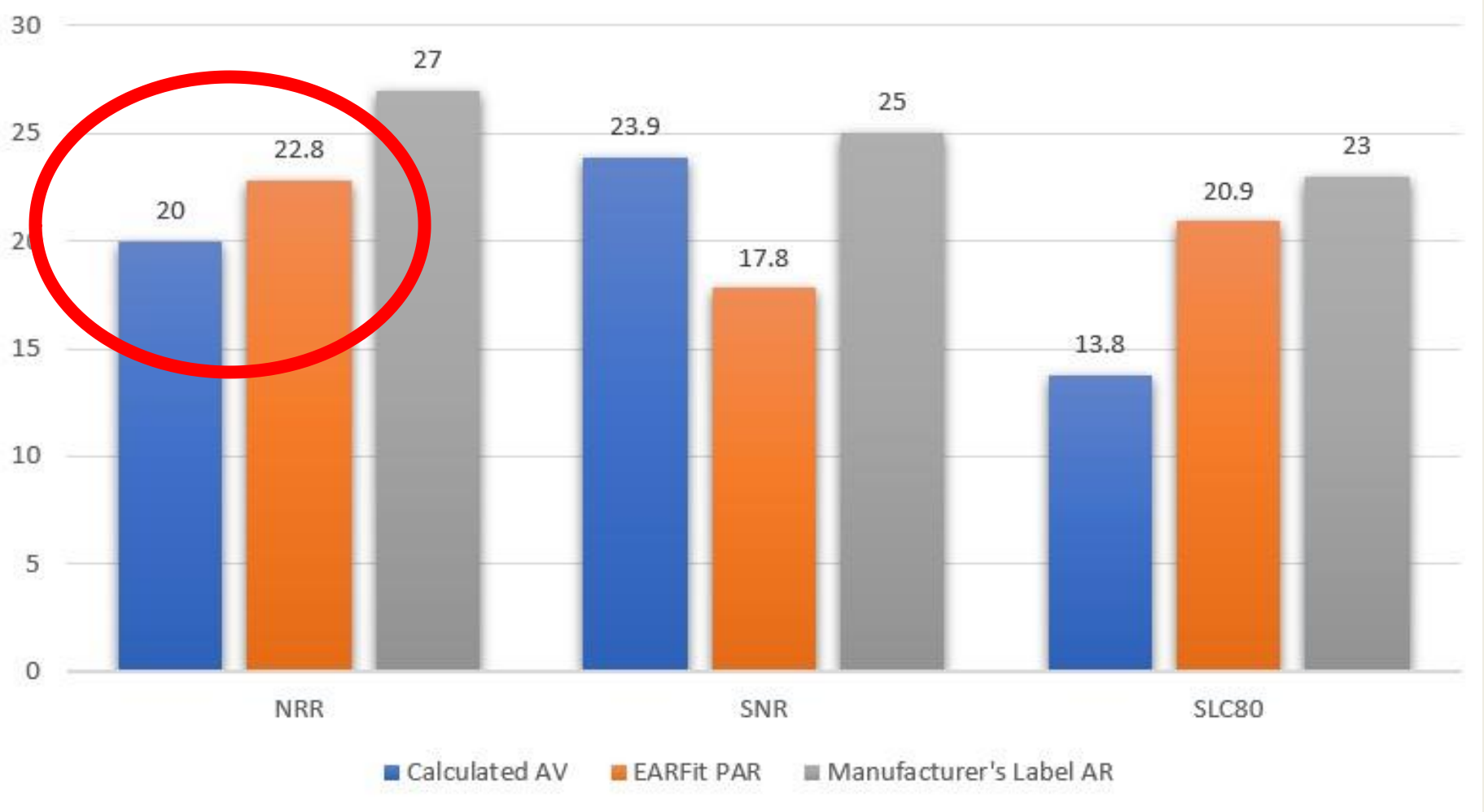
Calculated AV
EARFit PAR
Manufacturer's Label AR

Results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Calculated AV
EARFit PAR
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Results

Calculated NRR	Owner of De-rating Scheme	Input Weighting Scale	De-rating Equation	De-rated NRR (dBA)
20dB	OSHA & 3M	dB(A)	(NRR-7)/2	6.5
	OSHA & 3M	dB(C)	NRR/2	10
	NIOSH	Either	NRR/2	10
	CSA	dB(A)	(NRR/2)-3	7
	CSA	dB(C)	NRR/2	10

Non-derated NRR was the closest to the “field” values!

Results

- Experimental CSA Class was the same as manufacturer's label
- Experimental AUS Class was Class 2, manufacturer's label stated Class 4

Frequency, Hz	Minimum attenuation, dB		
	Class A	Class B	Class C
125	10(1)	5(1)	None
250	18	12	None
500	26	16	None
1000	31	21	11
2000	33	23	13
3150	33	23	13
4000	31	21	11
6300	33	23	13
8000	33	23	13

Table A1 and E1
AS/NZS 1269.3

Class	$L_{Aeq,8h}$ dB(A)	SLC_{80} Range
1	less than 90	10 to 13
2	90 to less than 95	14 to 17
3	95 to less than 100	18 to 21
4	100 to less than 105	22 to 25
5	105 to less than 110	26 or greater

Recommendations from study

- Further research required to increase strength of results
- Development of internationally-recognized Standard
- Elimination of Experimenter-Fit methods
  - *Subject-fit more applicable to field users*

- **OHS legislation should still be followed**

Take-home messages

- Fit testing will improve the performance of HPD's.
  - *Reduces likelihood of NIHL*
  - *Improves effectiveness of HPD's – Proactively identify issues*
  - *Shows personnel that proper fit matters - comparisons*
  - *Ensures personnel are using the correct HPD*
- No fit testing methods are perfect. Still more work to do!

How to properly fit earplugs

- Roll plug – no creases – Use practice holes on box
- Insert into ear canal while pulling out and up with opposite hand
- Check fit – Should only feel end of plug
- Check fit – Cover ears with cupped hands – Noise should be the same as uncovered ears
- If good fit cannot be obtained, try a different style/size and repeat above

How to ensure everyone is being protected

- Fit testing
- Training – How to use and maintain
- Ensure various types of HPD’s provided to suit personal preference and anatomical differences
- Proper selection by management – use CSA recommended derating!

References

- Arezes, P. & Geraldes, J. (2009). Assessing Differences in Methodologies for Effective Noise Exposure Calculation. International Journal of Occupational Safety and Ergonomics, 15:2, 183-191.
- Berger, E. (1993a) Earlog 20: The Naked Truth about NRRs. Berger, E. (1993b) What is a Personal Attenuation Rating (PAR)?
- Berger, E. (2005). Comparing hearing protector ratings – NRR, SNR, SLC80, and others. EARcal laboratory.
- Brazilian NR (2017). NR6 – Personal Protective Equipment.
- Berger, E. & Gauger, D. (2001). A new hearing protector rating: The Noise Reduction Statistic for use with A weighting (NRSA). Journal of The Acoustical Society of America - J ACOUST SOC AMER. 115. 2378-2378.
- Chiu, C. & Wan, T. (2020). Individual Fit Testing of Hearing-Protection Devices Based on Microphones in Real Ears among Workers in Industries with High-Noise-Level Manufacturing. health, 17(9), 3242.International journal of environmental research and public20
- Canadian Standards Association (CSA)(2014). CSA Z94.2-14 Hearing protection devices – Performance, selection, car,e and use.

References

- De Vito, C. (2017). Comparison of personal attenuation ratings attained by agricultural and industrial workers for four hearing protection types using the 3M E-A-Rfit dual validation system. ProQuest LLC.
- European Union (EU) (2003). Directive 2003/10/EC – noise.
- European Union (EU) (1989). Directive 89/656/EEC – use of personal protective equipment. Gerges, S (2001). Personal Measures And Hearing Conservation. Pages 297-316.
- OSHA Standards (2008a) 1910.95 - Occupational Noise Exposure.
- Safe Work Australia (2021). Chapter 4.1 Noise.
- OSHA Standards (2008b) 1910.95 App B - Methods for Estimating the Adequacy of Hearing Protection Attenuation.
- Williams, W. (2005). Improved calculation for hearing protector performance. Acoustics. 9-11 November, 2005.
- WorkSafeBC (2005). OHS Regulation Part 7, Division 1 Noise exposure, Section 7.7 Hearing protection and warning signs.

Questions?

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