New CSA Noise Standards and Noise Control

CAN/CSA Z107.56
Measurement of Occupational Noise Exposure

OHAO, Fall PDC
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Noise and Hearing Loss

- Second most prevalent self-reported work-related injury.
- 22 million American workers are exposed to hazardous noise (Tak et al., 2009) and 10 million suffer from hearing loss as a result (NIOSH, 2009).

http://www.dangerousdecibels.org/ with permission
Industrial workplace:

- In a sample of over 1.1 million US workers, about 18% had hearing loss (Masterson et al., 2012).
  - Adjusted Prevalence Ratios:
    - Mining: 1.65
    - Wood product manufacturing: 1.65
    - Construction of buildings: 1.52
Noise and Hearing Loss

Military environment:

- By midlife, 42% of Canadian Force service members show at least a mild hearing loss (>25 dB), and 26% a moderate to severe hearing loss (>40 dB) (Abel, 2005).
  - Twice more affected than by aging alone.
- Some military trades more at risk: Infantry, artillery, flight engineers.
Noise and Hearing Loss

Short-term effects of noise exposure:
- Temporary hearing loss (TTS)
- Interference with important hearing tasks
- Stress, fatigue

Long-term effects of noise exposure:
- Permanent hearing loss (PTS)
  - Hearing sensitivity (audibility)
  - Supra-threshold deficits (distortion)
- Tinnitus
- Cardiovascular and other diseases
Noise and Hearing Loss

Pure-tone audiogram

Hearing Research Laboratory
Hearing thresholds are poorly related to speech perception in noise and sound localization.

(Vaillancourt et al., 2011)
Noise and Hearing Loss

Effects:

- Individual
  - Quality of life (before and after retirement).
- Employer
  - High cost of rehabilitation services and compensation claims.
  - WSIB estimated cost of equipment (e.g., hearing aids) can reach 11000$ every four years in Ontario (Ministry of Labour, 2007).
- Workplace
  - Affects speech communication, warning signal perception, detection and localisation of critical sounds.
  - Decrease in situational awareness, safety, and work efficiency.
Standard CAN/CSA Z107.56

- Canada has been the first country to issue an occupational noise measurement standard (1986).
- The standards specify methods valid for sources “far” from the ears of workers using:
  - Dosimeter
  - Sound level meter (SLM)
  - Integrated sound level meter
- Since 2007, the exposure limit for 8 hours is 85 dBA in Ontario and 87 dBA for federal employees (CCOHS, 2011).
Standard CAN/CSA Z107.56

- **Revised version of Z107.56** (Published in August 2013).
- Sections 4-6 specifies instrumentation and procedures based on sound level meter and noise dosimeters.
- **NEW!** Section 7 specifies instrumentation and procedures for noise sources “close” to the ears such as headsets.
- **NEW!** Section 8 specifies procedures to account for use of music players, radios, and other sound reproduction devices.
Communication Headsets

- Exposing 3 million American workers to high levels of noise (OSHA, 1999).
- Increased use of wired and wireless communication headsets in many occupational settings in the past decade.
- Typical uses: call centers, airport ground and control, construction sites, military sites, industrial sites, etc.
Communication Headsets

Circum-aural
http://www.davidclark.com/

Supra-aural
http://www.plantronics.com/ca/

Intra-concha
http://www.sennheiser.ca/live/

Double Protection Muffs
http://www.sensear.com/

Monophonic
http://www.solutions.3mcanada.ca

Stereophonic

Inserts
http://www.sensear.com/
1) The measurement problem:

- Noise exposure arises from two sources:
  - External noise passing through headset
  - Internal audio signal (i.e. speech) from headset

- User adjusts volume setting to ensure the proper reception of speech/audio signal above the noise entering the device.
1) The measurement problem (cont.):

- Which equipment should be used to measure sound in the ears?
- Challenges:
  - Sound is produced at or in the ears.
    - SLM or noise dosimeter not suitable for in-ear measurements
  - Measurements must be carried out while the worker is conducting his/her normal duties.
  - Safety must be maintained.
2) The assessment problem:

• How to relate in-ear sound measurements to occupational noise limits?
2) The assessment problem (cont.):

- Sound level is measured at the ear but regulatory limit (e.g., 85 dBA) is defined in the sound field.

### Examples of diffuse-field and at-ear measurements

<table>
<thead>
<tr>
<th></th>
<th>Diffuse-Field Level (dBA)</th>
<th>At-Ear Level (dBA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speech</td>
<td>85</td>
<td>89.4</td>
</tr>
<tr>
<td>Airplane</td>
<td>85</td>
<td>86.6</td>
</tr>
<tr>
<td>Crowd</td>
<td>85</td>
<td>91.3</td>
</tr>
<tr>
<td>Riveter</td>
<td>85</td>
<td>93.6</td>
</tr>
</tbody>
</table>
New Procedures in CAN/CSA Z107.56

- From 2007-2011 a Working Group of Technical Committee s304 of the CSA surveyed suitable methods to conduct measurements under communication headsets.
- Version 2013 of the standard offers the use of either:
  - Specialized methods and equipment (Section 7.3.1-7.3.3) and
  - A simplified calculation method (Section 7.3.4).
- New methods extended to music exposure in workplace (Section 8).
1) Miniature/probe microphone in Real-ear (MIRE):

- Method is invasive (comfort, movement)
- Requires trained specialists to ensure safe and consistent placement (e.g., audiologist)
- Can be resisted by workers

Based on ISO 11904-1

More information can be found at:
- [www.svantek.com/](http://www.svantek.com/)
- [www.etymotic.com/](http://www.etymotic.com/)
Specialized Methods: Section 7.3.1-7.3.3

2) Manikin/artificial ears:
- Complicated logistics
- Need additional electronics and a pair of matched headsets
- Worker free to move but device must remain at close proximity

Artificial Ears

Acoustic Manikin (G.R.A.S.)
www.gras.dk/

Type 3.3 (G.R.A.S.)
www.gras.dk/

Type 2 (G.R.A.S.)
www.gras.dk/

Type 1 (B & K)
www.bksv.com/

Based on ISO 11904-2
Specialized Methods: Field Use
Specialized Methods: Section 7.3.1-7.3.3

Transforming At-Ear to Sound Field

**Long method (preferred):**
1) Measure 1/3 octave band levels at the ear.
2) Convert to sound-field levels using conversion table.
3) Apply A-weighting and sum-up 1/3 octave bands.

**Short method:**
- Use single number to correct from at-ear to sound field dBA levels (corrections based on AS/NZS standard).
- Manikin, Type 3.3, & Type 2: subtract 5 dB.
- Type 1: subtract 8 dB.

**WARNING**
Recent research indicates that single number corrections are not always in good agreement with 1/3 octave band conversions because of factors such as the frequency response of the headset and the spectrum of the audio signal (Nassrallah et al., 2013).
Specialized Methods: Example

Measurements of speech transmission in plane noise from David Clark headset using Type 3.3 artificial ear

Long method: 1/3 Octave Band Conversion

<table>
<thead>
<tr>
<th>1/3 Octave Frequency Band (Hz)</th>
<th>Artificial Ear Measurements (dB)</th>
<th>Z107.56 – Table 1 Diffuse-Field Correction (dB)</th>
<th>Z107.56 – Table 1 A-Weighting Factors (dB)</th>
<th>A-Weighted, Diffuse-Field Equivalent (dBA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>83.4</td>
<td>0.0</td>
<td>-19.1</td>
<td>64.3</td>
</tr>
<tr>
<td>125</td>
<td>87.5</td>
<td>0.3</td>
<td>-16.1</td>
<td>71.1</td>
</tr>
<tr>
<td>160</td>
<td>92.5</td>
<td>0.6</td>
<td>-13.4</td>
<td>78.5</td>
</tr>
<tr>
<td>200</td>
<td>86.9</td>
<td>0.9</td>
<td>-10.9</td>
<td>75.1</td>
</tr>
<tr>
<td>250</td>
<td>87.6</td>
<td>1.2</td>
<td>-8.6</td>
<td>77.8</td>
</tr>
<tr>
<td>315</td>
<td>83.3</td>
<td>1.4</td>
<td>-6.6</td>
<td>75.3</td>
</tr>
<tr>
<td>400</td>
<td>81.2</td>
<td>1.8</td>
<td>-4.8</td>
<td>74.6</td>
</tr>
<tr>
<td>500</td>
<td>81.6</td>
<td>2.3</td>
<td>-3.2</td>
<td>76.1</td>
</tr>
<tr>
<td>630</td>
<td>78.1</td>
<td>3.2</td>
<td>-1.9</td>
<td>73.0</td>
</tr>
<tr>
<td>800</td>
<td>76.3</td>
<td>4.0</td>
<td>-0.8</td>
<td>71.5</td>
</tr>
<tr>
<td>1000</td>
<td>79.1</td>
<td>4.6</td>
<td>0.0</td>
<td>74.5</td>
</tr>
<tr>
<td>1250</td>
<td>74.4</td>
<td>6.0</td>
<td>0.6</td>
<td>69.0</td>
</tr>
<tr>
<td>1600</td>
<td>76.4</td>
<td>8.1</td>
<td>1.0</td>
<td>69.3</td>
</tr>
<tr>
<td>2000</td>
<td>74.2</td>
<td>11.4</td>
<td>1.2</td>
<td>64.0</td>
</tr>
<tr>
<td>2500</td>
<td>72.4</td>
<td>15.0</td>
<td>1.3</td>
<td>58.7</td>
</tr>
<tr>
<td>3150</td>
<td>64.5</td>
<td>14.2</td>
<td>1.2</td>
<td>51.5</td>
</tr>
<tr>
<td>4000</td>
<td>61.7</td>
<td>11.9</td>
<td>1.0</td>
<td>50.8</td>
</tr>
<tr>
<td>5000</td>
<td>66.4</td>
<td>9.8</td>
<td>0.5</td>
<td>57.1</td>
</tr>
<tr>
<td>6300</td>
<td>72.2</td>
<td>8.5</td>
<td>-0.1</td>
<td>63.6</td>
</tr>
<tr>
<td>8000</td>
<td>68.0</td>
<td>11.0</td>
<td>-1.1</td>
<td>55.9</td>
</tr>
<tr>
<td>10000</td>
<td>52.7</td>
<td>7.1</td>
<td>-2.5</td>
<td>43.1</td>
</tr>
</tbody>
</table>

TOTAL = 85.7

Short method: Single Number Correction

(A-weighted artificial ear measurement) – 5 dB

88.7 dBA – 5dB = 83.7 dBA
Calculation Method: Section 7.3.4

- Simple tool to estimate (predict) noise exposure under communication headsets based on the relationship between the noise and signal sources:

\[
S = BN - NR + SNR
\]

- Recent analysis of the field data indicates a mean effective A-weighting listening signal/noise ratio (SNR) of 13.7 dB with a standard deviation 5.9 dB (Giguère et al., 2012).
- CAN/CSA Z107.56 specifies a SNR of 15 dB.
- Research is being carried out to further validate the use of a single number SNR.
Examples of noise exposure estimation under non-attenuating and attenuating headsets

<table>
<thead>
<tr>
<th></th>
<th>Example 1 Non-attenuating Headset</th>
<th>Example 2 Attenuating Headset</th>
</tr>
</thead>
<tbody>
<tr>
<td>Background Noise</td>
<td>BN</td>
<td>75 dBA</td>
</tr>
<tr>
<td>Noise Reduction</td>
<td>NR</td>
<td>0 dBA</td>
</tr>
<tr>
<td>Residual Noise</td>
<td>BN - NR</td>
<td>75 dBA</td>
</tr>
<tr>
<td>Signal Source</td>
<td>$S = BN - NR + SNR$</td>
<td>90 dBA</td>
</tr>
<tr>
<td>$Leq,t$</td>
<td>90.1 dBA</td>
<td>82.1 dBA</td>
</tr>
</tbody>
</table>
Calculation Method: Section 7.3.4

- Equivalent sound level arising from all work activities involving headsets ($L_{eq,t,\text{headset}}$) is given by:

$$L_{eq,t,\text{headset}} = 10 \log \left( 10^{(B_N - N_R)/10} + \frac{t_{on}}{t} \cdot 10^{(B_N - N_R + S\text{NR})/10} \right)$$

- The 8-hr noise exposure level, $L_{ex,8}$, is calculated by combining headset ($L_{eq,t,\text{headset}}$) and non-headset ($L_{eq,t,\text{non-headset}}$) work activities.

$t = \text{duration that the headset is worn during the work shift}$
$t_{on} = \text{duration that the headset signal is on during the work shift}$

$B_N = \text{measured A-weighted external background noise level}$
$N_R = \text{A-weighted noise reduction of headset (if any), according to CAN/CSA Z94.2}$
$S\text{NR} = \text{effective listening signal to noise ratio} = 15 \text{ dB}$
Exposure Estimation
A headset with an effective noise reduction (NR) of 8 dBA is used in a background noise BN of 84 dBA. The audio signal is present for $t_{on}$ of 4 hr out of a total headset usage $t$ of 6 hr in a typical 8-hr work shift.

| External background noise level (BN) | 84.0 dBA |
| Noise Reduction of Headset (NR) | 8.0 dBA |
| Effective background noise level when headset is worn (BN-NR) | 76.0 dBA | $t = 6$ hr |
| Effective headset communication signal level when present (BN-NR+SNR) | 91.0 dBA | $t_{on} = 4$ hr |
| Equivalent sound level when headset is worn ($L_{eq,6,headset}$) | 89.4 dBA | (headset usage 6 hr) |
| Equivalent sound level when headset is not worn ($L_{eq,2,non-headset}$) | 84.0 dBA | (no protection 2 hr) |
| Total noise exposure level ($L_{ex,8}$) | 88.6 dBA | $T = 8$ hr |
### Noise Mitigation

<table>
<thead>
<tr>
<th></th>
<th>Assessment</th>
<th>Option 1</th>
<th>Option 2</th>
<th>Option 3</th>
<th>Option 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Background Noise BN</td>
<td>84 dBA</td>
<td>76 dBA</td>
<td>-</td>
<td>-</td>
<td>80 dBA</td>
</tr>
<tr>
<td>Headset Noise Reduction NR</td>
<td>8 dBA</td>
<td>-</td>
<td>18 dBA</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Signal to Noise Ratio SNR</td>
<td>15 dBA</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Duration of Signal ( t_{on} )</td>
<td>4 hr</td>
<td>-</td>
<td>-</td>
<td>0.25 hr</td>
<td>1.5 hr</td>
</tr>
<tr>
<td>Duration of Headset Use ( t )</td>
<td>6 hr</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Work shift ( T )</td>
<td>8 hr</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>( L_{eq,t,headset} ) (dBA)</td>
<td>89.4</td>
<td>81.4</td>
<td>79.4</td>
<td>79.9</td>
<td>81.5</td>
</tr>
<tr>
<td>( L_{eq,t,non-headset} ) (dBA)</td>
<td>84.0</td>
<td>76.0</td>
<td>84.0</td>
<td>84.0</td>
<td>80.0</td>
</tr>
<tr>
<td>( L_{ex,8} ) (dBA)</td>
<td><strong>88.6</strong></td>
<td><strong>80.6</strong></td>
<td><strong>81.1</strong></td>
<td><strong>81.2</strong></td>
<td><strong>81.2</strong></td>
</tr>
</tbody>
</table>
Exposure to Music, Radios: Section 8

- Music players, radios and other sound reproduction devices, used for leisure and/or work-related communications, must be operated normally when estimating noise exposure.
  - For sources “far” from the ears (e.g. truck cab radio), use SLM or noise dosimeter
  - For sources “close” to the ears (e.g. headphone), use specialized measurement methods specified in Section 7.3.1-7.3.3
- If it is not possible to operate the sound reproduction device at the time of measurements, when it is known to be used in the workplace, the calculation procedure in Section 7.3.4 shall be used with a SNR of 15 dB.
### Truck Cab Noise Exposure Assessment

<table>
<thead>
<tr>
<th></th>
<th>Assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Background Noise</td>
<td>BN</td>
</tr>
<tr>
<td>Fraction of Time Sound Device is Operating</td>
<td>ton/t</td>
</tr>
<tr>
<td>Signal to Noise Ratio</td>
<td>SNR</td>
</tr>
<tr>
<td>Leq,t,device operating</td>
<td>BN + SNR + 10log(ton/t)</td>
</tr>
<tr>
<td>Leq,t,device non-operating</td>
<td>BN</td>
</tr>
<tr>
<td>( \text{Leq}, t ) (dBA)</td>
<td></td>
</tr>
</tbody>
</table>
Summary of CAN/CSA Z107.56-13

- Z107.56 proposes 2 types of methods to assess noise exposure from communication headsets:
  - Specialized direct measurements (MIRE, manikin, etc.)
  - Calculation method requiring only a SLM or noise dosimeter and information on the noise reduction rating of headset.
- **WARNING**: The calculation method provides only an indirect estimate. If results are close to or above the criterion level (e.g., 85 dBA), noise control measures are needed, e.g.:
  - reducing the external background noise,
  - using headsets with a higher noise reduction rating, and/or
  - limiting the output level and/or duration of headset use.
- If noise control measures are not sufficient to reduce calculated exposure below the criterion level, measurements with specialized methods are warranted.
Questionnaire - Survey

- Questionnaire to document:
  - Use of communication headsets in the workplace
  - Awareness of noise exposure under headsets
  - Use and access to noise measurement equipment
- Distributed electronically to researchers, audiologists, occupational hygienists, acoustical consultants, health and safety workers in Canada.
- 75 respondents
  - 11 in occupational hygiene
Questionnaire – Results

Awareness on noise measurement and hearing loss prevention

Awareness on the problem of noise exposure from communication headsets

Awareness on the techniques of noise measurement under communication headsets
Questionnaire - Results

Access to basic and specialized equipment to measure noise levels in the workplace

<table>
<thead>
<tr>
<th></th>
<th>Basic equipment: E.g., Sound level meter, Noise dosimeter</th>
<th>Specialized Equipment: E.g., Manikin, MIRE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Occupational Hygienists</td>
<td>100%</td>
<td>0%</td>
</tr>
<tr>
<td>Total Respondents</td>
<td>53.3%</td>
<td>46.7%</td>
</tr>
</tbody>
</table>

Most have access to a sound level meter and/or noise dosimeter

Most have access to a MIRE, followed by an artificial ear, and/or a manikin
From these individuals, only four respondents (no occupational hygienists), had taken noise measurements under communication headsets in the workplace during their career.
Conclusions

• CAN/CSA Z107.56 proposes 2 types of methods to assess noise exposure from communication headsets
  ▪ Specialized direct measurements
  ▪ Calculation method
• Calculation method is especially suitable for occupational hygienists given:
  ▪ Access to sound level meter or dosimeter is very high (100%) while access to specialized equipment is very limited (0%)
  ▪ Good overall knowledge of issues pertaining to noise measurements and hearing loss prevention
  ▪ Allow to take concrete actions and assess impact based on relatively simple calculations
References


