INTRODUCTION TO NOISE EVALUATION AND CONTROL

BRANDON PHILPOT

Workplace Noise Exposure

About 22 million workers in US are exposed to hazardous noise each year

34% of noise-exposed workers report not wearing hearing protection

About 16% of noise-exposed tested workers have a material hearing impairment. Hearing impairment is hearing loss that impacts day-to-day activities
Physics of Noise

What is sound?

Sound is a sequence of waves of pressure which propagate through all forms of matter, such as air or water. During their propagation, waves can be reflected, refracted, or attenuated by the medium.

Properties of Sound: Amplitude

Amplitude: the “depth” of the wave perceived as loudness by listener actually sound pressure level (dB)
Properties of Sound: Frequency

Frequency: the wave “length”

- Represents cycles occurring in 1 second (Hz)
- Healthy, young person can hear sounds with frequencies from roughly 20 to 20,000 Hz
- Critical speech frequencies range from 500 to 4,000 Hz

Sound waves

Sound is transmitted through gases, plasma, and liquid as longitudinal waves, or compression waves. In solids sound is transmitted as longitudinal waves and transverse waves.

Longitudinal waves are waves of alternating pressure deviations from the equilibrium pressure, causing local regions of compression and rarefaction.

Transverse waves in solids are waves of alternating shear stress at right angle to the direction of propagation.
Sound Pressure Level or Decibels

Sound pressure level (SPL) is the change in the equilibrium pressure measured in units of decibels (dB), which is a logarithmic ratio scale for comparison to a reference level. The reference level is 20 micropascals or 1 dB, the quietest sound a human can hear. This is roughly the sound of a mosquito flying 3 meters away. This dynamic range from 1 dB to the point of short term hearing damage like operating a chainsaw is a difference of one trillion, $1 \times 10^{12}$, which is 12 in base-10 logarithm, or 120 dB.

How We Hear, Effects of Noise and Hearing Loss
Noise-Induced Hearing Loss

- Also known as sensorineural hearing loss
- Major problem with a NIHL is a loss in clarity
- There is no medical surgical cure for NIHL
- Hearing aids offer some improvement, but they cannot completely compensate for the lost hearing

**Once it’s gone, it’s gone**

Hearing loss occurs without pain – no warning
Audiogram Illustrating NIHL and Speech Range

Frequency (Hz)

Hearing Threshold Level (dB)

Vowels
SPEECH
Consonants

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Tinnitus

- Tinnitus is the perception of a sound within the human ear in the absence of corresponding external sound.
- It is a symptom of hearing damage, mostly from NIHL but can also be caused by aging, medication or genetics.
- Tinnitus can be perceived in one or both ears or in the head. It is usually described as a ringing noise, but in some patients it takes the form of a high pitched whining, electric, buzzing, hissing, screaming, humming, tinging or whistling sound, or as ticking, clicking, roaring, "crickets" or "tree frogs" or "locusts (cicadas)", tunes, songs, beeping, or even a pure steady tone like that heard during a hearing test.

Can you hear that?

Title: Tinnitus PSA
TT: 59 seconds
Director: Jose Cassella
Editor: Akira Otaguro
www.KSFILMS.com
General Industry Requirements

- **85 dBA** as 8-hour TWA = ACTION LEVEL (AL)

  - The employer shall administer a hearing conservation program whenever employee noise exposures equal or exceed an 8-hour time-weighted average sound level (TWA) of 85 dBA (A-weighted scale)

  - The Hearing Conservation Program must be:
    - continuing and
    - effective
Construction Requirements

- Table D-2 gives allowable time at specific SPL
- Pre-dates modern dosimetry and integration of TWA
- Values in Table D-2 are equal to 90 dBA, when expressed as 8 hour TWA
- No Action Level
- No definition of Hearing Conservation Program

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<table>
<thead>
<tr>
<th>29 CFR 1926.52, Table D-2 – Permissible Noise Exposures</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Duration per Day (hours)</strong></td>
</tr>
<tr>
<td>8</td>
</tr>
<tr>
<td>6</td>
</tr>
<tr>
<td>4</td>
</tr>
<tr>
<td>3</td>
</tr>
<tr>
<td>2</td>
</tr>
<tr>
<td>1-½</td>
</tr>
<tr>
<td>1</td>
</tr>
<tr>
<td>½</td>
</tr>
<tr>
<td>¼ or less</td>
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</table>
The “Feasible Engineering” Concept

- “Feasible” definition evolves with technology
  - Current OSHA policy:
    - Citations not issued between 90-100 dBA
    - If a fully compliant Hearing Conservation Program is in place
    - 2010 reinterpretation of policy

Extended Work Shifts

- 1. OSHA Policy:
  - Adjust AL, but not PEL

- 2. Good Practice:
  - Adjust AL and PEL
**Extended Work Shifts**

### Examples (in dBA)

<table>
<thead>
<tr>
<th>Shift</th>
<th>AL</th>
<th>PEL</th>
<th>G.P.*</th>
</tr>
</thead>
<tbody>
<tr>
<td>9 hr</td>
<td>84.2</td>
<td>90.0</td>
<td>89.2</td>
</tr>
<tr>
<td>10 hr</td>
<td>83.4</td>
<td>90.0</td>
<td>88.4</td>
</tr>
<tr>
<td>11 hr</td>
<td>82.7</td>
<td>90.0</td>
<td>87.7</td>
</tr>
<tr>
<td>12 hr</td>
<td>82.1</td>
<td>90.0</td>
<td>87.1</td>
</tr>
</tbody>
</table>

*GP=Good Practice

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**Calculating Hearing Protector Attenuation for OSHA Compliance:**

Measured TWA – (NRR – 7)

(NRR=noise reduction rating on dBC scale.
Removing 7 adjusts dBC to dBA)
For OSHA Compliance
Example Calculation

1. Measure full-shift TWA exposure in dBA
   TWA Exposure = 95 dBA
   NRR = 29

2. Calculate expected TWA Exposure under HP: Measured TWA – (NRR - 7)
   \[ 95 \text{ dBA} - (29 - 7) = 73 \text{ dBA} \]

For Good Practice
Calculating Hearing Protector Attenuation:

\[ \text{Measured TWA} - \{(\text{NRR}-7)/2\} \]

May be called “Real World” value
\[(Dividing the OSHA value by 2 is a safety factor)\]
Good Practice

Example Calculation

1. Measure full-shift exposure TWA in dBA
   
   Exposure = 95 dBA
   
   NRR = 29

2. Calculate expected TWA Exposure under HP: Measured TWA - (NRR-7)/2
   
   95 dBA - (29-7)/2 = 84 dBA

Dual Hearing Protection

- Generally recommended for full-shift exposures above 100 dBA
- HP’er Not certain to provide enough protection if exposure > 105 dBA
- Good Practice calculation for dual protection is:
  - Measured TWA – ((NRR-7)/2) + 5 dBA
  - “Second” level of protection adds just 5 dBA
Common Complaints

- **Hearing protectors are uncomfortable.**
  - Hearing loss is “uncomfortable” permanently.

- **I don’t need hearing protection; I am used to the noise**
  - Ears don’t “get used to noise” – they get deaf.

- **I can’t hear my co-workers if I wear hearing protectors.**
  - You can’t hear them if you are deaf.

Effectiveness of Hearing Protection

- Effectiveness of hearing protectors are reduced greatly if they are worn only part time
- Removing a 30 dB hearing protector for only 5 minutes in an 8-hour work shift reduces the average protection to 20 dB
- Removing this protector for 45 minutes during the work shift reduces the average protection to about 10 dB
- **Conclusion: The amount of time a hearing protector is worn is far more important than the amount of protection it theoretically provides**
Audiometric Testing per OSHA

Baseline testing within 6 months of new employment

- Allowance to wait for 12 months if the company is:
  1. Using a mobile van, and
  2. Enforcing the use of hearing protectors
- Good Practice: test at new hire

Annual testing and comparison to baseline

Standard Threshold Shift

Definition: 10 dB shift between Baseline and Current Audiogram, on average, at 2K, 3K, & 4K Hz

An STS is Recordable when the STS is present AND falls below 25 dB from audiometric zero

<table>
<thead>
<tr>
<th>Frequency (Hz)</th>
<th>Baseline (dB)</th>
<th>Current Audiogram (dB)</th>
<th>Difference (dB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>10</td>
<td>20</td>
<td>10</td>
</tr>
<tr>
<td>3000</td>
<td>5</td>
<td>10</td>
<td>5</td>
</tr>
<tr>
<td>4000</td>
<td>15</td>
<td>30</td>
<td>15</td>
</tr>
<tr>
<td>Average</td>
<td>10</td>
<td>20</td>
<td>10</td>
</tr>
</tbody>
</table>

Notify worker, require use of Hearing Protectors, retest w/in 30 days, if appropriate.
Measurement of Noise

- **Sound Level Meter**
- **Octave Band Analyzer**
- **Noise Dosimeter**
- **Noise Detector**

For occupational noise, use a slow response and A-weighting on the meters.

**Sound Level Meter (SLM)**

- Used to take direct real-time measurements of noise.
- Consists of a microphone, electronic circuits and a readout display that directly indicates sound level (dBA).
- Type 2 is sufficiently accurate for field measurements.
- Typically used for area noise monitoring; ID’ing noise sources; formulating noise controls; validating personal noise dosimetry.
Calibration of SLM (and all other noise monitors)

- Calibrate before and after each use
- Instrument Calibration is completed using a “Calibrator”
- The calibrator is a noise source that is laboratory verified to emit a specific sound pressure level at a specific frequency.

Use of SLM

- Set to A-weighting, SLOW response
- Position the microphone in the worker’s hearing zone
- OSHA defines the hearing zone as a sphere with a 2-foot diameter surrounding the head
Octave Band Analyzer

- Most noise sources are not “pure tone” composed of only one frequency.
- Most noise sources generate air pressure variations at many frequencies, literally thousands of them.
- Each frequency has its own individual sound pressure level.
Octave Band Analyzer (cont)

- Using an octave band analyzer helps determine and design appropriate noise controls
- Controls for a high-frequency noise may be different than for a low-frequency noise

Every noise source can be broken up into frequency ranges called octave bands.
Personal Noise Dosimeter

- Measures average noise (TWA) exposure (in dBA) for a complete work shift
- Can be expressed as noise “dose”
- For OSHA compliance, a noise dose of 100% equals an 8 Hr TWA of 90 dBA
- A 50% dose equals an 8 Hr TWA of 85 dBA
- Doses can be easily added (dBA logs cannot so easily be added)

Personal Noise Dosimeter (cont)

- For OSHA measurements, dosimeters are programmed with:
  - HTL (High Threshold Level) with 90 dBA cutoff criterion level
    - Used for PEL evaluations
  - LTL (Low Threshold Level) with 80 dBA cutoff criterion level
    - Used for Action Level evaluations
  - 5dBA doubling rate for OSHA noise monitoring (3dBA for ACGIH/NIOSH)
  - “SLOW” response integration time
Personal Noise Dosimeter (cont.)

- For Non-OSHA sampling, these parameters can vary:
  - Military sampling
  - NIOSH/ACGIH sampling
  - Environmental sampling
- **Bottom Line:** a dosimeter does not measure total noise—it measures a portion of noise according to specific settings

Use of Noise Dosimeter

- Small device clips to a person’s belt (or pocket) with a small microphone that fastens to the person’s collar, close to an ear
- Place microphone near ear located *closest to noise source.*
Noise Indicators

New technology that provides an indication of noise that exceeds a set decibel threshold level, typically 85 dBA.

Green flashing light indicates noise below 85 dBA.

Red flashing light indicates noise above 85 dBA.

OSHA Hierarchy of Controls

- Substitution/Removal
- Engineering controls
- Work practice controls
- Administrative controls
- Personal protective equipment (PPE)
**Administrative Controls**

- Adjustments to the allocation of employees or employee time in regards to the source of the noise.
- Examples: employee rotation or time limits for employees working in certain areas.

**Work Practices**

- Changes made to how a job or task is performed, or materials used in the job or task.
- Examples: moving employee work station away from noise source, changing to another form of raw material.

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**The Four Basic Engineering Noise Controls**

- **Sound Insulation** - prevent the transmission of noise by the introduction of a mass barrier. Common materials have high-density properties such as brick, concrete, metal etc.

- **Sound Absorption** - a porous material which acts as a ‘noise sponge’ by converting the sound energy into heat within the material. Common sound absorption materials include open cell foams and fiberglass.

- **Vibration Damping** - applicable for large vibrating surfaces. The damping mechanism works by extracting the vibration energy from the thin sheet and dissipating it as heat. A common material is sound deadened steel.

- **Vibration Isolation** - prevents transmission of vibration energy from a source to a receiver by introducing a flexible element or a physical break. Common vibration isolators are springs, rubber mounts, cork etc.
Typical Engineering Controls Involve

- Reducing noise at the source
  - Installing a muffler
- Interrupting the noise path
  - Erecting acoustical enclosures and barriers
- Reducing reverberation
  - Installing sound absorbing material
- Reducing structure-borne vibration
  - Installing vibration mounts and providing proper lubrication