Health Hazard® Evaluation Program

Evaluation of Cutoff Saw Operators' Noise Exposures at an Unleaded Brass Foundry

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The Health Hazard Evaluation Program investigates possible health hazards in the workplace under the authority of the Occupational Safety and Health Act of 1970 [29 USC 669a(6)]. The Health Hazard Evaluation Program also provides, upon request, technical assistance to federal, state, and local agencies to investigate occupational health hazards and to prevent occupational disease or injury. Regulations guiding the Program can be found in Title 42, Code of Federal Regulations, Part 85; Requests for Health Hazard Evaluations [42 CFR Part 85].

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Introduction

Request

Management from an unleaded brass foundry requested a health hazard evaluation to evaluate noise exposures and identify potential noise controls for the abrasive cutoff saws in the foundry. Management also requested an evaluation on how well employees' hearing protectors worked.

Workplace

The facility consisted of a foundry, machining and manufacturing area, distribution department, and offices. The company produced lead-free valves such as backflow preventers, mixing valves, plumbing valves, heating valves, pressure reducing valves, temperature and pressure relief valves, and ball valves for use in residential, commercial, and industrial applications. The workplace had 250 employees and operated two work shifts per day. Employees normally worked 10-hour shifts.

To learn more about the workplace, go to Section A in the Supporting Technical Information

Our Approach

We visited the foundry in December 2019 to evaluate noise in the cutoff area. During our visit, six saw operators worked at the abrasive cutoff saws. Most of these saw operators divided their time between the cutoff saws and other areas with lower noise levels such as the grinders, core room, or melt deck. The cutoff saw operators worked 10-hour shifts. We completed the following activities during our visit:

- Observed work processes, production practices, and conditions.
- Measured full-shift personal noise exposures on six cutoff saw operators.
- Measured task or equipment related sound levels across noise frequencies in the cutoff area of the foundry.
- Conducted hearing protector fit-testing on six cutoff saw operators.

To learn more about our methods, go to Section B in the Supporting Technical Information

Our Key Findings

Cutoff saw operators were overexposed to noise

- Cutoff saw operators' noise exposures were well above the National Institute of Occupational Safety and Health (NIOSH) and Occupational Safety and Health Administration (OSHA) noise exposure limits for workplaces.

- Cutoff saw operators' noise exposures were above 120 decibels, A-weighted, for 5% to 15% of the work shift.

Hearing protector fit testing showed that cutoff saw operators' hearing protection did not always provide enough protection

- Foam-insert ear plugs reduced noise 15 to 31 decibels, and custom-made ear plugs reduced noise 18 to 28 decibels.
- Because of the high noise levels, the earplugs did not always block enough sound to keep employees' exposures below noise exposure limits.

Some employees did not always wear their hearing protection properly, which reduced how well the protectors worked

- Some employees did not fully insert ear plugs into their ears.
- Some employees improperly wore the head band of their earmuffs around the back of the head. However, the head bands were designed to be worn over the top of the head.

To learn more about our results, go to Section B in the Supporting Technical Information

Our Recommendations

The Occupational Safety and Health Act requires employers to provide a safe workplace.

Potential Benefits of Improving Workplace Health and Safety:

↑ Improved worker health and well-being	↑ Enhanced image and reputation
↑ Better workplace morale	↑ Superior products, processes, and services
↑ Easier employee recruiting and retention	↑ Increased overall cost savings

The recommendations below are based on the findings of our evaluation. For each recommendation, we list a series of actions you can take to address the issue at your workplace. The actions at the beginning of each list are preferable to the ones listed later. The list order is based on a well-accepted approach called the "hierarchy of controls." The hierarchy of controls is a way of determining which actions will best control exposures. In most cases, the preferred approach is to eliminate hazards or to replace the hazard with something less hazardous (i.e., substitution). Installing engineering controls to isolate people from the hazard is the next step in the hierarchy. Until such controls are in place, or if they are not effective or practical, administrative controls and personal protective equipment might be needed. Read more about the hierarchy of controls at https://www.cdc.gov/niosh/hierarchy-of-controls/about/index.html.

We encourage the company to use a health and safety committee to discuss our recommendations and develop an action plan. Both employee representatives and management representatives should be included on the committee. Helpful guidance can be found in *Recommended Practices for Safety and Health Programs* at https://www.osha.gov/safety-management.

Recommendation 1: Reduce hearing loss risk from on-the-job noise exposure

Why? Noise-induced hearing loss is an irreversible condition that can get worse with noise exposure. Unlike some other types of hearing disorders, noise-induced hearing loss cannot be medically treated. Noise-exposed workers can develop substantial noise-induced hearing loss before it is clearly recognized. Noise monitoring results showed that cutoff saw operators' noise exposures were well above occupational noise exposure limits.

How? At your workplace, we recommend these specific actions:

Use engineering controls at the saw blades, cutting deck, and enclosure to reduce noise exposure.

- Continue testing different abrasive saw blades to find ones that are effective but make the least noise. In general, saw noise can be reduced by
  - using blade stiffeners, dampeners, and stabilizers.
  - optimizing the rate at which castings are fed into the blade.
  - optimizing the rotational speed of the saw blade.
  - keeping the saw blades sharp and replacing them as needed.
- Eliminate the metal-to-metal contact of the casting and glide plate cutting deck by attaching high-strength plastic to the top of the cutting deck.
- Use acoustical damping perforated metal to line the inside of the cutoff saw enclosures. Regularly vacuum the inside of the enclosure because dust can build up on the perforated metal and reduce how well it works.
- Continue looking into using robotics (automation) for the cutoff operation.

Use administrative controls to reduce noise exposure.

- Continue to use a job rotation schedule that limits saw operators to a maximum of half a shift working at the cutoff saws. Move saw operators to other work activities with lower noise exposure.
- Use a "Buy Quiet" program, which is a long-term method to reduce noise exposures. When installing or replacing equipment, choose options that makes less noise. Information about Buy Quiet programs is available at https://www.cdc.gov/niosh/noise/prevent/eliminate.html.

Continue to include saw operators in a hearing loss prevention program.

- Conduct baseline and annual hearing tests. Keep records of employees' hearing test results.
    - Use both OSHA and NIOSH criteria to identify changes in hearing test results. The NIOSH criteria are more protective than OSHA criteria and will identify employees with hearing loss sooner.
- Conduct hearing protector fit testing to make sure the hearing protectors employees use fit well and reduce noise adequately. Hearing protector fit testing is also a way to help train employees on properly inserting their hearing protectors.
- Educate employees on noise exposures and hearing loss risks. Give them information about hearing hazards and hearing protection requirements. Make sure employees always wear their hearing protection correctly.
- Instruct employees to promptly report any symptoms that may be related to workplace noise exposure. Symptoms include trouble hearing clearly or ringing or buzzing in the ears. Keep track of such reports.
- Encourage employees with possible work-related hearing concerns to seek medical care from qualified healthcare professionals.

Supporting Technical Information

Evaluation of Cutoff Saw Operators' Noise Exposures at an Unleaded Brass Foundry

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Section A: Workplace Information

The foundry cast and manufactured non-lead brass plumbing and flow-control valves. The foundry had four abrasive cutoff saws where employees separated the solid metal valves from the casting trees (excess metal from the casting process) after they cooled.

Employees in the cutoff area operated four abrasive cutoff saws positioned around the perimeter of a large circular rotating table where finished castings, consisting of the valve and the casting tree, were transferred from the foundry via a barrel shaker. The saw operators picked up castings from the rotating table and then used cutoff saws equipped with a 20-inch diamond abrasive cutting blade to separate the valve from the casting tree. During cutting, the employees placed the casting onto a metal cutting deck and pushed the casting into the abrasive cutoff saw blade.

After separation, employees manually dropped or tossed the valve into a nearby metal bin for finishing. The casting trees went into a separate bin for recycling. Each cutoff saw was operated by a single employee. Each saw was enclosed in a five-sided metal enclosure with the front side open for operation. The enclosure dimensions were 38 inch in height, 55–56 inch in width (except Saw B which was 48 inch in width), and 60–62 inch in depth. The cutoff saws were positioned about 6 feet away from the rotating table holding castings and positioned along the east to south perimeter of the table. The saws were about 9 feet from adjacent saw(s) with Saw A and Saw D on the end. The cutoff saw area was open to the foundry. Six employees operated cutoff saws on the day of the site visit.

Section B: Methods, Results, and Discussion

Our objectives for the evaluation included the following:

- Observing work processes, practices, and workplace conditions.
- Characterizing one-third octave band noise frequency levels in the cutoff area.
- Measuring full-shift personal noise exposures of cutoff saw operators.
- Conducting quantitative fit-testing of the earplugs used by the cutoff saw operators.
- Identifying potential noise control strategies for the cutoff saw area.

Methods: Noise Exposure and Sound Level Measurements

We measured time-weighted average (TWA) personal noise exposures of six cutoff saw operators. We used Larson Davis Spark™ Model 706RC integrating noise dosimeters equipped with 0.375-inch random incidence microphones. The dosimeters recorded and data logged five-second averaged noise levels for the duration of the measurement period. The dosimeters were calibrated before and after the measurement periods according to the manufacturer's instructions.

We attached the dosimeter microphone to the outside the employee's clothing in an upright position midway between the neck and the edge of their shoulder. The microphone was covered with a windscreen to reduce artifact noise caused by air movement or by accidental contact. The dosimeters simultaneously collected noise data using three different settings to allow comparison of noise measurement results with three different noise exposure limits: the NIOSH recommended exposure limit (REL), the OSHA permissible exposure limit (PEL), and the OSHA action level (AL). At the end of the work shift, we downloaded the noise measurement data from the dosimeters using PCB Piezotronics Blaze™ software.

We used a Larson Davis Model 831 Type 1 integrating sound level meter and frequency analyzer equipped with a 0.5-inch random incidence microphone for sound level measurements. The sound level meter was calibrated before and after each day of measurements. The instrument integrated sound levels using linear averaging at 1-second time history intervals. During measurements, the sound level meter was handheld at a height of about 5–6 feet above floor or ground level to match standing height of employees. Most measurements were taken within 3–6 feet of employees for about 30–60 seconds. Following measurements, the noise measurement data stored on the instrument were downloaded, exported, and analyzed using Larson Davis G4® software and Microsoft Excel.

Results: Noise Exposure and Sound Level Measurements

Noise Exposure Measurements

Full-shift TWA personal noise exposure measurement results for the six cutoff saw operators are shown in Figure B1 and provided in Table C1 of Section C. We compared the employees' noise exposures with the occupational noise exposure limits set by NIOSH and OSHA. These limits represent the amount of noise that most employees can be exposed to without substantial risk of hearing loss. OSHA and NIOSH measure and calculate noise exposures in different ways, as noted in Section D.

For an 8-hour work shift, the NIOSH REL is 85 decibels, A-weighted (dBA); the OSHA AL is 85 dBA; and the OSHA PEL is 90 dBA. For a 10-hour shift, which employees worked at this facility, the NIOSH REL is reduced to 84 dBA, and the OSHA AL is reduced to 83.4 dBA. OSHA does not reduce the PEL for 10-hour shifts. Employers are required to keep noise exposures below OSHA limits. However, NIOSH considers its REL to be more protective.

These results reveal that all the saw operators' personal noise exposures were well above the NIOSH REL, OSHA AL, and OSHA PEL. Specifically, full-shift TWA noise exposures ranged 112–116 dBA based on NIOSH noise measurement criteria and ranged 107–114 dBA based on OSHA noise measurement criteria. In addition, TWA noise exposures were well above 100 dBA. At 100 dBA, NIOSH recommends, and OSHA requires, employees to use dual hearing protection, that is, wearing both ear plugs and earmuffs.

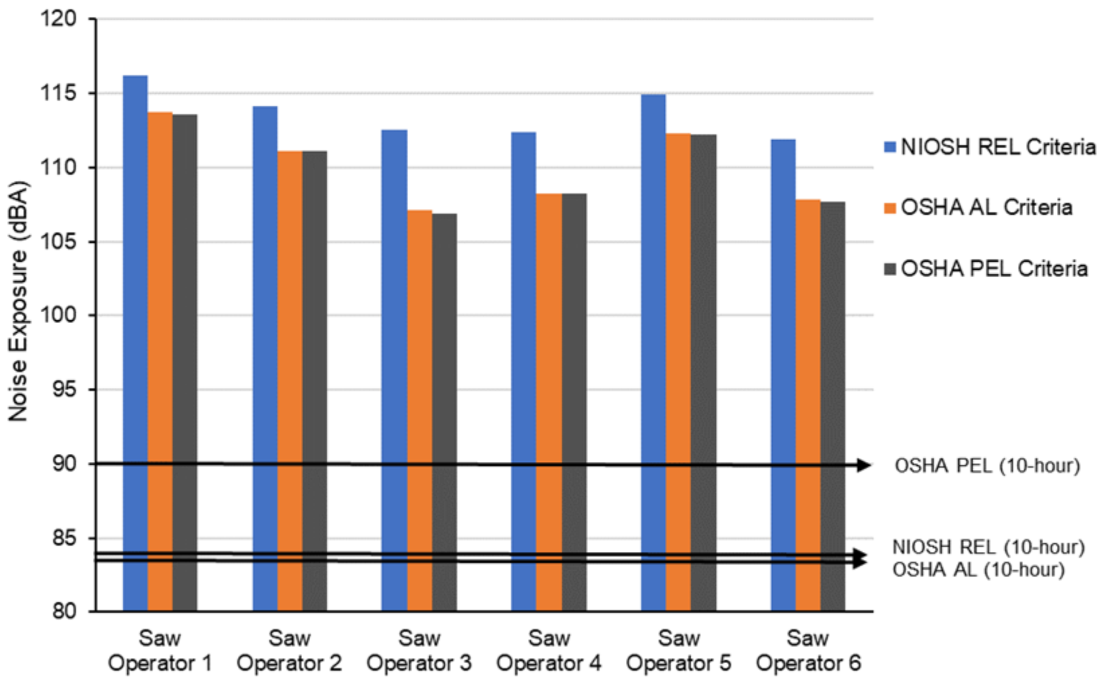

Figure B1. Saw operators' full-shift time-weighted average (dBA) noise exposure measurement results compared with occupational noise exposure limits: NIOSH recommended exposure limit (REL) and OSHA action level (AL) and permissible exposure limit (PEL).

Figure B2 shows the time-history noise exposure profiles for the six saw operators. These profiles reveal that during their time working at the cutoff saws, noise exposures generally ranged 100–120 dBA; however, at times they reached or exceeded 120 dBA. When saw operators worked in other areas, their noise exposures generally ranged 85–95 dBA. This can be seen in the time-history profiles in Figure B2 for Saw Operators 3 and 4 for the first part of their work shift and Saw Operators 5 and 6 for the last part of the work shift.

During break periods or when saw operators left the production areas, noise exposures were below 70 dBA. Saw Operators 1 and 5 spent the greatest proportion of the work shift at the cutoff saws and had slightly higher TWA noise exposures than the other saw operators (Table C1). Saw Operator 4 started working later in the morning and left the workplace for about an hour during the shift. When Saw Operator 4 was out of the workplace, the noise dosimeter was paused and did not integrate noise exposure. This is why there is a gap in the time history profile for Saw Operator 4 in Figure B2.

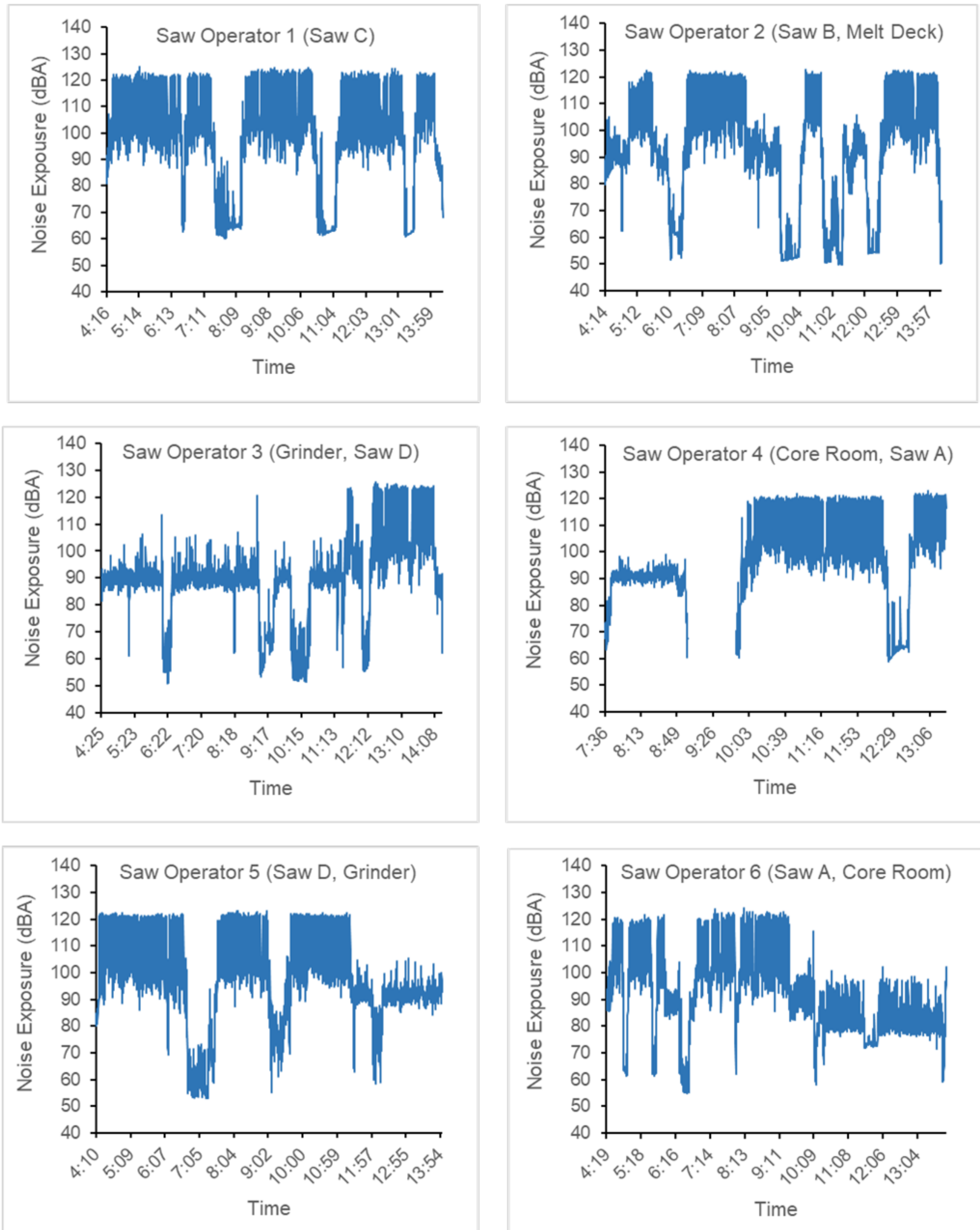

Figure B2. Time history noise exposure profiles for the six saw operators.

Figure B3 shows the percentage of time the six saw operators noise exposures exceeded different noise threshold levels. Depending on their time at the cutoff saw, the saw operators' exposures were above 120 dBA for 5%–15% of the work shift and above 100 dBA for 16%–55% of the shift.

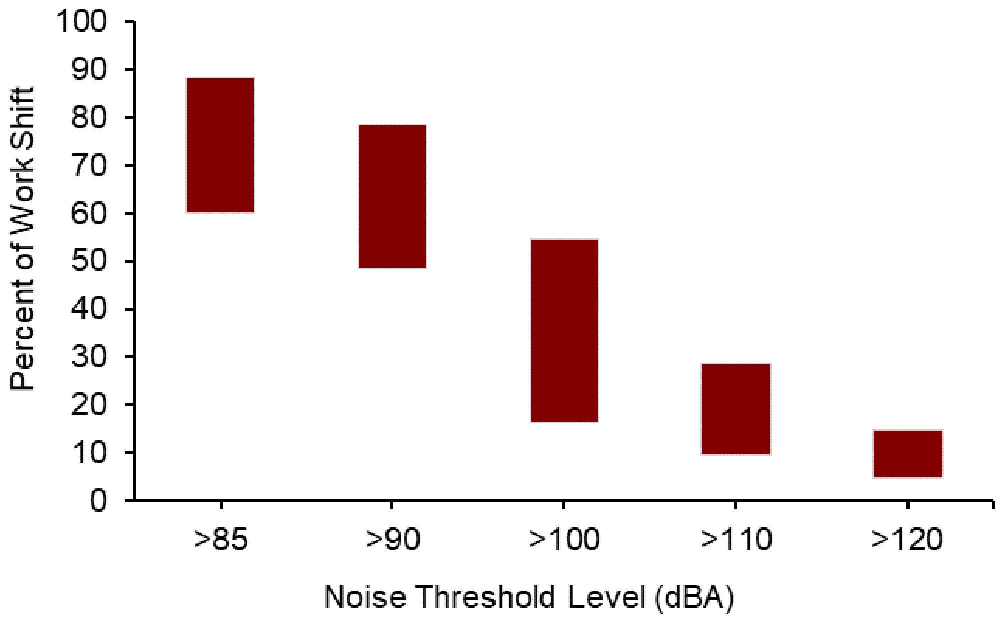

Figure B3. Percentage of work shift (range) saw operators' noise exposures exceeded threshold levels.

Sound Level Measurements

Results of short duration integrated sound level measurements taken near each of the four cutoff saws are shown in Figure B4. Overall, the sound levels ranged 110–122 dBA. The sound levels were slightly higher at Saw C and Saw D. The results also indicated that Saw B and Saw D had a slightly greater range of sound levels (9 dBA) than Saw A and Saw C (7 dBA). Sound levels at each of the saws were not notably affected by the sound from one or more of the other saws. Sound levels decreased to about 99–109 dBA at a distance of 5–15 feet from the saws. Two of the saw operators worked at grinders for part of their work shift. Sound levels measured at the grinders were 89–92 dBA.

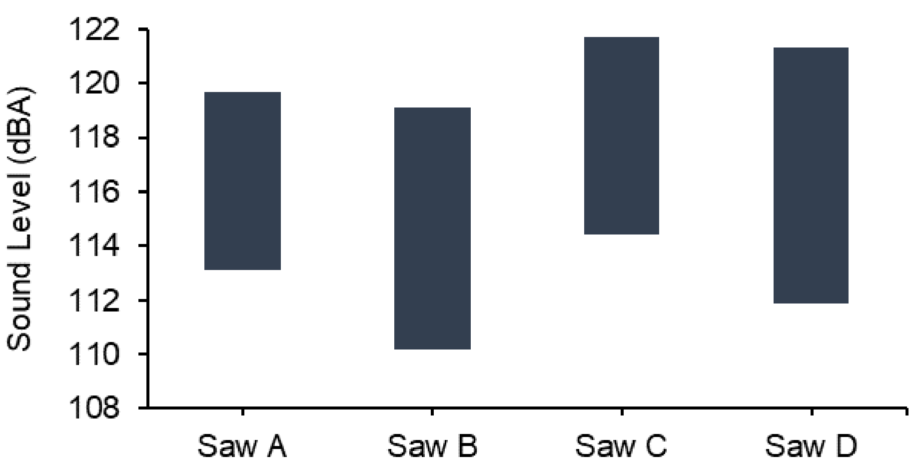

Figure B4. Range of short duration integrated sound levels measured at the four cutoff saws.

Results of one-third band octave band measurements are provided in Figure B5. All four cutoff saws had similar patterns for frequencies above 20 Hz. Below that frequency, cutoff Saw B was about 20 dB less than the other three saws; the reason for this difference was not identified. Overall, the highest frequency specific sound levels (102–115 dB) generated during use of the cutoff saws were in mid to upper frequencies from 2,500–10,000 Hz, with the highest level (107–115 dB) at 5,000 Hz. At low frequencies, below 100 Hz, the locally highest sound levels were at 16 Hz for Saws A and D, 20 Hz for Saw B, and 6.3 Hz for Saw C. The sound levels at these frequencies were 100 dB or less.

Sound level measurements taken when the saws were not operating showed that the highest sound level (100 dB) was at 16 Hz (likely due to frequency-related noise from the nearby barrel shaker that was running), whereas the sound levels across frequencies 2,500–10,000 Hz were less than 90 dB.

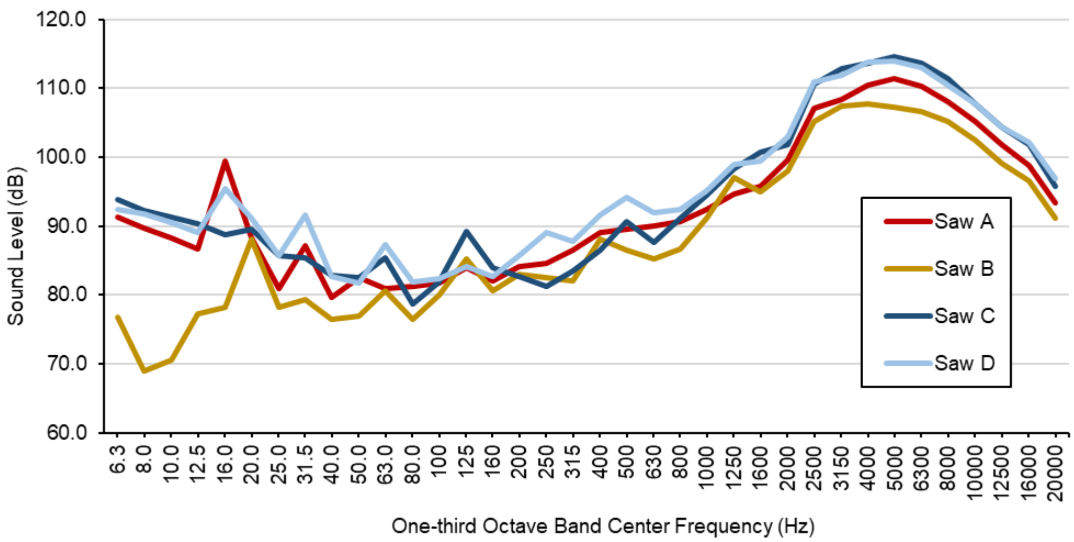

Figure B5. One-third octave band sound levels at the four cutoff saws.

Methods: Quantitative Hearing Protector Fit Testing

We conducted quantitative hearing protector fit-testing to determine the personal attenuation of the ear plugs worn by saw operators using the NIOSH HPD WellFit™ system. This system uses a real-ear attenuation at threshold method to measure the difference between occluded (using earplugs) and unoccluded (without earplugs) hearing thresholds determined under circumaural headphones that emit test tones. Those being fit tested listened to pulsed one-third octave-band noise tones at frequencies of 500, 1,000, and 2,000 hertz (Hz) through the headphones, used the scroll wheel of the computer mouse to adjust the volume of the signal to a level that was just audible, and pressed the mouse button to record that threshold level. The test signal was then increased by a random amount between 10 and 20 dB, and the employee repeated the procedure. Three successive threshold identifications within a tolerance range of 6 dB were required to establish a final threshold at each test frequency. Testing was first done unoccluded and then occluded. The fit testing was done individually in a quiet conference room.

Results: Quantitative Hearing Protector Fit Testing

Results of quantitative hearing protector fit testing are provided in Table C2. The range of attenuation we measured for saw operators tested while wearing 3M™ E-A-Rsoft™ Yellow Neons™ foam insert earplugs was 15.0–31.1 dB. The range of attenuation for saw operators tested while wearing Phonak Serenity Classic custom fit hearing protection was 18.5–28.5 dB. For saw operators tested using foam insert earplugs and custom fit earplugs (N = 3), we found that for two of the operators, the custom fit earplugs provided greater attenuation. For one of the operators, the foam insert earplugs provided greater attenuation. Based on each saw operators' measured hearing protector attenuation and measured full-shift noise exposure, we calculated the maximum noise exposure permissible when using dual hearing protection (see Table C2). We found that for about half of the saw operators tested, their measured noise exposure based on the NIOSH REL or OSHA AL criteria was greater than the maximum noise exposure allowed when using dual hearing protection. For dual hearing protection to be adequately protective based on the NIOSH REL criteria, all operators would need to have a minimum attenuation of 27 dB for their insert hearing protectors.

Discussion

Noise Exposures

Cutoff saw operators' full-shift TWA noise exposures were well above occupational noise exposure limits. Exposures exceeded 100 dBA, ranging from 112–116 dBA based on NIOSH noise measurement criteria and 107–114 dBA based on OSHA criteria. When exposures are above 100 dBA, OSHA requires, and NIOSH recommends, the use of dual hearing protection (i.e., the combination of both insert ear plugs and earmuffs). The company required that saw operators used dual hearing protection, and we observed this compliance.

During cutting, saw operators stood directly in front of the saw (approximately 18 inches from the saw) while manually pushing the casting into the abrasive cutting saw blade. Sound level measurements across the four cutoff saws ranged 110–122 dBA. The sound levels were slightly higher (112–122 dBA) at Saws C and D compared with Saws A and B (110–120) dBA. Due to the proximity of high sound levels from the saw itself, we did not find that sound levels were noticeably influenced by sound from operation of one or more of the other cutoff saws.

At an exposure level of 120 dBA, a worker's noise exposure reaches the NIOSH REL in 9 seconds and reaches the OSHA AL in 225 seconds. Based on the noise exposure time history results from the dosimeters, the saw operators' exposures were at or above 120 dBA for 5%–15% of their work shift, above 110 dBA for 10%–29% of shift, and above 100 dBA for 16%–55% of shift.

The cutoff process had multiple noise generating mechanisms. Noise was primarily generated by the interaction of the abrasive cutoff saw blade with the casting when cutting the metal tree off the valve. Noise during the cutting process also included vibration and ringing (resonance) of the saw blade during cutting. While idling, noise comes from air turbulence from the abrasive cutoff saw blade as it rotates at high speeds, vibration of casting and cutting deck, and reverberant noise within the five-sided enclosure housing the cutoff saw. Background noise was also present due to mechanical and operational noise from other nearby production areas. However, relative to noise generated by the cutoff saws, the background noise was not a substantial contributor to saw operators' noise exposures.

We used an acoustic camera (CAE SoundCam) to identify sound sources during cutting. The camera uses beamforming for processing measurements from multiple microphones to localize and provide an acoustic image showing directionality and proportionality of sound levels. Figure B6 is an acoustic image showing the sequence of sound generation during the beginning, middle, and end as a single casting is cut. As the casting is initially pushed into the saw blade, sound is generated at the lower half of the saw blade and at the interface of the blade and casting. Sound levels of increasing intensity extend outward and particularly downward as the casting is cut, and a decrease in downward intensity occurs as the cut is completed.

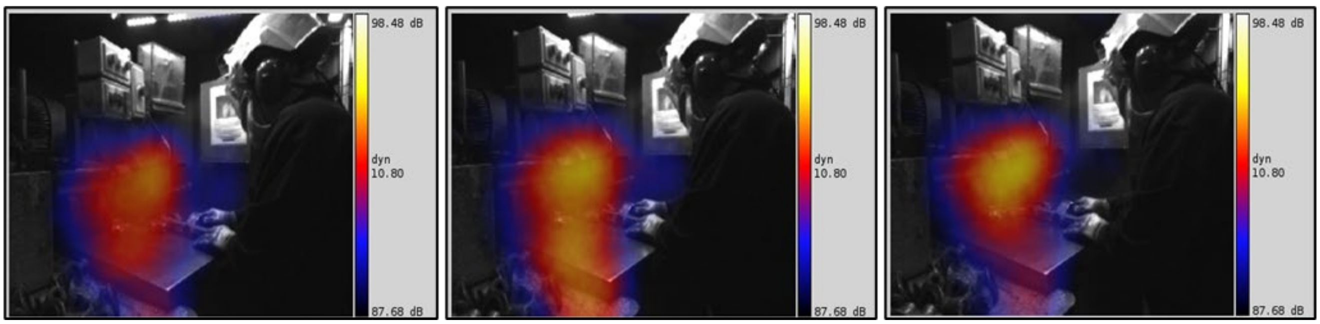

Figure B6. Acoustic image of sound generation during the sequence of a single casting being cut at the cutoff saw showing the beginning (left), mid-point (middle), and end (right) of the process. Photo by NIOSH

Octave Band Sound Level Measurements and Engineering Controls

Engineering controls for noise should focus on reducing noise at the cutoff saws, which were the primary contributors to the operators' exposure. The company had ongoing evaluations of different blade designs, adjusting saw blade rotational speed, and building partial enclosures for the saws.

In general, strategies for reducing saw noise should include using blade stiffeners/dampeners (covering 50% of the blade when possible), optimizing rotational speed of the saw blade, and reducing idling noise. In addition, keeping the saw blades sharp is critical to increase the speed and efficiency of cutting, leading to noise reduction. Adding an ultra-high-molecular-weight polyethylene plastic layer to the surface of the metal cutting deck could help reduce noise from metal-to-metal contact between the casting and cutting deck during sawing.

Octave band noise frequency measurements are used to characterize the noise frequencies of sound sources and help guide selection of appropriate engineering noise controls. Noise frequency measurements at the cutoff saws showed that the highest levels generated during the cutoff process were primarily in the mid to upper frequencies ranging 2,500–10,000 Hz, with the highest levels at 5,000 Hz. Equipment enclosures and noise barriers are one of the strategies for helping reduce high frequency noise exposures [Driscoll 2022]. A full enclosure of the cutoff saw is not feasible as the operators must access and manually use the cutoff saws; however, the company had constructed and installed five-sided partial enclosures of the saws. These enclosures were lined with acoustical material to help reduce reverberant noise, but we observed that the material had degraded over time and some sections were not present on the interior of the enclosure walls.

Instead of using a degradable polymeric foam, an alternative could include sound absorbing and vibration reduction treatments. Constrained layer damping treatment (i.e., damping material sandwiched between other stiff materials) can be applied to the walls of the enclosure to reduce vibration of the enclosure. A sound absorbing perforated metal acoustical lining could be applied to the interior walls. Although the saws were connected to exhaust ventilation, metal dust can still be generated during cutting. Therefore, regular cleaning of the perforated metal surface using a vacuum would be needed to remove dust and ensure its continued effectiveness.

Noise reduction should also be part of an overall long-term strategy. For example, when equipment is replaced, the amount of noise generated by the new equipment should be considered as part of the purchasing decision. "Buy Quiet" is a concept by which companies can reduce hazardous noise levels through the procurement process. Through this process, purchasers are encouraged to consult with equipment and tool manufacturers, compare noise emission levels for differing models of equipment and, whenever possible, choose equipment that produces less noise and vibration. In addition, we recommend that the company continue to investigate the feasibility of using of robotics for the cutoff process to reduce employees' noise exposures.

The company used job rotation to help reduce saw operators' noise exposures. On the day of our site visit, five of the six saw operators rotated for part of their shift from working at the saws to working in other areas with lower noise levels such as grinders, core room, or melt deck. Noise exposures when employees were in these other work areas generally ranged 85–95 dBA. Saw Operator 1, who did not rotate to less noisy jobs, had a TWA noise exposure that was about 1–4 dBA higher based on NIOSH measurement criteria and 1–7 dBA higher based on OSHA criteria. This difference varied with time spent in less noisy areas away from the saw but shows the positive benefit of job rotation.

Hearing Protector Fit Testing

The company provided employees with two different types of hearing protectors. Our quantitative fit testing of saw operators revealed a similar but wide range of attenuation for the two types tested. They ranged 15.0–31.1 dB for 3M™ E-A-Rsoft™ Yellow Neons™ foam insert earplugs and 18.5–28.5 dB for Phonak Serenity Classic custom fit hearing protectors. Three of the saw operators were tested on both types. For two operators, the custom fit earplugs provided greater attenuation, and for one operator, the foam insert earplugs provided greater attenuation. Hearing protectors must attenuate noise levels to less than 85 dBA to provide adequate protection. Noise attenuation of earplugs depends on the type of hearing protector, how well the hearing protector fits, and proper insertion of the earplug into the ear canal.

Due to the high TWA noise exposures, we found that half of the saw operators' hearing protection was inadequate. Even when combining earplugs (based on fit test results) with earmuffs (which provides an additional 5 dB of attenuation), their noise exposure at the ear still exceeded the NIOSH REL and OSHA AL. For adequate attenuation of the noise exposures we measured, earplugs need to provide a minimum attenuation of 27 dB.

The hearing protectors used by these employees, if well-fitting, can provide adequate attenuation. Poor fit can be due to improper insertion of hearing protectors or inability of a specific brand/model of hearing protector to properly fit an individual employee. These fit testing results highlight the value of conducting hearing protection fit testing to determine whether workers are receiving enough attenuation for their noise exposures. Fit testing can also help identify hearing protectors that are most effective for individual employees. Insufficient hearing protector attenuation found during fit testing can be addressed by retraining employees on how to properly insert hearing protection and providing other brands/models of hearing protectors that provide better fit.

We observed that some employees did not fully insert foam hearing protectors into their ear canal. We also observed some employees wore the head band of their earmuffs around the back of the head. However, the head bands were designed to be worn over the top of the head. Research has shown that ear plugs can appear to be properly inserted into the ear canal but still provide minimal noise attenuation because of poor fit due to factors such as improper insertion technique and incorrectly sized ear plug for the wearer [NIOSH 1998; Smalt et al. 2021].

Limitations

This evaluation is subject to limitations. The employee noise exposure assessment, sound level measurements, and quantitative hearing protector fit testing only documented exposures, conditions, and results on the day that the evaluation occurred. These assessment and measurement results are subject to day-to-day variation and may not be representative of other days.

Conclusions

We found that cutoff saw operators' full-shift TWA noise exposures were well above occupational noise exposure limits, ranging 112–116 dBA based on NIOSH noise measurement criteria and 107–114 dBA based on OSHA criteria. Saw operators' noise exposures were above 120 dBA for 5%–15% of their work shift. Noise generated during use of the abrasive cutoff saws was the primary contributor to saw operators' noise exposures. Quantitative hearing protector fit testing indicated that for some of the saw operators, their ear plugs did not provide enough attenuation to reduce their noise exposure to less than occupational noise exposure limits. Strategies to reduce noise exposure and the risk of hearing loss include reducing saw blade noise, using partial saw enclosures and barriers, using job rotation, adopting buy quiet strategies, and providing effective hearing protection.

Section C: Tables

Table C1. Cutoff saw operators' full-shift noise exposure measurement results in dBA.

Employee (location)	Result using NIOSH REL criteria*	Result using OSHA AL criteria*	Result using OSHA PEL criteria†
Saw operator 1 (Saw C)	116.2	113.7	113.6
Saw operator 2 (Saw B)	114.1	111.1	111.1
Saw operator 3 (Grinder, Saw D)	112.5	107.1	106.9
Saw operator 4 (Core room, Saw A)	112.4	108.2	108.2
Saw operator 5 (Saw D, Grinder)	114.9	112.3	112.2
Saw operator 6 (Saw A, Core Room)	111.9	107.8	107.7
Noise exposure limits (8-hour work shift)	85.0	85.0	90.0
Noise exposure limits (adjusted for 10-hour work shift)	84.0	83.4	90.0

Abbreviations: dBA = decibels, A-weighted; REL = recommended exposure limit; AL = action limit

* The criteria for calculating the NIOSH REL and OSHA AL include all noise exposures greater than or equal to 80 dBA.

† The criteria for calculating the OSHA PEL include all noise exposures greater than or equal to 90 dBA.

Table C2. Hearing protector attenuation measured by fit testing and the maximum noise exposure allowed for dual hearing protection based on a 10-hour work shift.

Employee	Type of hearing protection	Measured hearing protector attenuation (dB)	Full-shift time-weighted average noise exposure measurement results (dBA)			Maximum noise exposure allowed* using dual hearing protection† (dBA)		
			NIOSH REL criteria	OSHA AL criteria	OSHA PEL criteria	NIOSH REL criteria	OSHA AL criteria	OSHA PEL criteria
Saw operator 1	3M Yellow Neons	31.1	116.2	113.7	113.6	120.1	119.5	126.1
Saw operator 1	Phonak Serenity Classic	18.5	116.2	113.7	113.6	107.5	106.9	113.5
Saw operator 2	3M Yellow Neons	21.9	114.1	111.1	111.1	110.9	110.3	116.9
Saw operator 3	3M Yellow Neons	15.0	112.5	107.1	106.9	104.0	103.4	110.0
Saw operator 4	3M Yellow Neons	24.3	112.4	108.2	108.2	113.3	112.7	119.3
Saw operator 4	Phonak Serenity Classic	28.5	112.4	108.2	108.2	117.5	116.9	123.5
Saw operator 5	3M Yellow Neons	21.5	114.9	112.3	112.2	110.5	109.9	116.5
Saw operator 5	Phonak Serenity Classic	26.6	114.9	112.3	112.2	115.6	115.0	121.6
Saw operator 6	Phonak Serenity Classic	26.1	111.9	107.8	107.7	115.1	114.5	121.1

Abbreviations: dBA = decibels, A-weighted; REL = recommended exposure limit; AL = action limit

* Maximum noise exposure allowed is calculated by adding the measured hearing protector attenuation to the NIOSH REL and OSHA AL for 10-hour work shifts. The PEL is not adjusted for extended work shifts.

† Use of dual hearing protection (using both ear plugs and earmuffs) adds an extra 5 dBA of attenuation.

Section D: Occupational Exposure Limits

NIOSH investigators refer to mandatory (legally enforceable) and recommended occupational exposure limits (OELs) for chemical, physical, and biological agents when evaluating workplace hazards. OELs have been developed by federal agencies and safety and health organizations to prevent adverse health effects from workplace exposures. Generally, OELs suggest levels of exposure that most employees may be exposed to for up to 10 hours per day, 40 hours per week, for a working lifetime, without experiencing adverse health effects.

However, not all employees will be protected if their exposures are maintained below these levels. Some may have adverse health effects because of individual susceptibility, a preexisting medical condition, or a hypersensitivity (allergy). In addition, some hazardous substances act in combination with other exposures, with the general environment, or with medications or personal habits of the employee to produce adverse health effects. Most OELs address airborne exposures, but some substances can be absorbed directly through the skin and mucous membranes.

Most OELs are expressed as a time-weighted average (TWA) exposure. A TWA refers to the average exposure during a normal 8- to 10-hour workday. Some chemical substances and physical agents have recommended short-term exposure limits (STEL) or ceiling values. Unless otherwise noted, the STEL is a 15-minute TWA exposure. It should not be exceeded at any time during a workday. The ceiling limit should not be exceeded at any time.

In the United States, OELs have been established by federal agencies, professional organizations, state and local governments, and other entities. Some OELs are legally enforceable limits; others are recommendations.

- OSHA, an agency of the U.S. Department of Labor, publishes permissible exposure limits [29 CFR 1910 for general industry; 29 CFR 1926 for construction industry; and 29 CFR 1917 for maritime industry] called PELs. These legal limits are enforceable in workplaces covered under the Occupational Safety and Health Act of 1970.
- NIOSH recommended exposure limits (RELs) are recommendations based on a critical review of the scientific and technical information and the adequacy of methods to identify and control the hazard. NIOSH RELs are published in the *NIOSH Pocket Guide to Chemical Hazards* [NIOSH 2007]. NIOSH also recommends risk management practices (e.g., engineering controls, safe work practices, employee education/training, PPE, and exposure and medical monitoring) to minimize the risk of exposure and adverse health effects.
- Another set of OELs commonly used and cited in the United States includes the threshold limit values or TLVs, which are recommended by the American Conference of Governmental Industrial Hygienists (ACGIH). The ACGIH TLVs are developed by committee members of this professional organization from a review of the published, peer-reviewed literature. TLVs are not consensus standards. They are considered voluntary exposure guidelines for use by industrial hygienists and others trained in this discipline “to assist in the control of health hazards” [ACGIH 2024].

Outside the United States, OELs have been established by various agencies and organizations and include legal and recommended limits. The Institut für Arbeitsschutz der Deutschen Gesetzlichen Unfallversicherung (Institute for Occupational Safety and Health of the German Social Accident Insurance) maintains a database of international OELs from European Union member states, Canada (Québec), Japan, Switzerland, and the United States. The database, available at https://www.dguv.de/ifa/gestis/gestis-stoffdatenbank/index-2.jsp, contains international limits for more than 2,000 hazardous substances and is updated periodically.

OSHA (Public Law 91-596) requires an employer to furnish employees a place of employment free from recognized hazards that cause or are likely to cause death or serious physical harm. This is true in the absence of a specific OEL. It also is important to keep in mind that OELs may not reflect current health-based information.

When multiple OELs exist for a substance or agent, NIOSH investigators generally encourage employers to use the lowest OEL when making risk assessment and risk management decisions.

Noise

Noise-induced hearing loss (NIHL) is an irreversible condition that progresses with noise exposure. NIHL is caused by damage to the nerve cells of the inner ear and, unlike some other types of hearing disorders, cannot be treated medically [AIHA 2022]. Approximately 25% of U.S. workers have been exposed to hazardous noise [Kerns et al. 2018], and more than 22 million U.S. workers are estimated to be exposed to workplace noise levels above 85 dBA [Tak et al. 2009]. NIOSH estimates that workers exposed to an average daily noise level of 85 dBA over a 40-year working lifetime have an 8% excess risk of material hearing impairment. This excess risk increases to 25% for an average daily noise exposure of 90 dBA [NIOSH 1998]. NIOSH defines material hearing impairment as an average of the hearing threshold levels (HTLs) for both ears that exceeds 25 dB at frequencies of 1 kilohertz (kHz), 2 kHz, 3 kHz, and 4 kHz.

Although hearing ability commonly declines with age, exposure to excessive noise can increase the rate of hearing loss. In most cases, NIHL develops slowly from repeated exposure to noise over time, but the progression of hearing loss is typically the greatest during the first several years of noise exposure [Rosler 1994]. NIHL can result from short duration exposures to high noise levels or even from a single exposure to an impulsive noise or a continuous noise, depending on the intensity of the noise and the individual's susceptibility to NIHL [AIHA 2022]. Noise exposed workers can develop substantial NIHL before it is clearly recognized. Even mild hearing losses can impair one's ability to understand speech and hear many important sounds. In addition, some people with NIHL also develop tinnitus. Tinnitus is a condition in which a person perceives hearing sound in one or both ears, but no external sound is present. Persons with tinnitus often describe hearing ringing, hissing, buzzing, whistling, clicking, or chirping like crickets. Tinnitus can be intermittent or continuous and the perceived volume can range from soft to loud. Currently, no cure for tinnitus exists.

Noise measurements are usually reported as dBA. A-weighting is used because it approximates the "equal loudness perception characteristics of human hearing for pure tones relative to a reference of 40 dB at a frequency of 1 kHz" and is considered to provide a better estimation of hearing loss risk than using unweighted or other weighting measurements [Murphy et al. 2022]. The dB unit is dimensionless, and it represents the logarithm of the ratio of the squares of the measured sound pressure to a reference sound pressure of 20 micropascals. The reference pressure is defined as the threshold of normal human hearing at a frequency of 1 kHz. Because the dB is logarithmic, an increase of 3 dB is a doubling of the sound energy, an increase of 10 dB is a 10-fold increase, and an increase of 20 dB is a 100-fold increase in sound energy. Noise exposures expressed in dB or dBA cannot be averaged using the arithmetic mean.

Workers exposed to noise should have baseline and yearly hearing tests (audiograms) to evaluate their hearing thresholds and determine whether their hearing has changed over time. Hearing testing should be done in a quiet location, such as an audiometric test booth, where background noise does not interfere with accurate measurement of hearing thresholds. In workplace hearing conservation programs, hearing thresholds must be measured at frequencies of 0.5 kHz, 1 kHz, 2 kHz, 3 kHz, 4 kHz, and 6 kHz. NIOSH also recommends testing be done at 8 kHz [NIOSH 1998].

The OSHA hearing conservation standard requires analysis of hearing changes from baseline hearing thresholds to determine if a standard threshold shift (STS) has occurred. OSHA defines an STS as a change in hearing threshold relative to the baseline hearing test of an average of 10 dB or more at 2 kHz, 3 kHz, and 4 kHz in either ear [29 CFR 1910.95]. If an STS occurs, the company must determine if the hearing loss also meets the requirements to be recorded on the OSHA Form 300 Log of Work-Related Injuries and Illnesses [29 CFR 1904.1]. In contrast to OSHA, NIOSH defines a significant threshold shift as an increase in the hearing threshold level of 15 dB or more, relative to the baseline audiogram, at any test frequency in either ear measured twice in succession [NIOSH 1998].

Hearing test results are often presented in an audiogram, which is a plot of an individual's hearing thresholds (*y*-axis) at each test frequency (*x*-axis). HTLs are plotted such that fainter sounds are shown at the top of the *y*-axis, and more intense sounds are plotted below. Typical audiograms show HTLs from −10 or 0 dB to about 100 dB. Lower frequencies are plotted on the left side of the audiogram, and higher frequencies are plotted on the right.

NIHL often manifests itself as a "notch" at 3 kHz, 4 kHz, or 6 kHz, depending on the frequency spectrum of the workplace noise and the anatomy of the individual's ear [Mirza et al. 2018; Osguthorpe and Klein 1991; Schlauch and Carney 2011; Suter 2002]. A notch in an individual with normal hearing may indicate early onset of NIHL. A notch is defined as the frequency where the HTL is preceded by an improvement of at least 10 dB at the previous test frequency and followed by an improvement of at least 5 dB at the next test frequency.

NIOSH has an REL for noise of 85 dBA as an 8-hour TWA. For calculating exposure limits, NIOSH uses a 3-dB time/intensity trading relationship, or exchange rate. Using this criterion, an employee can be exposed to 88 dBA for no more than 4 hours, 91 dBA for 2 hours, 94 dBA for 1 hour, 97 dBA for 0.5 hours, etc. Exposure to impulsive noise should never exceed a peak level of 140 dBA. For extended work shifts, NIOSH adjusts the REL to 84.5 dBA for a 9-hour shift, 84.0 dBA for a 10-hour shift, 83.6 dBA for an 11-hour shift, and 83.2 dBA for a 12-hour work shift. When noise exposures exceed the REL, NIOSH recommends the using hearing protection and implementing a hearing loss prevention program [NIOSH 1998].

The OSHA noise standard specifies a PEL of 90 dBA and an AL of 85 dBA, both as 8-hour TWAs. OSHA uses a less conservative 5-dB exchange rate for calculating the PEL and AL. Using the OSHA criterion, an employee may be exposed to noise levels of 95 dBA for no more than 4 hours, 100 dBA for 2 hours, 105 dBA for 1 hour, 110 dBA for 0.5 hours, etc. Exposure to impulsive noise must not exceed 140 dB peak noise level. OSHA does not adjust the PEL for extended work shifts. However, the AL is adjusted to 84.1 dBA for a 9-hour shift, 83.4 dBA for a 10-hour shift, 82.7 dBA for an 11-hour shift, and 82.1 dBA for a 12-hour work shift. OSHA requires implementation of a hearing conservation program when noise exposures exceed the AL [29 CFR 1910.95].

An employee's daily noise dose, based on the duration and intensity of noise exposure, can be calculated according to the formula: Dose = $100 \times (C_1/T_1 + C_2/T_2 + ... + C_n/T_n)$, where C_n indicates the total time of exposure at a specific noise level, and Tn indicates the reference exposure duration for which noise at that level becomes hazardous. A noise dose greater than 100% exceeds the noise exposure limit.

Section E: References

Discussion

Driscoll DP [2022]. Noise control engineering. In: Meinke DK, Berger EH, Driscoll DP, Neitzel RL, Bright K, eds. The noise manual. 6th ed. Falls Church VA: American Industrial Hygiene Association, pp. 201–264.

NIOSH [1998]. Criteria for a recommended standard: occupational noise exposure (revised criteria 1998). Cincinnati, OH: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 98-126, https://www.cdc.gov/niosh/docs/98-126/default.html.

Smalt CJ, Ciccarelli GA, Rodriguez AR, Murphy WJ [2021]. A deep neural-network classifier for photograph-based estimation of hearing protection attenuation and fit. J Acoust Soc Am *150*(2):1067–1075, https://doi.org/10.1121/10.0005820.

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ACGIH [2024]. 2024 TLVs and BEIs: threshold limit values for chemical substances and physical agents and biological exposure indices. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

AIHA [2022]. The noise manual. 6th ed. Meinke DK, Berger EH, Driscoll DP, Neitzel RL, Bright K, eds. Falls Church, VA: American Industrial Hygiene Association.

CFR [2025]. Code of Federal Regulations. Washington, DC: U.S. Government Printing Office, Office of the Federal Register, https://www.ecfr.gov/.

Kerns E, Masterson EA, Themann CL, Calvert GM [2018]. Cardiovascular conditions, hearing difficulty, and occupational noise exposure within U.S. industries and occupations. Am J Ind Med *61*(6):477–491, https://doi.org/10.1002/ajim.22833.

Mirza R, Kirchner DB, Dobie RA, Crawford J [2018]. Occupational noise-induced hearing loss. American College of Occupational and Environmental Medicine (ACOEM) guidance statement. J Occup Environ Med *60*(9):e498–e501, https://doi.org/10.1097/JOM.0000000000001423.

Murphy WJ, Kardous CA, Brueck SE [2022]. Sound measurement: instrumentation and noise metrics. In: The noise manual. 6th ed. Falls Church, VA: American Industrial Hygiene Association.

NIOSH [1998]. Criteria for a recommended standard: occupational noise exposure (revised criteria 1998). Cincinnati, OH; U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 98-126, https://www.cdc.gov/niosh/docs/98-126/default.html.

NIOSH [2007]. NIOSH pocket guide to chemical hazards. Cincinnati, OH: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 2005-149, http://www.cdc.gov/niosh/npg/.

Osguthorpe JD, Klein AJ [1991]. Occupational hearing conservation. Otolaryngol Clin North Am *24*(2):403–414, https://doi.org/10.1016/S0030-6665(20)31147-6.

Rosler G [1994]. Progression of hearing loss caused by occupational noise. Scand Audiol *23*(1):13–37, https://doi.org/10.3109/01050399409047483.

Schlauch RS, Carney E [2011]. Are false-positive rates leading to an overestimation of noise-induced hearing loss? J Speech Lang Hear Res *54*(2):679–692, https://doi.org/10.1044/1092-4388(2010/09-0132).

Suter AH [2002]. Hearing conservation manual. 4th ed. Milwaukee, WI: Council for Accreditation in Occupational Hearing Conservation.

Tak S, Davis RR, Calvert GM [2009]. Exposure to hazardous workplace noise and use of hearing protection devices among U.S. workers—NHANES, 1999–2004. Am J Ind Med *52*(5):358–371, https://doi.org/10.1002/ajim.20690.

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