# Evaluation of Noise Exposures at a Gray and Ductile Iron Foundry

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The cover photo is a close-up image of sorbent tubes, which are used by the HHE Program to measure airborne exposures. This photo is an artistic representation that may not be related to this Health Hazard Evaluation. Photo by NIOSH.

# Highlights of this Evaluation

The Health Hazard Evaluation Program received a request from a gray and ductile iron foundry. The employer was concerned about high noise levels.

## What We Did

- We measured the amount of noise employees were exposed to in several production areas.
- We measured sound levels and noise frequencies at work equipment and during different work activities.

## What We Found

- Noise levels in many work areas were very high (above 100 decibels). Most noise was caused by metal-to-metal contact, grinders and saws, compressed air, and vibration from equipment and shaker conveyors.
- All employees we monitored were exposed to noise above noise exposure limits, and some employees noise exposures were above 100 decibels, A-weighted.
- Some employees did not insert their foam earplugs properly.

We measured noise levels and noise exposures in a gray and ductile iron foundry. All employees we monitored had noise exposures greater than noise exposure limits. We recommended installing noise controls and reducing noise exposure by replacing current equipment with less noisy equipment.

## What the Employer Can Do

- Install noise controls to reduce noise caused by metal-to-metal contact, grinders and saws, compressed air, and vibration from equipment and shaker conveyors.
- Consult with equipment makers when purchasing new equipment or replacing equipment to get equipment that makes the least amount of noise.
- Require employees working in areas where noise exposures are above 100 decibels, A-weighted to wear earplugs and earmuffs.
- Make sure employees wear their hearing protection properly.
- Use National Institute for Occupational Safety and Health recommendations for evaluating employees' hearing tests.

## What Employees Can Do

- Wear hearing protection properly to help prevent hearing loss.
- Wear earplugs and earmuffs when working at the 30-inch grinders, chop saws, V-8 chipper/grinder, molding area, and shakeout/knockoff areas.
- Tell your doctor that you work in areas with high noise levels and about hearing problems you have.

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# Abbreviations

| | |
|---|---|
| AL | Action level |
| CFR | Code of Federal Regulations |
| dB | Decibels |
| dBA | Decibels, A-weighted |
| Hz | Hertz |
| NIOSH | National Institute for Occupational Safety and Health |
| NIHL | Noise induced hearing loss |
| OEL | Occupational exposure limit |
| OSHA | Occupational Safety and Health Administration |
| PEL | Permissible exposure limit |
| REL | Recommended exposure limit |
| TLV® | Threshold limit value |
| TWA | Time-weighted average |
| WEEL™ | Workplace environmental exposure level |

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## Introduction

The Health Hazard Evaluation Program received a request from a gray and ductile iron foundry. The employer was concerned about noise exposures in the molding, knockoff, grinding, and inspection areas. The company was seeking guidance on noise control solutions for these work areas. The Occupational Safety and Health Administration (OSHA) had inspected the foundry in 2010 and suggested that the company contact the Health Hazard Evaluation Program for additional noise evaluation. We visited the facility in April 2011 to discuss concerns with managers and employees, observe work activities and processes, measure noise levels in the knockoff area, and assess potential noise control options. We provided a summary of personal noise measurement results and preliminary noise control recommendations in an interim report in July 2012.

The foundry had three production buildings, which the company designated as plant 1, plant 2, and plant 3. In the knockoff areas iron castings were separated from the metal riser and runner gatings (excess metal from the casting process) by striking the gating with a sledgehammer. For some castings, large chop saws were used to remove gating. Following gating removal, rough metal edges on most of the castings were smoothed using large stationary abrasive stone grinders or shotblast tumblers. Sometimes hand-held grinders were used. Plant 1 had four small grinding booths with approximately 300 square feet of floor area in each booth, designed to limit noise emitted to adjacent work areas. Employees working in these booths used 10-inch stationary grinders and smaller hand-held grinders. Plant 1 also had 30-inch grinders and V-8 chipper/grinders. These grinders were not housed in booths, so were open to adjacent areas. Plant 2 housed mold preparation machines, shakeout/knockoff areas, inspection areas, cast sorting, and 30-inch grinders. Employees in plant 3 used chop saws to remove gating and used hand-held pneumatic chisels and grinders to smooth rough edges on engine part castings. The foundry operated three shifts per day and had about 200 employees. Employees worked 10-hour shifts. Part of the third shift overlapped with the second shift.

## Methods

Our primary objectives were to evaluate employees' noise exposures, sound levels and noise frequencies, and possible noise control options.

We measured employees' full-shift time-weighted average (TWA) noise exposures on the first, second, and third shifts. We monitored eight employees during the first shift, two employees during the second shift, and five employees during the third shift. We used Larson Davis Spark™ model 706RC integrating noise dosimeters. We placed the dosimeter microphone on the top of the employee's shoulder at the midpoint between the neck and edge of the shoulder. The dosimeters simultaneously collected data using three different settings to allow comparison of noise measurement results with three different noise exposure limits, the OSHA permissible exposure limit (PEL), the OSHA action level (AL), and the National Institute for Occupational Safety and Health (NIOSH) recommended exposure limit (REL). OSHA uses a 5-decibel (dB) exchange rate, and NIOSH uses a 3-dB exchange rate. The exchange rate refers to the amount of dB by which the sound level may increase if the exposure time is halved, or decrease if exposure time is doubled. NIOSH considers noise measured using the 3-dB exchange rate to more accurately relate to hearing loss risk. Additional information on noise exposure limits and health effects is provided in Appendix B.

We used Larson Davis Model 824 integrating sound level meters and frequency analyzers to measure sound levels and one-third octave band noise frequency levels (i.e., measurement of noise levels across 30 different frequencies). For most measurements we positioned the instrument, either by using a tripod or holding by hand, at a height of approximately 5 feet above the floor and within 3–6 feet of the employees or the primary noise source in the vicinity.

We also reviewed the company's hearing conservation program and results of audiometric testing from 2010 and 2011.

# Results and Discussion

## Personal Noise Dosimetry Measurements

We compared employees' noise monitoring results to the noise exposure limits set by OSHA and NIOSH. These noise exposure limits are meant to be 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 above. For an 8-hour work shift, the OSHA AL is 85 decibels, A-weighted (dBA), and the OSHA PEL is 90 dBA. The NIOSH REL is 85 dBA. For a 10-hour work shift, the OSHA AL is 83.4 dBA and the NIOSH REL is 84 dBA, but the OSHA PEL stays at 90 dBA. Employers are required to keep noise exposures below OSHA limits. However, NIOSH considers its REL to be more protective.

Results from the personal noise dosimetry measurements are in Table 1. All participants' TWA noise exposures exceeded the OSHA AL, OSHA PEL, and NIOSH REL. Using the OSHA PEL noise measurement criterion, full-shift noise exposures were 91.3–103.6 dBA. Employees in the V-8 chipper/grinder area and shakeout/knockoff areas had TWA noise exposures that were above 100 dBA. Using the NIOSH criterion, employees with TWA noise exposures greater than 100 dBA included those at the 30-inch grinder, chop saw, V-8 chipper/grinder, molding, and shakeout/knockoff areas. Our noise measurement results are similar to those OSHA reported following an inspection in 2010. OSHA full-shift TWA noise measurements were 95.1–99.4 dBA, using the OSHA PEL noise measurement criterion.

Table 1. Time-weighted average personal noise measurement results

| Plant | Job location | Shift | Duration (h:mm) | OSHA AL TWA (dBA) | OSHA PEL TWA (dBA) | NIOSH REL TWA (dBA) |
|---|---|---|---|---|---|---|
| 1 | 30-inch grinder | 1 | 9:59 | 94.4 | 93.6 | 97.7 |
| 1 | 30-inch and booth 4 grinder | 1 | 9:46 | 98.7 | 98.4 | 101.8 |
| 1 | Chop saw and spin blast | 1 | 9:11 | 99.3 | 98.9 | 105.9 |
| 1 | V-8 chipper/grinder | 2 | 9:24 | 103.7 | 103.6 | 105.7 |
| 1 | V-8 chipper/grinder | 2 | 9:28 | 97.4 | 97.2 | 99.3 |
| 2 | 30-inch grinder | 1 | 9:36 | 99.0 | 98.9 | 101.0 |
| 2 | 30-inch grinder | 3 | 9:48 | 96.1 | 96.0 | 97.2 |
| 2 | Casting sorter | 1 | 9:35 | 98.0 | 97.9 | 98.8 |
| 2 | Casting sorter | 3 | 9:49 | 95.6 | 95.6 | 96.3 |
| 2 | Inspector | 3 | 9:45 | 95.5 | 95.2 | 97.6 |
| 2 | Mold machine 2547 | 3 | 10:01 | 92.8 | 91.3 | 94.2 |
| 2 | Mold machine 797 | 1 | 9:14 | 98.2 | 98.2 | 101.2 |
| 2 | Shakeout/knockoff | 1 | 9:34 | 101.5 | 101.5 | 102.4 |
| 2 | Shakeout/knockoff | 3 | 9:48 | 99.4 | 99.3 | 100.5 |
| 3 | Chop saw | 1 | 8:27 | 97.8 | 97.3 | 101.3 |
| Noise exposure limits (8-hour work shift) | | | | 85 | 90 | 85 |
| Noise exposure limits (10-hour work shift) | | | | 83.4 | 90 | 84 |

## One-third Octave Band Noise Frequency Spectrum Measurements and Noise Controls

Most workplace noise is broadband noise, which is widely distributed over a wide range of frequencies. For analysis of the frequency distribution characteristics of workplace noise, the frequency spectrum is broken into smaller frequency bands called bandwidths, the most common being the octave band (defined as a frequency band where the upper band frequency is twice the lower band-edge frequency). The one-third octave band further divides each of the single octave bands into three smaller frequency bands to provide even more detailed information about the noise frequency distribution characteristics. This information is useful for identifying the dominant frequencies of noise sources and determining appropriate engineering controls or other noise reduction measures. For example, if low frequency noise is dominant (i.e., the highest sound levels occur in frequencies of 500 Hertz [Hz] or less), noise is likely generated by vibration, and noise controls that reduce or isolate the vibration from tools or equipment might help decrease noise levels. If high frequency noise is dominant (i.e., the highest sound levels occur in frequencies of 3,000 Hz or greater), the most effective approach for noise reduction is to use noise enclosures, barriers, or sound absorption [Driscoll and Royster 2003].

One-third octave band noise measurement results are provided in Appendix A. Predominant noise sources included noise from metal-to-metal contact, vibration noise from equipment and metal surfaces after impact, machine noise from abrasive grinders and metal saws, and noise from use of compressed air and from release of air from pneumatic tools.

## Metal-to-Metal Contact Noise

Noise from metal-to-metal contact was a substantial contributor to employees' noise exposures throughout the facility. Metal-to-metal noise occurred primarily when metal castings or riser and runner gatings were dropped, dumped, or tossed into metal-sided bins or onto flat metal shaker conveyors. Noise was also generated by castings and gatings bouncing on shaker pans. Employees in the knockoff areas were exposed to impact noise when using sledgehammers to remove riser and runner gatings. In addition to noise from direct metal impacts, noise was also generated by vibration and noise reverberation of the metal surfaces that were struck, particularly when a metal bin was empty or mostly empty.

Figure 1 shows large finished metal castings falling from a shaker conveyor into metal bins. Average noise levels when the castings were moving down the shaker conveyor and falling into the bin were 103 dBA. This noise resulted from castings bouncing on the shaker conveyor, mechanical noise from the shaker conveyor, and impact noise from parts falling into the bin. Peak noise levels reached 128 dB when castings fell up to 5 feet into the metal bin and struck the bottom or side.

Figure 1. NIOSH investigator taking sound level and octave band noise frequency spectrum measurements while metal castings drop from shaker conveyor into metal bins. Photo by NIOSH.

Figure 2 shows castings from the shotblast shaker conveyor that had dropped onto another shaker conveyor. Noise from the combined operation of the shotblast, operation of the shaker conveyor, and metal impacts as parts bounced on the shaker conveyor and dropped from one conveyor onto another were about 98 dBA. Peak levels reached 118 dB. The shaker conveyor at the shotblast had a rubber-like coating on it, but the coating material had worn away in several places.


Figure 2. Metal castings dropping from shaker conveyor at the shotblast onto another conveyor below. Photo by NIOSH.

In some locations employees tossed castings several feet from the work area into a metal bin. At the chop saw and knockoff area, after removing risers and runners from castings using metal sledge hammers, employees tossed the casting several feet to the metal bin behind the work station (Figure 3). Noise levels were slightly above 100 dBA during sledgehammer strikes and averaged 105–110 dBA when castings were tossed into the metal bin, reaching peak levels of 136 dB. At the 30-inch grinder in plant 1, average noise levels were 102 dBA when an employee tossed castings into the nearby bin. Peak levels were up to 130 dB from metal impacts.

Figure 3. Metal bin into which employees tossed castings after using a sledgehammer to remove riser and runner gating. Photo by NIOSH.

At the elevated inspection station employees tossed castings by hand from the inspection conveyor onto downward sloping metal slide pans. Castings slid downward to grinder stations about 15 feet from the inspection station. Background noise levels in this area were 97–99 dBA, primarily from the shaker conveyor located about 10 feet behind the casting sorter workstation and the barrel house shakeout located about 20 feet from the casting sorter workstation. Peak noise levels reached 124 dB from impact of metal castings on the slide pans.

Some of the slide pans were mounted flush with the inspection conveyor, and some were positioned approximately 18 inches above the inspection conveyor (Figure 4). Tossing the castings the greater distance to the slide pans mounted above the inspection conveyor produced higher impact noise levels. The slide pans were constructed of two metal layers with textile damping material in between. However, the top metal layer on the pans had separated and was arching in the middle (Figure 5). This created a small gap between the layers, decreasing noise damping and likely generating some reverberant noise between the layers as castings struck the top metal layer.

Reducing the speed and force of impacts and reducing vibration and resulting reverberant ringing of flat metal surfaces after impact can help decrease metal-to-metal noise. Overall noise reduction strategies include reducing the distance that metal castings fall or are tossed, increasing the thickness or damping of metal surfaces on bins and shaker conveyors, covering metal surfaces with durable polymers, replacing metal bins with durable plastic bins, and changing work practices so that employees more gently place or drop castings into bins or conveyors.

Figure 4. Multiple metal slide pans positioned either flush with or above the inspection station conveyor. Photo by NIOSH.

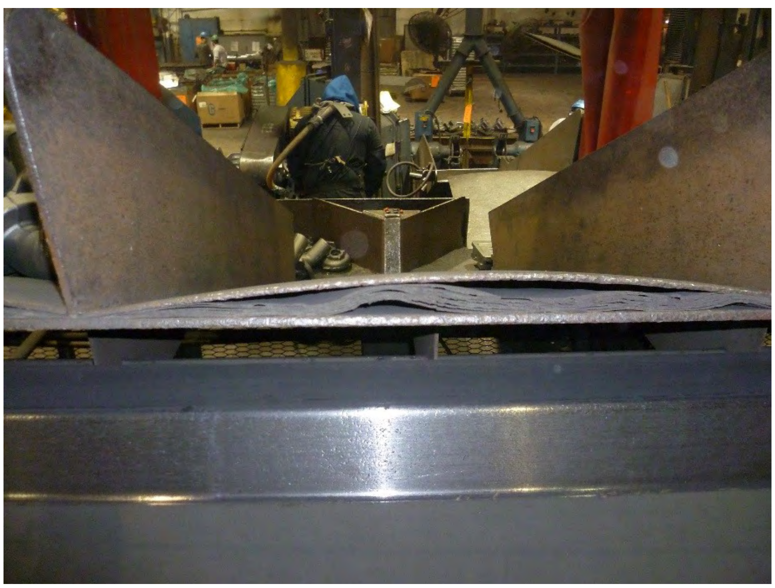

Figure 5. Close-up photo showing the top edge of the downward sloping metal slide pan at the inspection station. Photo by NIOSH.

## Noise from Vibration of Equipment

The barrel house shakeout was a substantial source of low frequency noise throughout plant 2, primarily caused by transmission of vibration from the shakeout to the surrounding floor surfaces. One-third octave band noise frequency measurements taken near the entrance and exit of the barrel house shakeout revealed that the highest noise levels (121 dB) were at the lowest one-third octave band frequency (12.5 Hz). Secondarily, one-third octave band noise levels at the barrel house shakeout were 103–109 dB at 25 Hz. Figure A1 in Appendix A shows the significant effect of low frequency noise from the barrel house shakeout at the plant 2 knockoff and casting areas. Noise levels at 12.5 Hz in these work areas were 109–110 dB. Although the barrel house shakeout was mounted on heavy-duty vibration isolation springs (Figure 6), the high noise levels at these low frequencies may indicate that the springs were not effectively reducing transmission of vibration from the equipment to surrounding surfaces. Additional vibration damping or different vibration isolation springs may be needed to decrease low frequency noise.

Knockoff areas and several other locations in the foundry had shaker conveyors to help shake excess sand off and move the castings. Vibration of the shaker pan and frame also generated and transmitted mechanical vibration, though not as substantially as the barrel house. Employees working at the plant 2 shakeout/knockoff area had full-shift TWA noise exposures greater than 100 dBA. Reducing the low frequency noise at the barrel house shakeout and shaker conveyors may also reduce these employees' noise exposures.

Figure 6. Vibration isolation springs on barrel house shakeout. Photo by NIOSH.

Octave band noise frequency spectrum measurements taken at the shotblast showed that the predominant noise was at 31.5–40 Hz and 250–315 Hz (Figure A2 in Appendix A). Comparison of background measurements taken near the shotblast to measurements taken close to the shotblast motor indicate that vibration from operation of the shotblast was generating noise primarily at 31.5–40 Hz; whereas, the shotblast motor was primarily generating noise at 250–315 Hz. Low frequency noise could most likely be decreased by improving vibration damping of the shotblast unit and the shotblast motor mounts.

## Noise from Abrasive Grinders and Metal Saws

Employees in several work areas used hand-held grinders, swing grinders, large 30-inch fixed grinders, or large chop saws to prepare castings or remove gating. In general, noise from abrasive grinders and chop saws is caused by movement of air and from cutting or grinding. Air noise in grinders, and more significantly in saws, is generated by the movement of air at the outer edges of the grinding wheel or saw blade during use. Number, configuration, and angle of saw blade teeth can affect noise levels and frequency of noise. In general, noise tends to increase as rotational speed of the saw blades or grinder wheels increase. Likewise, predominant noise frequencies can vary with saw blade or grinding wheel speed. Pneumatic powered hand-held grinders also generate noise from release of air during grinding.

In addition to air noise from the grinding wheel or saw blade, noise from grinding or cutting was also generated by the direct action (caused by friction) of the abrasive grinding wheel or sawblade teeth on the casting. Noise levels and the frequency characteristics of noise can vary depending on the size and configuration of the casting. Larger or thicker castings may have more natural damping and generate less noise or lower frequency noise, whereas thinner castings with less natural damping may generate more noise and higher frequency noise from increased vibrational ringing of the casting. Saw noise can also be caused by vibration of the blade during cutting. Additionally, during grinding on some of the large heavy castings, especially at the large 30-inch grinders, vibration from the grinding process can be transmitted through the casting, tool rest, and grinder body to the floor.

One-third octave band noise frequency spectrum analysis in grinding booth #1 in plant 1 during use of a hand grinder or a 30-inch grinder to grind large disc shaped castings shows that predominant noise frequencies were 1,600–3,150 Hz and 31.5 Hz (Figure A3 in Appendix A). Noise in the higher frequencies is most likely caused directly by the grinding process. Additionally, high noise levels at 12,500 Hz from measurements during hand grinding and air chisel use likely indicate noise caused by release of compressed air during use of the pneumatic chisel. The low frequency noise at 31.5 Hz and secondarily at 63–80 Hz may be a result of vibration transmitted to the floor through the 30-inch grinder or through the roller conveyor, which is used as a work surface to hold the large casting during hand grinding. The conveyor used as a work surface for hand grinding and the 30-inch grinder were connected directly to the floor (Figure 7), but neither had vibration isolation pads to help restrict vibration transmission. Similarly, the bottoms of the legs on the small metal table sometimes used to hold oversized castings during grinding did not have vibration isolation pads (Figure 8). Overall, sound levels during hand grinding and when using the 30-inch grinder were about 101 dBA and reached peaks of 118 dB. For noise reduction in some of the grinding booths, the company had lined the interior walls with perforated metal or acoustic noise reduction blankets. Although most of the employees' noise exposures in the grinding booths were directly from the tools or equipment they were using, these wall coverings can help reduce some of the reverberant noise in these spaces. However, we observed that in some cases the perforated metal openings were filled with dust or the acoustic blankets were dirty. Both of these conditions can reduce the effectiveness of these noise controls.

Figure 7. Employee in a grinding booth using a hand grinder to smooth the surface of a large casting. The employee is wearing a loose-fitting supplied air hood to reduce air contaminant exposures during grinding. Photo by NIOSH.

Figure 8. An employee in a grinding booth using the 30-inch grinder to smooth the outside edges of a large casting. The employee is wearing a loose-fitting supplied air hood to reduce air contaminant exposures during grinding. Photo by NIOSH.

One-third octave band noise frequency measurements at the swing grinder in plant 1 (Figure 9) showed that the predominant noise frequencies were 8,000–16,000 Hz (Figure A4 in Appendix A). Overall sound levels ranged from 95–102 dBA when grinding and 78–80 dBA when the employee was not grinding. Because the noise characteristics are high frequency, a noise barrier could help reduce the operator's noise exposure. The operator at the swing grinder placed a square rubber mat on the surface of the metal swing grinder table and under the casting to create a nonslip surface and keep the casting in place during grinding. This mat may have also helped to dampen noise of the casting during grinding.


Figure 9. NIOSH investigator taking one-third octave band noise frequency spectrum measurement at a swing grinder. Photo by NIOSH.

Figure A5 in Appendix A shows one-third octave band measurements during use of a chop saw in plant 1 and in plant 2 (Figure 10). Although these chop saws were located in different buildings, noise frequency characteristics were nearly identical. The only difference was that the one-third octave band results for the plant 2 chop saw showed substantial low frequency noise at frequencies less than 20 Hz. However, this low frequency noise was from the barrel house shakeout in plant 2 rather than the chop saw. Sound levels during use of the chop saws were nearly 114 dBA. The chop saw blades did not have vibration damping collars.

Figure 10. Employee cutting excess gating off casting at a large chop saw. Photo by NIOSH.

## Noise from Compressed Air

Compressed air nozzles were used for cleaning debris off castings or work surfaces in several work areas. Figure 11 provides an example of a gun-type nozzle used in the molding area. We also observed that in some work areas employees used nozzles made from a thin length of hollow metal tubing. Blowing air out of an open tube, regardless of whether it is a gun-shaped nozzle or a straight length of tubing, generates substantial air turbulence that causes high noise levels as the air exits the tip of the tube. These types of nozzles also use significantly more compressed air than necessary and are therefore much more costly. Some manufacturers of engineered compressed air nozzles have shown that open tube nozzles generate up to 10 dB more noise than properly engineered nozzles. Additionally, the open tube design can present a safety risk because the nozzle does not have a mechanism to reduce air pressure to less than 30 pounds per square inch if the end of the nozzle becomes blocked.

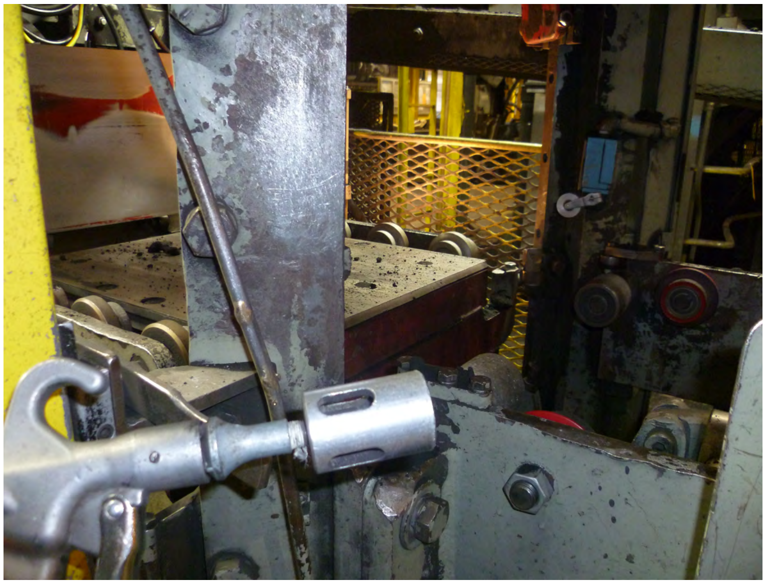

Figure 11. Compressed air nozzle used in the molding area. Photo by NIOSH.

### "Buy Quiet" Noise Control Program (Header 3)

Because effective noise engineering controls can be challenging to design and implement, noise reduction should be considered as 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 their procurement process. Purchasers can compare noise emission levels for differing models of equipment and, whenever possible, choose the quieter equipment.

### Hearing Conservation Program

The company included all employees in a hearing conservation program and provided yearly audiometric testing. We reviewed audiometric test results for about 100 employees in 2010 and 2011. In 2010, seven employees had hearing threshold shifts, but the employees did not have repeat audiometric testing to confirm the threshold shifts. When a hearing threshold shift is identified during audiometry, NIOSH recommends an immediate retest audiogram. If the retest does not show a threshold shift, the retest audiogram should become the test of record. If the retest shows a threshold shift, NIOSH recommends additional audiometric testing to confirm the hearing threshold shift. In 2011, no employees had hearing threshold shifts.

The company offered three models of earplugs and an earmuff. All employees we saw in the foundry wore foam insert earplugs. However, we observed that some employees did not properly insert their hearing protection, which can substantially reduce the ability of the hearing protectors to attenuate noise. None of the employees wore dual hearing protection, a combination of insert earplugs and earmuffs.

# Conclusions

Employees' TWA noise exposures in all jobs we monitored exceeded the NIOSH REL, OSHA PEL, and OSHA AL. Using the NIOSH noise measurement criterion, employees working in the 30-inch grinder, chop saw, V-8 chipper/grinder, molding, and shakeout/knockoff areas had TWA noise exposures greater than 100 dBA. We recommend installing noise controls and implementing a Buy Quiet program to help reduce noise exposures. We also recommend that employees exposed to TWA noise levels above 100 dBA wear dual hearing protection.

# Recommendations

On the basis of our findings, we recommend the actions listed below. We encourage the company to use a labor-management health and safety committee or working group to discuss our recommendations and develop an action plan. Those involved in the work can best set priorities and assess the feasibility of our recommendations for the specific situation at this company.

Our recommendations are based on an approach known as the hierarchy of controls (Appendix B: Occupational Exposure Limits and Health Effects). This approach groups actions by their likely effectiveness in reducing or removing hazards. In most cases, the preferred approach is to eliminate hazardous materials or processes and install engineering controls to reduce exposure or shield employees. Until such controls are in place, or if they are not effective or feasible, administrative measures and personal protective equipment may be needed.

## Elimination and Substitution

Eliminating or substituting hazardous processes or materials reduces hazards and protects employees more effectively than other approaches. Prevention through design, considering elimination or substitution when designing or developing a project, reduces the need for additional controls in the future.

1. Replace shaker conveyors with belt-driven conveyors, where feasible.

## Engineering Controls

Engineering controls reduce employees' exposures by removing the hazard from the process or by placing a barrier between the hazard and the employee. Engineering controls protect employees effectively without placing primary responsibility of implementation on the employee. No single noise engineering control will likely reduce employees' noise exposures to below the noise exposure limits. However, a combination of multiple engineering controls can help reduce overall noise exposures.

1. In general, noise from metal-to-metal impact in foundry operations can be decreased by reducing the speed and force of impacts and by reducing vibration and reverberant ringing of flat metal surfaces after impact. Specifically,

a. Reduce the distance that metal castings or scrap gating pieces drop into bins and onto shaker pans or conveyors.
b. Use slide pans with an angle of 45 degrees or less to move castings or scrap pieces from one level to a lower level instead of allowing the pieces to drop straight down.
c. Place bins for castings and scrap metal close to workstations.
d. Increase the thickness of metal surfaces on shaker conveyors and walls of metal bins with thicker metal or constrained layer damped metal. Alternatively, replace metal bins with bins made of durable plastic polymer materials.
e. Attach resilient plastic polymer material to the surface of flat metal pans and shaker conveyors to reduce noise from metal casting bouncing or moving on these surfaces.
f. Modify work practices so that employees more gently place or drop castings into bins or conveyors.

2. Improving vibration isolation:

   a. Replace the vibration isolation springs at the barrel house shakeout with springs that decrease transmission of vibration. Using vibration isolation pads and increasing the damping of external surfaces of the barrel house shakeout may also help reduce noise.
   b. Ensure that all shaker conveyors are placed on vibration isolation springs or pads and, where possible, eliminate direct metal to metal connection to other structures of the shaker frame.
   c. Place 30-inch grinders on vibration isolation pads, and turn off the grinders when not in use.
   d. Place vibration isolation pads on the legs of the roller conveyors used to hold large castings in the grinding booths during hand grinding and on the legs of tables used to hold large castings at the 30-inch grinder.
   e. Place castings on vibration damping mats when hand grinding in the grinding booth in addition to using plywood.

3. Plant 2 Inspection Station:

   a. Position the top of all the slide pans so they are mounted flush with the inspection conveyor to make it easier for employees to slide castings rather than toss them.
   b. Repair the slide pans. Alternatively, replace them with slide pans made of a single layer of thick metal or constrained layer damped metal. It may also be possible to attach a surface layer of durable plastic composite material to the slide pans.

4. Swing grinder:

   a. Mount a lightweight clear acrylic panel to the handle of the swing grinder between the operator and the grinding wheel to act as a noise barrier.

b. Use a thicker rubber mat under the casting during grinding to improve noise damping.

c. Place the swing grinder and the work table on vibration isolation pads.

5. Contact the grinding wheel manufacturers to help identify and select grinding wheels that generate less noise. Decreasing the rotational speed of the grinding wheel may also reduce noise levels.

6. Contact the saw blade manufacturers to help identify and select saw blades that generate less noise. Using composite saw blades, keeping saw teeth sharp, and adding noise damping collars to saw blades can reduce noise levels.

7. Replace compressed air nozzles with nozzles that are designed to produce less turbulence and noise and that meet OSHA safety standards for maximum air pressure.

## Administrative Controls

The term administrative controls refers to employer-dictated work practices and policies to reduce or prevent hazardous exposures. Their effectiveness depends on employer commitment and employee acceptance. Regular monitoring and reinforcement are necessary to ensure that policies and procedures are followed consistently.

1. Consult with an acoustical engineer with experience in foundry noise control for additional guidance on noise control designs.

2. Implement a long-term strategy to reduce noise exposures by purchasing new equipment that generates less noise. Information on Buy Quiet programs can be found at http://www.cdc.gov/niosh/topics/buyquiet/.

3. Refer to OSHA's Technical Manual for additional information on noise and noise control at https://www.osha.gov/dts/osta/otm/new_noise/index.html. NIOSH has noise control information at http://www.cdc.gov/niosh/topics/noisecontrol/ and information on noise generated by power tools in the NIOSH power tools database at http://wwwn.cdc.gov/niosh-sound-vibration/.

4. Conduct noise measurement surveys after noise controls have been installed to evaluate whether the controls have adequately reduced noise levels and employees' noise exposures.

5. Immediately repeat audiometry when a monitoring audiogram shows a hearing threshold shift. If the retest does not show a hearing threshold shift, the retest audiogram should become the test of record. If the retest shows a threshold shift, NIOSH recommends additional audiometric testing within 30 days to confirm the hearing threshold shift. Review all audiometric test results each year to identify hearing loss trends across departments or job titles. Refer to NIOSH audiometric evaluation and monitoring recommendations at http://www.cdc.gov/niosh/docs/98-126/ for additional information on audiometric testing and hearing loss prevention programs.

6. Advise employees to report any hearing problems to their healthcare provider.

## Personal Protective Equipment

Personal protective equipment is the least effective means for controlling hazardous exposures. Proper use of personal protective equipment requires a comprehensive program and a high level of employee involvement and commitment. The right personal protective equipment must be chosen for each hazard. Supporting programs such as training, change-out schedules, and medical assessment may be needed. Personal protective equipment should not be the sole method for controlling hazardous exposures. Rather, personal protective equipment should be used until effective engineering and administrative controls are in place.

1. Require that all employees who work in areas where TWA noise exposures exceed 100 dBA (using NIOSH criteria) wear dual hearing protection, which includes earplugs and earmuffs. On the basis of our evaluation, this recommendation applies to employees in the 30-inch grinder, chop saw, V-8 chipper/grinder, molding, and shakeout/knockoff areas. Supervisors should be responsible for ensuring that all employees wear hearing protection properly.
2. Provide additional hands-on training for all employees and supervisors on how to insert hearing protectors properly and the importance of proper hearing protector fit.

# Appendix A: Figures

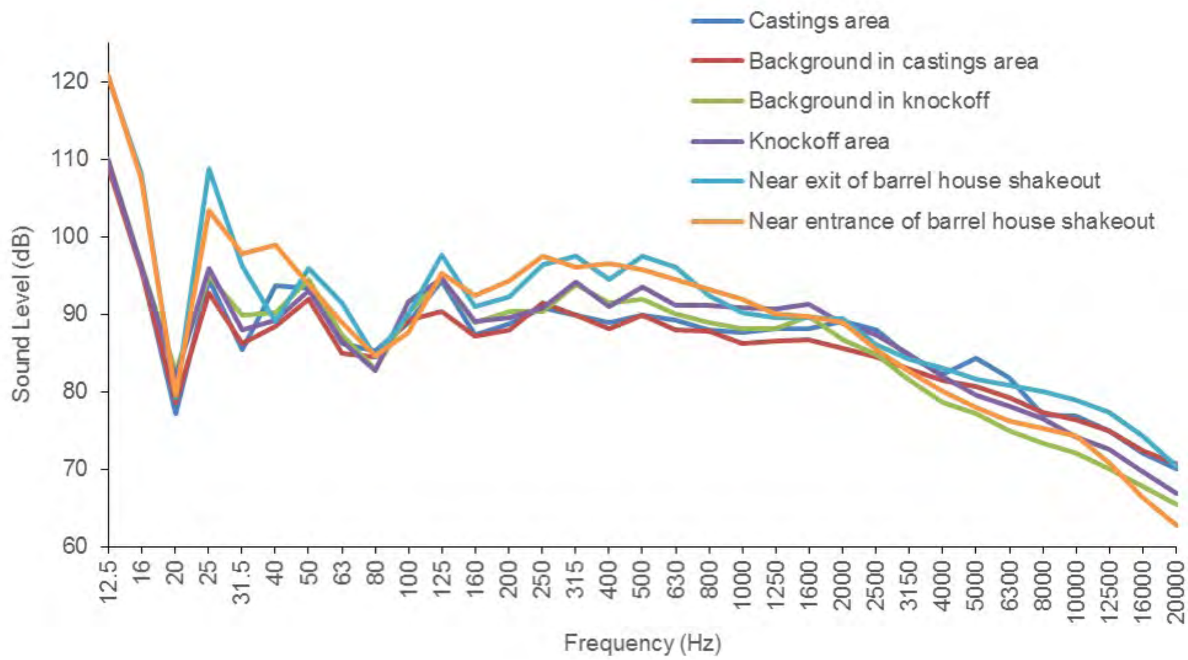


Figure A1. One-third octave band noise frequency spectrum measurements at the castings, knockoff, and barrel house shakeout in plant 2.

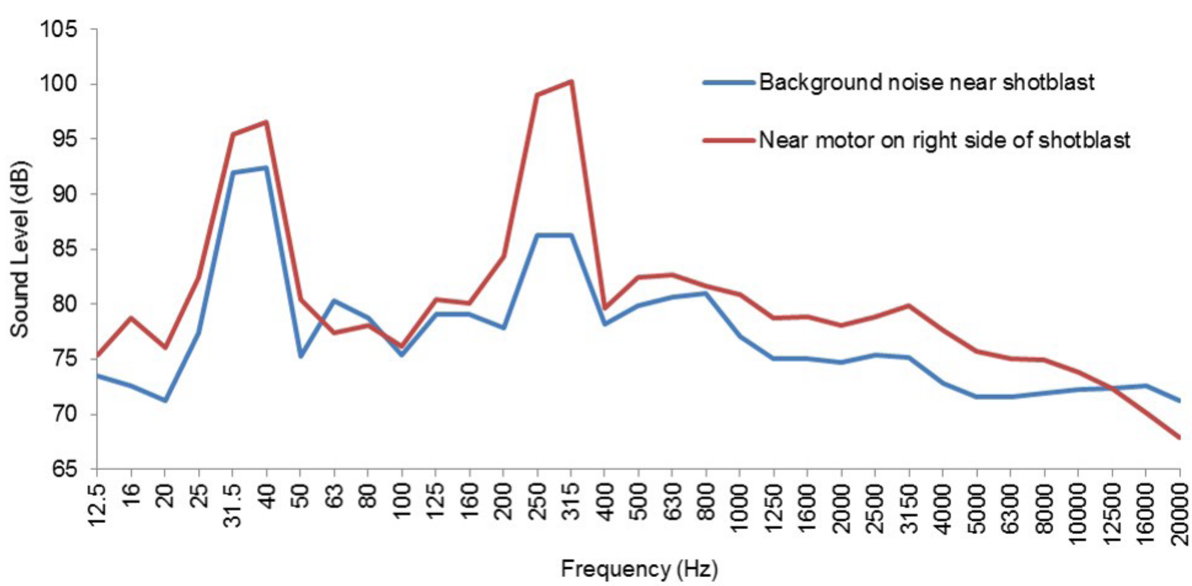


Figure A2. One-third octave band noise frequency spectrum measurements at the shotblast.

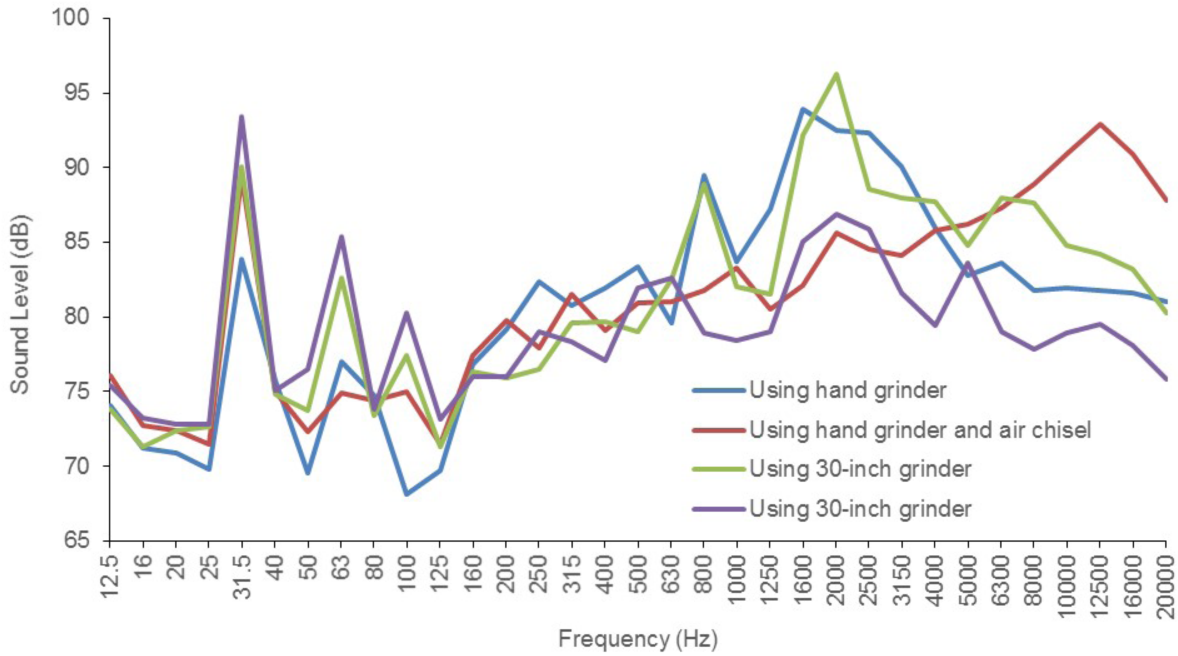


Figure A3. One-third octave band noise frequency spectrum measurements during use of hand grinders and 30-inch grinders.

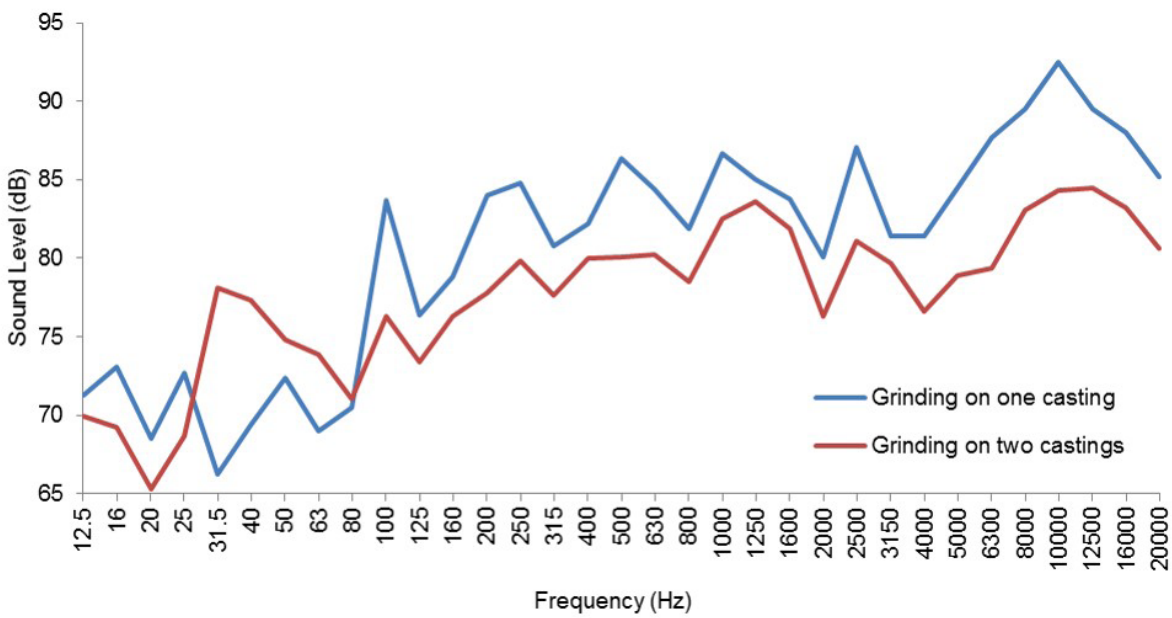


Figure A4. One-third octave band noise frequency spectrum measurements during use of the swing grinder in plant 1.

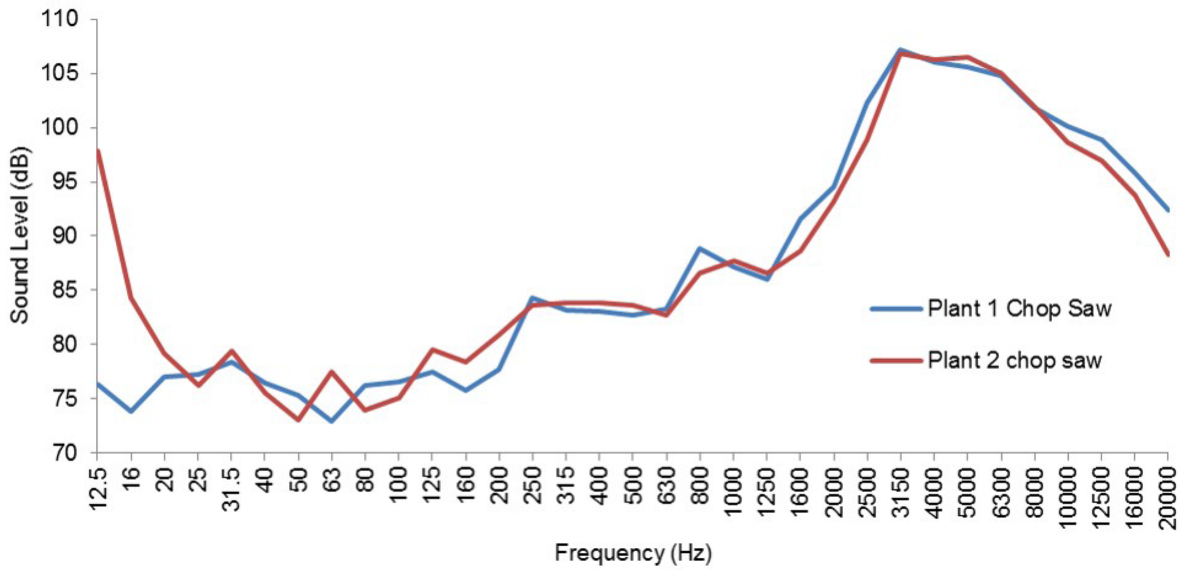


Figure A5. One-third octave band noise frequency spectrum measurements during use of chop saws.

# Appendix B: Occupational Exposure Limits and Health Effects

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 pre-existing 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 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 or ceiling values. Unless otherwise noted, the short-term exposure limit 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.

- The U.S. Department of Labor OSHA PELs (29 CFR 1910 [general industry]; 29 CFR 1926 [construction industry]; and 29 CFR 1917 [maritime industry]) are legal limits. These limits are enforceable in workplaces covered under the Occupational Safety and Health Act of 1970.
- NIOSH 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 2010]. NIOSH also recommends risk management practices (e.g., engineering controls, safe work practices, employee education/training, personal protective equipment, and exposure and medical monitoring) to minimize the risk of exposure and adverse health effects.
- Other OELs commonly used and cited in the United States include the threshold limit values (TLVs), which are recommended by the American Conference of Governmental Industrial Hygienists, a professional organization, and the workplace environmental exposure levels (WEELs), which are recommended by the American Industrial Hygiene Association, another professional organization. The TLVs and WEELs are developed by committee members of these associations from a review of the published, peer-reviewed literature. These OELs are not consensus standards. TLVs 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 2015]. WEELs have been established for some chemicals "when no other legal or authoritative limits exist" [AIHA 2015].

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 http://www.dguv.de/ifa/GESTIS/GESTIS-Internationale-Grenzwerte-für-chemische-Substanzen-limit-values-for-chemical-agents/index-2.jsp, contains international limits for more than 1,500 hazardous substances and is updated periodically.

OSHA 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 [Occupational Safety and Health Act of 1970 (Public Law 91–596, sec. 5(a)(1))]. 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. NIOSH investigators also encourage use of the hierarchy of controls approach to eliminate or minimize workplace hazards. This includes, in order of preference, the use of (1) substitution or elimination of the hazardous agent, (2) engineering controls (e.g., local exhaust ventilation, process enclosure, dilution ventilation), (3) administrative controls (e.g., limiting time of exposure, employee training, work practice changes, medical surveillance), and (4) personal protective equipment (e.g., respiratory protection, gloves, eye protection, hearing protection). Control banding, a qualitative risk assessment and risk management tool, is a complementary approach to protecting employee health. Control banding focuses on how broad categories of risk should be managed. Information on control banding is available at http://www.cdc.gov/niosh/topics/ctrlbanding/. This approach can be applied in situations where OELs have not been established or can be used to supplement existing OELs.

## Noise

Noise induced hearing loss (NIHL) is an irreversible condition that progresses with noise exposure. It is caused by damage to the nerve cells of the inner ear and, unlike some other types of hearing disorders, cannot be treated medically [Berger et al. 2003]. 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 for both ears that exceeds 25 dB at frequencies of 1000, 2000, 3000, and 4000 Hz.

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. NIHL can also result from short duration exposures to high noise levels or even from a single exposure to an impulse noise or a continuous noise, depending on the intensity of the noise and the individual's susceptibility to NIHL [Berger et al. 2003]. 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.

The preferred unit for reporting of noise measurements is the decibel, A-weighted. 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 1,000 Hz" and is considered to provide a better estimation of hearing loss risk than using unweighted or other weighting measurements [Earshen 2003]. The dB unit is dimensionless, and it represents the logarithmic ratio of the measured sound pressure level to an arbitrary reference sound pressure (20 micropascals, which is defined as the threshold of normal human hearing at a frequency of 1,000 Hz). Decibels are used because of the very large range of sound pressure levels audible to the human ear. 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 decibels cannot be averaged by taking the arithmetic mean.

Workers exposed to noise should have baseline and yearly hearing tests 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 500, 1000, 2000, 3000, 4000, and 6000 Hz. Additionally, NIOSH recommends testing at 8000 Hz [NIOSH 1998]. The OSHA hearing conservation standard requires analysis of changes from baseline hearing thresholds to determine if the changes are substantial enough to meet OSHA criteria for a standard threshold shift. OSHA defines a standard threshold shift as a change in hearing threshold relative to the baseline hearing test of an average of 10 dB or more at 2000, 3000, and 4000 Hz in either ear [29 CFR 1910.95]. If a standard threshold shift 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). Hearing threshold levels 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 hearing threshold levels 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 3000, 4000, or 6000 Hz, depending on the frequency spectrum of the workplace noise and the anatomy of the individual's ear [ACOM 1989; Osguthorpe and Klein 2001; Suter 2002; Schlaucha and Carneya 2011]. A notch in an individual with normal hearing may indicate early onset of NIHL. For NIOSH Health Hazard Evaluations, a notch is defined as the frequency where the hearing threshold level 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 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 use of hearing protection and implementation of 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 or impact 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 x (C1/T1 + C2/T2 + ... + Cn/Tn ), where Cn 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.

To calculate the noise dose using NIOSH criteria, the reference duration (Tn) for each time period must be calculated using the following formula: T (minutes) = 480/2(L−85)/3, where L = the measured noise exposure level for each time period. To calculate noise dose using OSHA criteria, the reference duration (Tn) for each time period must be calculated using a slightly different formula: T (minutes) = 480/2(L−90)/5, where L = the measured noise exposure level for each time period.

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Copies of this report have been sent to the employer, union, and employees at the facility. The state and local health department and the Occupational Safety and Health Administration Regional Office have also received a copy. This report is not copyrighted and may be freely reproduced.

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