Workplace design solutions

NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH

Preventing Hazardous Noise and Hearing Loss during Project Design and Operation

Prevention through Design (PtD)

Prevention through Design (PtD) can be defined as designing out or eliminating safety and health hazards associated with processes, structures, equipment, tools, or work organization. The National Institute for Occupational Safety and Health (NIOSH) launched a PtD initiative in 2007. The mission is to reduce or prevent occupational injuries, illnesses, and fatalities by considering hazard prevention in the design, re-design, and retrofit of new and existing workplaces, tools, equipment, and work processes [NIOSH 2008a,b].

Contents

Why is PtD Needed?

Integrating PtD concepts into business processes helps reduce injury and illness in the workplace, as well as costs associated with injuries. PtD lays the foundation for a sustainable culture of safety with lower workers' compensation expenses, fewer retrofits, and improved productivity. When PtD concepts are introduced early in the design process, resources can be allocated more efficiently.

Summary

Exposure to high noise levels in the workplace can cause hearing loss and affect worker productivity and compensation costs. This document describes case studies in which noise controls were implemented that reduced worker noise exposure. NIOSH recommends considering PtD concepts and incorporating engineering noise controls during the project design phase of processes and operations.

Description of Exposure

Prolonged exposure to high noise levels can cause hearing loss and tinnitus. Other health effects include headaches, fatigue, stress, and cardiovascular problems [Yueh et al. 2003]. High noise levels can also cause workers to be distracted and interfere with communication and warning signals. If workers do not hear warning signals, they may not take precautions to prevent hazards or injuries [NIOSH 1996, 1998; Yoon et al. 2015; Cantley et al. 2015].

Workers at Risk

An estimated twenty-two million workers are exposed to potentially damaging noise each year [NIOSH 2014a]. Although any worker can be at risk for noise-induced hearing loss in the workplace, workers in agriculture, mining, construction, manufacturing and utilities, transportation, and the military are at greater risk [Masterson et al. 2013; NIOSH 2001].

DEPARTMENT OF HEALTH AND HUMAN SERVICES
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Exposure Limits

In the United States, occupational regulations and standards were established to protect workers against the health effects of exposure to hazardous substances and agents when certain values, or limits, are reached. NIOSH establishes recommended exposure limits (RELs) for various hazards, but those limits are not enforceable by law; they are based on best available science and practices. The REL for noise is 85 decibels, using the A-weighting frequency response over an 8-hour average, usually referred to as time-weighted average (TWA); exposures at or above this level are considered hazardous [NIOSH 1998]. The Occupational Safety and Health Administration (OSHA) sets legally-enforceable *permissible* exposure limits (PELs) that require employers to take actions to reduce worker exposures. The OSHA PEL for noise is 90 dBA as an 8-hr TWA [29 CFR* 1910.95].

Occupational standards specify a maximum allowable daily noise dose, expressed in percentages. For example, a person exposed to 85 dBA per NIOSH or 90 dBA per OSHA over an 8-hour work shift, will reach 100% of their daily noise dose. The noise dose is based on both the sound exposure level and how long it lasts (duration) so for each increase of 3-dB (NIOSH) or 5-dB (OSHA) in noise levels, the duration of the exposure should be cut in half (these are referred to as exchange rates in standards). Table 1 illustrates the relationship between sound exposure levels and durations for both NIOSH and OSHA.

The Mine Safety and Health Administration (MSHA) PEL for miners is 90 dBA. If a miner's noise exposure continues to exceed the PEL despite the use of engineering and administrative controls, the mine operator must continue to use the engineering and administrative controls to reduce the miner's noise exposure to as low a level as is feasible [30 CFR § 62.130].

Protecting Workers from Hearing Loss

Noise-induced hearing loss (NIHL) is 100% preventable; however, once acquired, it is permanent and irreversible [NIOSH 1998]. Understanding and minimizing the risks are the keys to preventing noise-related injuries and hearing loss. Eliminating or lowering facility and equipment-related noise at the source reduces the risks related to NIHL and results in improved safety, productivity, and comfort [Tak et al. 2009].

The best way to reduce noise exposure and reduce resulting hearing loss is to address noise at the source by considering PtD principles. "Engineering out" hazardous noise found in the workplace before the exposure occurs (e.g., by installing quieter equipment or building an acoustic barrier) is the most effective way to reduce noise levels in the workplace [NIOSH 2001]. According to the hierarchy of controls (http://www.cdc.gov/niosh/topics/hierarchy/), such measures take precedence over using personal protective equipment such as earplugs [NIOSH 2015].

These noise reduction measures can lower costs associated with workers' compensation for hearing loss, protect workers' hearing, and improve productivity. Costs associated with retrofitting noisy equipment are also no longer necessary.

Case Studies

The following case studies demonstrate how small design and operational changes can reduce noise levels and reduce associated costs.

Case Study 1

Compressed air is often the most common noise source in manufacturing plants and other industries. It is used to operate equipment, such as air cylinders, air valves, solenoids, etc., or move parts/product, blow off debris, close flaps on corrugated containers (boxes/cases), or perform similar service-type actions. The noise generated by compressed air is caused by turbulence from the mixing of gases with widely different velocities, particularly when the high-velocity air stream flows into the relatively still surrounding air. Additional turbulence is created as the compressed air blows against objects, such as parts or sections of the machinery.

Compressed air noise can be controlled by reducing the air velocity to as low as practical while maintaining performance requirements and by treating all open-ended discharge lines and ports, including standard air jets and nozzles with commercially-available *quiet-design* nozzles or pneumatic silencers [IRSST 2015]. Addressing the noise produced by compressed air provides the greatest noise reduction per dollar invested, and can even have a payback in dollars through energy savings and life expectancy of equipment. Blowing compressed air through a 3/8-inch open pipe at a pressure of 71.5 pounds per

Code of Federal Regulations. See CFR in References.

Table 1. The average sound exposure levels needed to reach the maximum allowable daily dose of 100%

Time to reach 100% noise dose	Exposure level per NIOSH REL	Exposure level per OSHA PEL
8 hours	85 dBA	90 dBA
4 hours	88 dBA	95 dBA
2 hours	91 dBA	100 dBA
1 hour	94 dBA	105 dBA
30 minutes	97 dBA	110 dBA
15 minutes	100 dBA	115 dBA

square inch (psi) uses 109 standard feet per cubic minute (scfm). At an average cost of $0.015 per 35.3 standard cubic feet (scf), and an estimated use time of 40%, this equates to 704 hours of consumption per year. Therefore, the annual cost for the open pipe is: 109 ft^3/min x $0.015/35.3 ft^3 × 60 min /hr × 704 hours = $1956.44. By using a *quiet-design* nozzle that provides the same air-flow service, but only uses 55.9 scfm, the resulting annual cost would be $1003.35, a savings of $953.09 per nozzle while reducing noise levels by 20 dBA [Driscoll 2011].

This approach was successfully demonstrated by two of the Safe-in-Sound Excellence in Hearing Loss Prevention Award™ (www.safeinsound.us) recipients. One of the recipients (Colgate-Palmolive Company) created a guidance document to optimize system operation, minimize air leaks and provide guidance on appropriate use of air tools. (http://www.safeinsound.us/swf/colgate/). This effort involved (1) measuring, documenting, and optimizing air pressure settings for all pneumatic devices, (2) maintaining the pneumatic equipment and monitoring the optimized settings over time, and (3) locating and repairing compressed air leaks from cracked hoses, failed seals, etc. At the beginning of the implementation phase, worker doses were reduced from 113 to 90 dBA 8-hr TWA, and energy consumption was also reduced. This was also one of the approaches taken by another Safe-in-Sound recipient (United Technologies) (http://www.safeinsound.us/swf/UTC/index.html) who reduced worker noise doses from 90 to 85 dBA†.

Case study 2

A NIOSH investigation of the sound levels in the truck cab of an air-rotary drilling rig (see Figure 1) found that workers had exposure levels between 91 to 112 dBA. Tests were conducted to identify and isolate the dominant noise sources. Isolating the cause of the in-cab noise indicated that vibrations were transmitted from multiple hydraulic pumps to the control panel producing the dominant spike in the sound level spectrum. The researchers also conducted field tests to evaluate noise controls to reduce in-cab sound levels. Hydraulic noise suppressors were successfully used to reduce the structure-borne noise that is transmitted from the structure to the control panel. Further, the hydraulic noise suppressors and enhanced soundproofing lessened the risk of hearing loss for workers by reducing the in-cab exposure levels by as much as 4 dBA at high idle and by 1 dBA when the rig was hammer drilling. Covering a gap at the cab/inside door interface with lead-fiberglass blankets further reduced noise levels by 3 dBA compared with baseline conditions [Yantek et al. 2007].

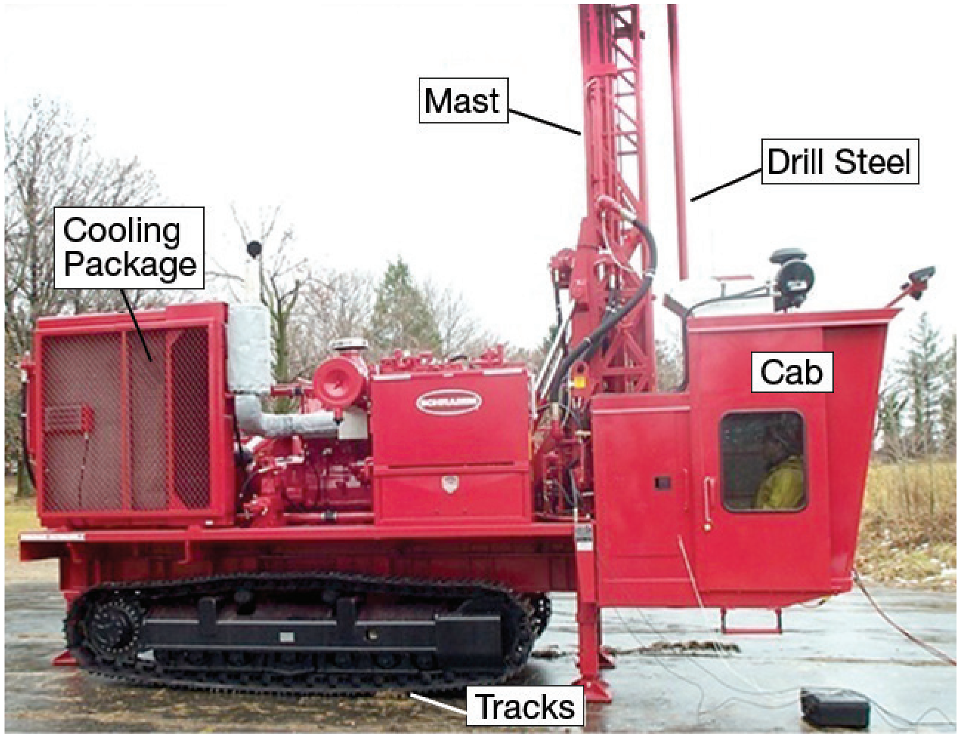

Figure 1. Track mounted, air rotary drill rig

Case study 3

Continuous mining machines are used to cut and gather coal. These machines contain an onboard conveyor consisting of a chain with flight bars that drag the coal along the base of the conveyor system. The traditional machine chains and flight bars generate excessive noise when they vibrate against the metal base. Because of the higher noise levels, mine operators working near these machines are at greater risk of developing NIHL. The flight bars and the conveyor belt tail rotor were coated with a thick, durable urethane coating to reduce noise and improve the lifespan of the equipment. The redesigned chain and flight bars reduced sound levels by 6-7dBA at the operator ear. The reduction in noise allowed the noise exposure to remain within the MSHA PEL [NIOSH 2009].

Recommendations

To reduce the incidence and severity of work-related hearing loss, NIOSH recommends hearing conservation programs for all workplaces with noise levels that exceed the REL of 85 dBA. In most cases, the preferred approach to reduce noise in the workplace is to eliminate or reduce the source of noise and to follow the hierarchy of controls [NIOSH 2014b; 2015]. NIOSH recommends the following at each stage of the design process:

Conceptual Design: Identify and apply relevant noise control regulations, consensus standards, and codes to establish project noise emission goals.

†More information about the awards and proceedings from the conference can be found in Meinke et al. 2013.

Preliminary Design: Assess the risk for noise hazards, factoring in noise from various sources that can affect workers' overall noise exposures and develop risk control alternatives.

Identify noise sources and work processes that have the potential to contribute to a worker's overall noise exposure. Eliminate or reduce potential noise sources by substituting quieter processes, elements, parts, and equipment.

Buy-Quiet: Implement a Buy Quiet program and set design specifications regarding noise levels to be adhered to in equipment purchasing decisions [NIOSH 2014c]. Develop equipment specifications that will be included in procurement documents. Develop test protocols for factory acceptance testing and commissioning.

Procurement: In accordance with Buy Quiet program implementation, ensure noise levels of all equipment purchases are specified by the manufacturer. Gather like model equipment noise levels, specifications, and pricing from equipment suppliers. Accounting for operational needs and level of commitment to Buy Quiet initiatives, execute appropriate purchases. Ensure that purchased equipment meets design specifications and doesn't exceed maximum noise levels as specified.

Commissioning: Conduct tests to ensure that specified noise levels have been achieved. Consider including this testing in factory acceptance tests. Acceptance test data can be reported in A-weighted sound power level for small machines and A-weighted sound pressure level for large machines based on the recommended operator position. All test measurements shall be made with manufacturer-recommended operating conditions [Hayden and Zechmann 2007].

Start-up and Ongoing Operations and Maintenance: Conduct noise surveys to ensure that noise levels do not exceed the NIOSH REL of 85 dBA sound pressure level. Develop Standard operating procedures (SOPs) to maintain noise controls and ensure worker noise exposures are controlled as new equipment is introduced or existing equipment is modified. Equipment noise levels should be noted post-maintenance and periodically in the Buy Quiet documentation.

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References

CFR. Code of Federal regulations. Washington, DC: U.S. Government Printing Office, Office of the Federal Register. https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=9735

Cantley LF Galusha D, Cullen MR, Dixon-Ernst C, Rabinowitz PM, Neitzel RL [2015]. Association between ambient noise exposure, hearing acuity, and risk of acute occupational injury. Scand J Work Environ Health *41*(1):75–83.

Driscoll D [2011]. The economics of noise control engineering versus the hearing conservation program. Professional Development Course. Portland, OR: 2011 American Industrial Hygiene Conference & Exposition (AIHce). https://www.osha.gov/dts/osta/otm/new_noise/appendixk.pdf

Hayden CS II, Zechmann E [2007]. Estimation of sound pressure level exposures from sound power level measurements of powered handtools. Noise Control Eng J *55*:4.

IRSST [2015]. Choosing a safe, efficient blow gun. Montreal, Canada: Institut de Recherche Robert Sauvé en Santé et Securité au Travail. http://www.irsst.qc.ca/media/documents/PubIRSST/RF-867.pdf

Masterson EA, Tak S, Themann CL, Wall DK, Groenewold, MR, Deddens JA, Calvert GM [2013]. Prevalence of hearing loss in the United States by industry. Am J Ind Med *56*:670–681. http://onlinelibrary.wiley.com/doi/10.1002ajim.22082/abstract

Meinke D, Morata TC, Hayden C [2013]. Noise control strategies: lessons from Safe-in-Sound Excellence in Hearing Loss Prevention™ awards. Denver, CO: Proceedings of Noise-Con 2013.

NIOSH [1996]. Preventing occupational hearing loss—a practical guide. By Franks JR, Stephenson MR, Stephenson CJ. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 96-110. http://www.cdc.gov/niosh/docs/96-110/

NIOSH [1998]. Criteria for a recommended standard: occupational noise exposure. DHHS (NIOSH) Publication Number 98-126. http://www.cdc.gov/niosh/docs/98-126/pdfs/98-126.pdf

NIOSH [2001]. Work-related hearing loss. DHHS (NIOSH) Publication No. 2001-103. http://www.cdc.gov/niosh/docs/2001-103/

NIOSH [2008a].Prevention through Design: introduction. By Howard J. J Safety Research *39*:113. http://www.cdc.gov/niosh/topics/PtD/pdfs/Howard.pdf

NIOSH [2008b]. National Prevention through Design (PtD) Initiative. By Schulte P, Rinehart R, Okun A, Geraci C, Heidel D. http://www.cdc.gov/niosh/topics/ptd/pdfs/Schulte.pdf

NIOSH [2009]. A dual sprocket chain as a noise control for a continuous mining machine. By Kovalchik P, Smith A, Matetic R, Alcorn L. http://www.cdc.gov/niosh/mining/UserFiles/works/pdfs/adsca.pdf

NIOSH [2014a]. NIOSH safety and health topic: noise and hearing loss prevention. http://www.cdc.gov/niosh/topics/noise/

NIOSH [2014b]. NIOSH safety and health topic: noise control. http://www.cdc.gov/niosh/topics/noisecontrol/default.html

NIOSH [2014c]. NIOSH safety and health topic: Buy Quiet components. http://www.cdc.gov/niosh/topics/buyquiet/component.html

NIOSH [2015]. NIOSH workplace safety and health topic: hierarchy of controls. http://www.cdc.gov/niosh/topics/hierarchy/

Tak S, Davis RR, Calvert GM [2009]. Exposure to hazardous workplace noise and use of hearing protection devices among US workers—NHANES, 1999–2004. Am J Ind Med 52:358–371. http://onlinelibrary.wiley.com/doi/10.1002/ajim.20690/abstract;jsessionid=C6A7EEFA952F701624E48A959EF4C53D.f02t03, http://www.ncbi.nlm.nih.gov/pubmed/19267354

Yantek D, Ingram D, Matetic R [2007]. In-cab noise reduction on an air-rotary drill rig. Noise Control Eng J *55*(3):294–310. http://www.cdc.gov/niosh/miing/works/coversheet1672.html

Yoon JH, Hong JS, Roh J, Kim CN, Won, JU [2015]. Dose-response relationship between noise exposure and the risk of occupational injury. Noise Health *17*:43–47.

Yueh B, Shapiro N, MacLean CH, Shekelle PG [2003]. Screening and management of adult hearing loss in primary care: scientific review. J Am Med Assoc *289*(5):1976–1985. http://jama.jamanetwork.com/article.aspx?articleid=196401

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Information

The information in this document is based on research related to Prevention through Design (PtD) initiatives. More information about PtD is available on the NIOSH Website at http://www.cdc.gov/niosh/topics/PtD/

Several noise control examples can be found among the Safe-in-Sound Excellence in Hearing Loss prevention Award™ recipients:

- http://www.safeinsound.us/winners.html

For more information about noise exposure and control, visit:

- http://www.cdc.gov/niosh/topics/noisecontrol/default.html
- http://www.cdc.gov/niosh/topics/buyquiet/

For more information about hearing loss, visit:

- http://www.cdc.gov/niosh/topics/noise/

To obtain information about other occupational safety and health topics, contact NIOSH at:

Telephone: 1–800–CDC–INFO (1–800–232–4636)
TTY: 1–888–232–6348 • CDC INFO: www.cdc.gov/info

or visit the NIOSH website at www.cdc.gov/niosh
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As part of the Centers for Disease Control and Prevention, NIOSH is the Federal agency responsible for conducting research and making recommendations to prevent work-related illness and injuries.

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