Summary of longwall and continuous miner section noise studies in underground coal mines

D.R. BABICH AND E.R. BAUER

D.R. Babich and **E.R. Bauer**, member SME, are mining engineers with the National Institute for Occupational Safety and Health (NIOSH), Pittsburgh Research Laboratory, Pittsburgh, PA.

Abstract

Noise-induced hearing loss (NIHL) in mine workers, especially underground coal miners, continues to be a problem in the mining industry. The recently enacted MSHA noise standard, Part 62 – Occupational Noise Exposure (Federal Register, 1999), is aimed at reducing NIHL in the mining industry. The U.S. National Institute for Occupational Safety and Health (NIOSH) is conducting a cross-sectional survey of noise sources and worker noise exposures to address NIHL in various aspects of coal mining including surface mining, coal preparation plants and underground mining. In underground bituminous coal mining, noise surveys, consisting of full-shift worker noise exposure, time-motion studies and equipment noise profiling, have been completed on longwall and continuous miner sections in six underground coal mines. The studies revealed widely varying shift-to-shift worker exposures, with workers in certain occupations routinely exposed to potentially hazardous levels of noise. A summary of these studies is reported, including worker dose, source/dose relationships and equipment noise profiles.

Introduction

Prolonged exposure to noise can result in permanent damage to the auditory nerve and/or its sensory components. This irreversible damage, known as noise-induced hearing loss (NIHL), makes it difficult to hear and understand speech. NIHL is the most common occupational disease in the United States today, with approximately 30 million workers exposed to excessive noise levels or to toxic agents that are potentially hazardous to their hearing (NIOSH, 1996a). The problem is particularly severe in all areas of mining (surface, processing plants and underground), with studies indicating that 70 percent to 90 percent of all miners have NIHL great enough to be classified as a hearing disability (NIOSH, 1996b). An early analysis of NIHL in 1,500 coal miners revealed an alarming prevalence of severe hearing loss, as shown in Fig. 1 (NIOSH, 1976). For example, by age 60 more than 70 percent of the miners studied had a hearing loss of more than 25 dB, and about 25 percent had a hearing loss of more than 40 dB.

In addition to government researchers, Weeks (1995) reported that the policies and practices for preventing occupational hearing loss among miners are inadequate and noted that there are deficiencies in nearly every sector: surveillance of exposure or of outcome, analysis and intervention. A more recent analysis of NIHL in miners showed an apparent worsening of NIHL, as shown in Fig. 2 (NIOSH, 1996b). This analysis of a private company's 20,022 audiograms for 3,449 coal miners indicated that the number of miners with hearing impairment increased exponentially with age until age 52, at which time 90 percent of the miners had a hearing impairment. NIOSH defines hearing impairment as an average hearing threshold level of 25dB or greater for the frequencies 1,000, 2,000, 3,000 and 4,000 Hz (NIOSH, 1996b, 1997).

The Federal Coal Mine Health and Safety Act of 1969 established requirements for protecting coal miners from excessive noise. Subsequently, the Federal Mine Safety and Health Act of 1977 broadened the scope to include all miners, regardless of mineral type (Code of Federal Regulations [CFR] 30, 1997). Since the passage of these Acts, there has been some progress in controlling mining noise. In fact, data from more than 60,000 full-shift MSHA noise surveys show that, in general, the noise exposure of selected occupations has decreased since the 1970s (Seiler et al., 1994). However, for these same surveys, the percentage of coal miners with noise exposures exceeding federal regulations, unadjusted for the wearing of hearing protection, was 26.5 percent and 21.6 percent for surface and underground mining, respectively (Seiler et al., 1994).

Despite the extensive work with engineering controls, education and hearing conservation in the 1970s and 1980s, NIHL is still a pervasive problem in the mining industry (*Federal Register*, 1996). MSHA recently published new Noise Health Standards for Mining (*Federal Register*, 1999), and one of the changes is the adoption of a provision similar to OSHA's Hearing Conservation Amendment. MSHA concluded in a recent survey that if an OSHA-like hearing conservation program were adopted, hypothetically, 78 percent of the coal miners surveyed would be required to be in a hearing conservation program (Seiler and Giardino, 1994). Other requirements of the new regulations are a permissible exposure level (PEL) of 90 dB(A) TWA8 (which stands for time weighted average – 8 hour and is defined as the sound level that if constant over 8 hours would result in the same noise dose as is measured [*Federal Register*, 1999]); no credit for the use of personal hearing protection; and the primacy of engineering and administrative controls for noise exposure reduction.

Complicating the problem of NIHL in mining, much of the existing noise and worker-exposure information is outdated and has limited value for current research and engineering control decision-making. In many cases, the data are specific to machine type and were obtained for characterizing noise sources rather than exposure assessment. There is also a great range in noise levels for a given occupation. For example, noise levels for continuous miner operators range from 80 to 105 dB(A) (MSHA, 1997). As determined using the new Noise Health Standards, a noise level of 80 dB(A) translates into a daily noise dose of 0 percent, while a 105 dB(A) level represents a daily noise dose of 800 percent.

Yet, at present, there is insufficient information to explain this great variation in exposure for this and other mining occupations and an understanding of this variability is necessary to identify appropriate solutions. Specifically, noise level data are needed that provide a time exposure history for workers in addition to further information on noise sources. This information will provide the basis for targeting and selecting engineering controls, in combination with administrative controls, and the use of personal protective equipment, to reduce noise exposures among the mining workforce.

FIGURE 1

Hearing loss as a function of age (adopted from NIOSH, 1976).

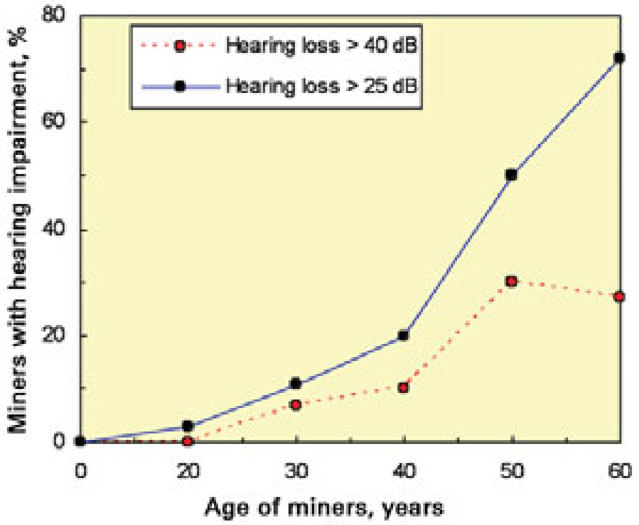


Table 1

Occupations experiencing noise exposures, arranged by percent doses of more than 132 percent.

Occupatons (sample size)	Range of dose, %	Doses greater than MSHA PEL of 100%, %	Doses greater than 132%, %
Longwall:			
Shearer operator (37)	22-786[1]	73	62
Headgate/stageloader operator (15)	36-386	73	53
Relief shearer operator (2)	22-193	50	50
Shieldman/jacksetter (35)	13-192	40	20
Foreman (14)	23-203	36	14
Electrician/mechanic (21)	5-156	33	5
Continuous mining:			
Roof bolter operator (16)	57-355	81	69
CM operator/helper (14)	43-347	86	57
Miner/bolter roof bolters (30)	9-275	60	40
Utility man/faceman (37)	6-297	32	22
Miner/bolter operator (14)	45-195	64	21
Foreman (16)	17-232	31	19
Shuttle car operator (31)	9-165	16	7
Mechanic/electrician (18)	4-162	6	6
Ram car operator (4)	83-122	25	0
Loading machine operator (12)	25-81	0	0
Center bolter operator (17)	17-57	0	0

[1]786 percent — No noise level at or above 105 dB(A) was recorded at the worker locations for this person (note: microphone was found pinned to worker's breast shirt pocket). The next highest recorded dose for this occupation was 408 percent.

Scope of research

This research effort was conducted at six underground coal mines located in Alabama, Colorado, Pennsylvania and West Virginia. Thirty-three shifts were spent collecting approximately 333 worker noise exposures, 43 worker task observations and 80 equipment noise profiles. Worker noise exposure was monitored using Quest Q-400 Noise Dosimeters, which were configured to monitor the MSHA Permissible Exposure Level (PEL) (TWA8 of 90 dB(A), or equivalently a dose of 100 percent). Task observations were conducted for workers who routinely experienced noise exposures above the MSHA PEL.

The equipment noise profiles, which were made using a Quest Model 2900 Sound Level Meter, include both longwall and continuous mining section equipment. The measurement recorded was the A-weighted linear equivalent continuous sound pressure level ($Leq_{(A)}$. The $Leq_{(A)}$ in decibels is the average sound level for a measurement period based on a 3-dB exchange rate. The 3-dB exchange rate is the method most firmly supported by scientific evidence for assessing hearing impairment as a function of noise level and duration (NIOSH, 1998). Descriptions of how these worker dose and noise profiles were obtained and the types of equipment measured are included below.

Results

Summaries and representative examples of data collected are presented that include worker dose, task observations keyed to cumulative dose plots and sound profile plots of equipment noise. The volume of data collected in this study precludes including all results.

Worker dose. Full-shift dosimetry measurements (ranging from 8 to 12 hours) were recorded for 333 underground workers primarily engaged in coal extraction at the face. The worker dose measurements indicated that 42 percent (141 of 333) of the total doses recorded were above the MSHA PEL of 100 percent. Of those above the PEL of 100 percent, 65 percent (91 of 141) were above the MSHA citable PEL of 132 percent (citable level is 132 percent because of 2 dB error of Type 2 instruments, i.e., 100 percent 2 dB (32 percent)). In other words, approximately 27 percent (91 of 333) of the total recorded doses were citable under MSHA guidelines.

Table 1 lists occupations in longwall and continuous mining sections and a summary of dose measurements. The table illustrates that the range of dose within each occupation varies considerably. Many of these occupations or job classifications routinely experience noise exposures above the PEL. These workers are periodically subjected to noise levels that have the potential to cause NIHL.

Task observations. Workers experiencing doses above the PEL were task observed while wearing a dosimeter. The task observations (time-motion studies) included the duration of the tasks the worker performed and his location with respect to the equipment and/or noise sources. The goal was to identify the tasks and associated noise sources responsible for the workers measured dose and to provide mine operators with sufficient information to begin implementing noise exposure reduction efforts. A cumulative dose plot for a miner/bolter operator, with task observations annotated, is illustrated in Fig. 3. The rate of dose accumulation was greatest (indicated by the steep slope of the line) while trimming a corner with the conveyor running empty, followed by cutting/bolting/hang tubing at the face. Little dose was accumulated while the worker was at lunch and during equipment idle times as illustrated by the flat slope of the cumulative dose line.

Figure 4 is an example of a cumulative dose plot for a longwall headgate/stageloader operator. The plot illustrates that other than during equipment idle times, the headgate/stageloader operator experienced a uniform dose throughout the shift, with the greatest rate of accumulation while working within 1 m (3 ft) of the head drive. The periodic no dose times (flat slopes) occurred when the worker left the headgate to get supplies, carry out belt structure and take breaks.

Equipment noise. As noted above, 80 equipment noise profiles were completed in underground coal mines. Some of these profiles were done on similar equipment but in different mines. The equipment profiled included continuous mining machines, combination continuous miner-bolter machines, roof bolting machines (both dual-boom and single-boom center bolter), loading machines, shuttle cars, auxiliary fans used at the face, feeder-breakers, electrical power centers, longwall shearers, longwall stageloaders and track-mounted longwall hydraulic pump car assemblies. Results of the noise profiles for the differ-

FIGURE 2

Hearing impairment in coal miners, non-coal miners and non-exposed males (NIOSH, 1996b, 1997).

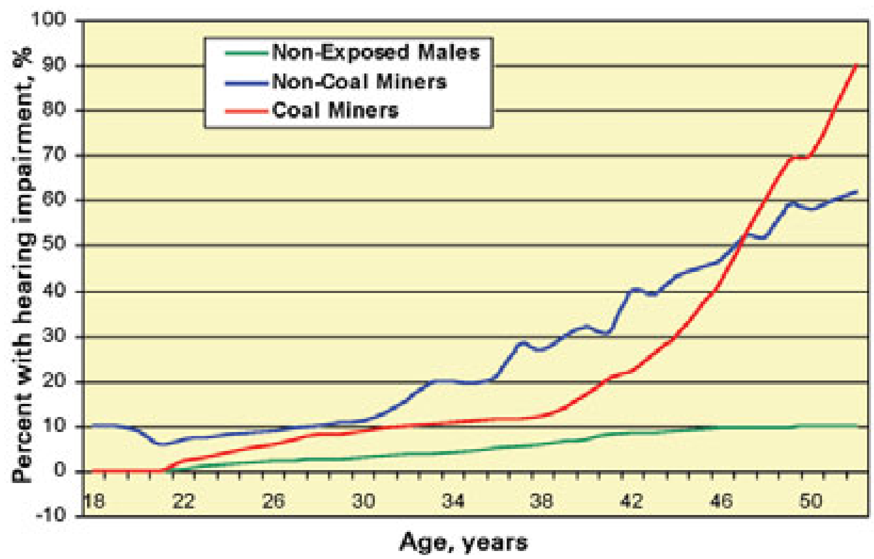


FIGURE 3

Cumulative dose plot for miner/bolter operator.

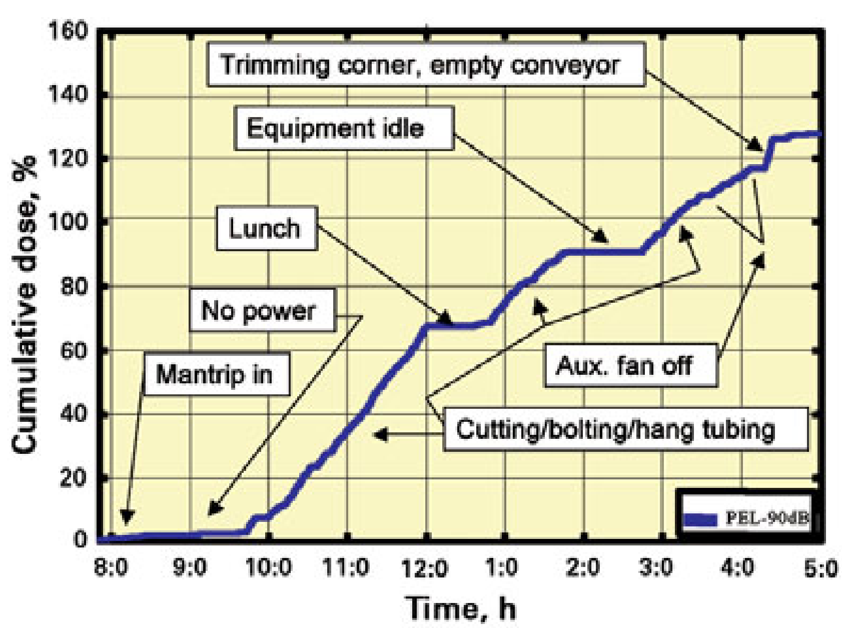


Table 2

Range of $Leq_{(A)}$ noise levels measured on a fixed grid for continuous mining section equipment.

Equipment	Range, dB(A)	Measured location of highest noise Level
Auxiliary fan	84-120	Exhaust side
Miner/bolter	84-112	At drill stations
Continuous miner	78-109	Within 5 m (15 ft) of tail
Roof bolter	92-103	At drill stations
Feeder/breaker	81-97	Discharge end
Shuttle car[1]	78-89	In operator's cab during unloading

[1]Includes drive-by, stationary loading and stationary unloading measurements

FIGURE 4

Cumulative dose plot for longwall headgate/stageloader operator.

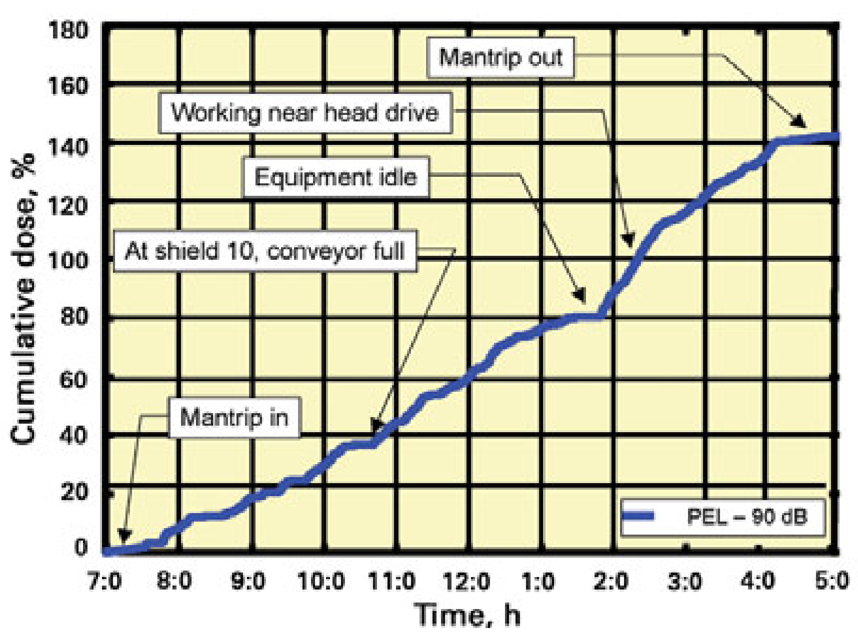
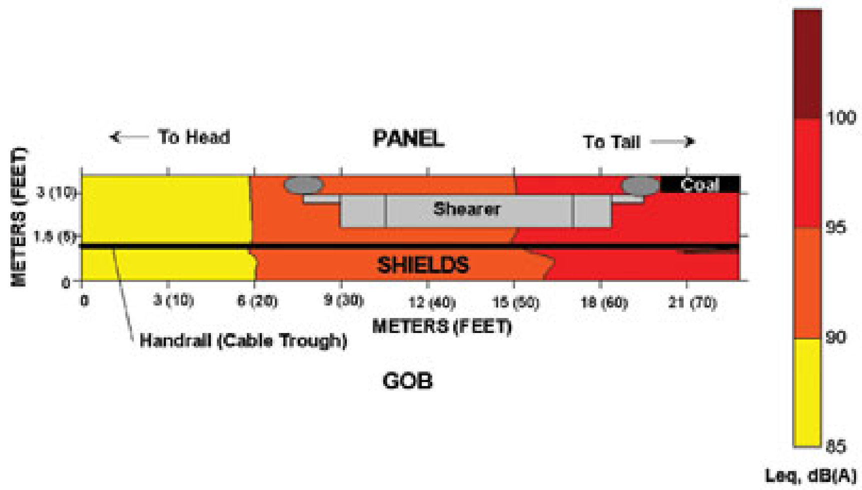


FIGURE 5

Sound profile plot for longwall shearer while cutting from headgate to tailgate.



ent types of equipment are shown in Tables 2 and 3.

The profile measurements were taken at 1-m (3-ft) intervals (grid), starting 1 m (3 ft) from the equipment, and included several points above the equipment. Some measurements were made closer to the equipment when clearance between equipment and rib was less than 1 m (3 ft). The readings were taken only when the equipment was in operation. Some readings, particularly those at the very front of a continuous miner, loading machine or longwall shearer, were unable to be taken for obvious safety reasons.

For analysis, the noise data collected from around the mining equipment were converted to sound profile plots. Although space limitations prevent presenting all the noise profiles, several examples from both longwall and continuous mining sections are included. Figure 5 is a sound profile plot for a longwall shearer as it is cutting from headgate to tailgate. Note that the highest noise levels are at the lead drum end of the machine when cutting in this direction. The noise levels drop significantly along the machine toward the headgate and trailing drum. This figure illustrates that, if the head shearer operator is positioned 3 m (10 ft) or more outby (the direction away from the working face) on the stageloader side of the trailing drum, the operators dose should be less than the PEL. Likewise, the lead drum operator needs to position himself as far away from the lead drum toward the head as possible, or at least at the middle of the shearer, to minimize his noise exposure.

Figure 6 presents a sound profile plot for a longwall stageloader and panel belt. The highest noise levels were found near the crusher, which breaks the larger lumps of coal and rock, and near the tail piece where the stageloader conveyor chain drive motors are located. These are the two areas that the headgate operator, and all other longwall workers, should minimize their time spent.

Figure 7 is from a continuous miner section and illustrates the noise around a dual-boom roof-bolting machine. The data were collected during several complete bolting cycles. The highest noise levels were recorded near the right side operator's location during the bolting cycle. Noise levels dropped below 90 dB(A) approximately 4 m (12 ft) outby the drill.

Finally, Fig. 8 is an example of a pair of auxiliary ventilation fans located on a continuous mining section. These fans were extremely noisy, reaching 118 dB(A) near one fan on the inby (the direction toward the working face) side of the curtain. Even at 14 m (46 ft) inby, the noise level was still over 100 dB(A). For any worker traveling within this distance, the dose would accumulate rapidly, and as such, the area should be avoided when possible.

Implications for noise exposure reduction

Although the goal of this research was to coordinate a survey of noise sources and worker noise exposures, some general implications for reducing worker noise exposures can be drawn. The results suggest that workers directly involved with coal extraction at the face are most likely to experience overexposure to noise. As such, these are the occupations where mine operators should concentrate their noise control efforts. The occupations that should be the first to be included in any noise exposure reduction efforts are the continuous miner and miner/bolter operators, miner/bolter roof bolter operators, roof bolter operators, longwall shearer operators and headgate/stageloader operators. As illustrated in Table 1, these are the occupations with the highest percentage of recorded doses over the MSHA PEL.

According to the MSHA noise standard Part 62, mine operators must use all feasible engineering and administrative controls to reduce the miner's noise exposure below the permissible exposure level (*Federal Register*, 1999). Engineering controls reduce noise exposure by decreasing the amount of noise reaching a worker. Sound profile plots can indicate which equipment is generating the highest noise levels, but not what specific component of the piece of equipment is responsible. This at least gives mine operators a starting point based on reliable and accurate information. Examples of engineering controls include maintenance, acoustic isolation or absorption, barriers, motor enclosures, fan silencers, modification of machine mounting, mufflers and replacement of noisy equipment with quieter equipment.

Administrative controls reduce exposure by limiting the time a worker is exposed to noise.

By evaluating the cumulative dose plots, task observations and sound profile plots, the tasks, equipment or areas that significantly influence a worker's dose can be identified and then modified or avoided to minimize exposures. Examples of administrative controls include job rotation (switching a worker with high noise exposure with someone having less noise exposure), modifying the job or equipment operation to reduce exposure to noisy areas or equipment, shift length reduction when more than 8 hours, and where possible, providing quiet areas or areas from which remote monitoring utilizing gauges and/or video can take place.

Summary

Overexposure to noise among mine workers continues to be a problem for the mining industry. This research effort found that 27 percent (91 of 333) of the underground face workers studied experienced noise exposures above the MSHA citable level of 132 percent, and 42 percent (141 of 333) experienced doses greater than 100 percent. The equipment generating the highest noise levels include

Table 3

Range of $Leq_{(A)}$ noise levels measured on a fixed grid for longwall mining section equipment.

Equipment	Range, dB(A)	Measured location of highest noise level
Stageloader	84-102	Head drive, crusher, gearboxes and bridge conveyor
Shearer	85-99	Adjacent to drum
Hydraulic pump car	78-99	Motors and pumps
Head drive	89-96	At gear box on shield side
Tail drive	92-94	At return escapeway end
Panline	78-91	At head drive
Dinner hole	<60-90	When located within 1.8 m (6 ft) of stageloader

FIGURE 6

Sound profile plot for longwall stageloader.

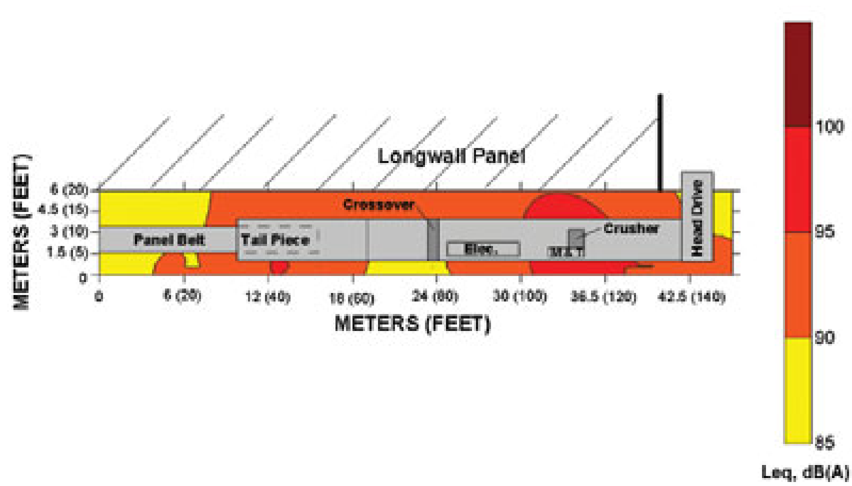


FIGURE 7

Sound profile plot of sound levels around a dual-boom roof-bolting machine.

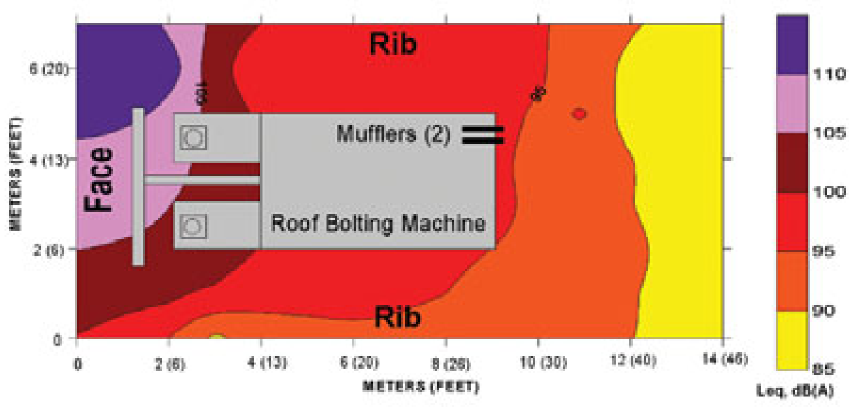
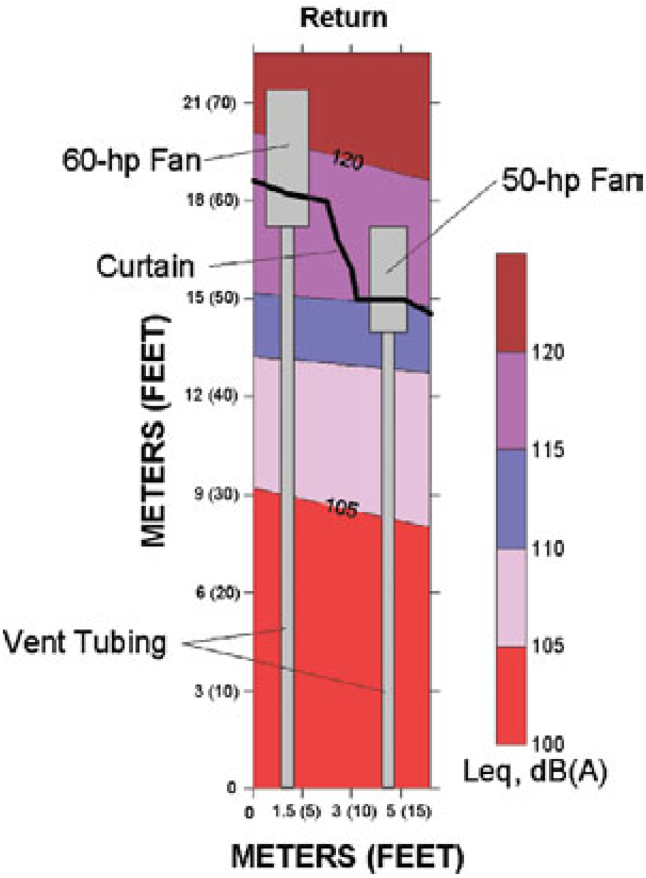


FIGURE 8

Sound profile plot for auxiliary fans.



the stageloader (102 dB(A)) and shearer (99 dB(A)) in longwall sections and include the auxiliary fans (120 dB(A)), miner/bolters (112 dB(A)), continuous miner (109 dB(A)) and roof bolting machines (103 dB(A)) in continuous mining sections.

The solutions to reducing mine-worker noise exposure are many and difficult and will need to include a combination of engineering and administrative approaches. They will also include providing additional training and supervision to increase the underground worker's awareness of high noise areas and the beneficial effects of moving out or away from those areas when possible. The cooperation of all parties (labor, management, regulatory and research community) is necessary if NIHL among mine workers is to be reduced and/or eliminated. ■

References

CFR 30, 1997, Code of Federal Regulations (CFR) governing noise exposure in mining, CFR 30, Subchapter O, Part 70, Subpart F: Noise Standards for Underground Coal Mines; Subchapter O, Part 71, Subpart D: Noise Standards for Surface Work Areas of Underground Coal Mines and Surface Coal Mines; Subchapter O, Part 55, Section 55.5: Metal and Nonmetal Open Pit Mines; Section 56.5: Sand, Gravel, and Crushed Stone Operations; 57.5: Metal and Nonmetal Underground Mines.

Federal Register, 1996, "Health Standards for Occupational Noise Exposure in Coal, Metal, and Nonmetal Mines: Proposed Rule," Department of Labor, Mine Safety and Health Administration, 30 CFR Parts 56, 57, 62, 70, and 71, Vol. 61, No. 243, Tuesday Dec. 17, pp. 66348-66469.

Federal Register, 1999, "Health Standards for Occupational Noise Exposure: Final Rule," Department of Labor, Mine Safety and Health Administration, 30 CFR Parts 56 and 57 et al., Vol. 64, No. 176, Monday, Sept. 13, pp. 49548-49634.

MSHA, 1997, "Environmental Noise Report, District Summaries, Fiscal Year 1997."

NIOSH, 1976, "Survey of Hearing Loss in the Coal Mining Industry," National Institute for Occupational Safety and Health, Publication No. 76-172, June, 70 pp.

NIOSH, 1996a, "Preventing Occupational Hearing Loss — A Practical Guide," J.R. Franks, M.R. Stephenson and C.J. Merry, eds., National Institute for Occupational Safety and Health, Cincinnati, OH, DHHS (NIOSH) Publication No. 96-110, 91 pp.

NIOSH, 1996b, "Analysis of Audiograms for a Large Cohort of Noise-Exposed Miners," J.R. Franks, National Institute for Occupational Safety and Health, Cincinnati, OH, internal report, 7 pp.

NIOSH, 1997, "Prevalence of Hearing Loss for Noise-Exposed Metal/Nonmetal Miners," J.R. Franks, National Institute for Occupational Safety and Health, Cincinnati, OH, internal report, 5 pp.

NIOSH, 1998, "Criteria for a recommended standard: occupational noise exposure, revised criteria 1998," Cincinnati, OH, U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 98–126, 105 pp.

Seiler, J.P., Valoski, M.P., and Crivaro, M.A., 1994, "Noise Exposure in U.S. Coal Mines," U.S. Dept. of Labor, Mine Safety and Health Administration, informational report IR 1214, 46 pp.

Seiler, J.P., and Giardino, D.A., 1994, "The Effect of Threshold on Noise Dosimeter Measurements and Interpretation of Their Results," U.S. Dept. of Labor, Mine Safety and Health Administration, informational report IR 1224, 16 pp.

Weeks, J.L., 1995, "Policies and Practices for Preventing Occupational Hearing Loss Among Miners are Inadequate," Proceedings of Hearing Conference III/XX, Cincinnati, OH, March, pp. 16-19.