CROSS-SECTIONAL SURVEY OF NOISE EXPOSURE IN THE MINING INDUSTRY

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ABSTRACT

Prolonged exposure to noise over a period of years generally causes permanent damage to the auditory nerve and/or its sensory components. This irreversible damage, known as noise-induced hearing loss (NIHL), is the most common occupational disease in the United States today. Workers suffering from NIHL have difficulty understanding human speech and hearing other workplace cues. Despite the use of regulations and efforts by government and industry to reduce NIHL, the problem today is as prevalent as it was more than two decades ago. Recently, the Mine Safety and Health Administration (MSHA) promulgated a new regulation that is designed to reduce NIHL in the mining industry. One of the more significant provisions is the elimination of MSHA's past practice of giving "credit" for the use of personal hearing protection, thereby reestablishing the primacy of engineering and administrative controls.

However, there is a knowledge gap that is impeding the development and implementation of engineering and administrative controls. Although significant data exist on the exposure to noise by occupational code, little is known about the noise sources that contribute the most to the worker's dose. This is problematic in a workplace with multiple noise sources and workers who travel among noise sources. Yet without this knowledge, it is difficult to focus control efforts in any practical manner. Thus, it is important to characterize noise sources sufficiently well so that the sources most hazardous to hearing are identified and those conditions of exposure that are most amenable to engineering controls are pinpointed as well. The Pittsburgh Research Laboratory (PRL) of the National Institute for Occupational Safety and Health (NIOSH) is conducting a cross-sectional survey of noise sources and worker noise exposures in the mining industry to address this deficiency. The initial effort, conducted at a coal preparation plant and results are described in this paper. Preliminary analyses indicate that the noise levels on all floors exceeds 90 dBA in most areas, and that levels as high as 115 dBA were recorded. In addition, the one worker whose responsibility is to monitor the equipment and "house clean" the plant is slightly overexposed, even though he spends only half the shift in the plant. General information on the hearing loss problem in mining, a review of hearing protection use and noise regulations in mining, and other background materials are also presented.

INTRODUCTION

Noise is often regarded as a nuisance rather than as an occupational hazard. However, overexposure to noise can cause serious hearing loss. In 1996, NIOSH reported that occupational hearing loss is the most common occupational disease in the United States today, with 30 million workers exposed to excessive noise levels (NIOSH, 1996). The problem is particularly severe in all areas of mining (surface, processing plants, and underground), with studies indicating that 70% to 90% of miners have a NIHL large enough to be classified as a hearing disability (NIOSH, 1976; Franks, 1996). This alarming prevalence of hearing loss among miners is shown in Figure 1. For example, the median hearing threshold of retired miners was 20 decibels (dB) greater than that of the general population. By age 60, over 70% of miners had a hearing loss of more than 25 dB, and about 25% had a hearing loss of more than 40 dB. Franks (1996) review of a private company's 20,022 audiograms indicated that the number of miners with hearing impairments increased exponentially with age until age 50, at which time 90% of the miners had a hearing impairment.

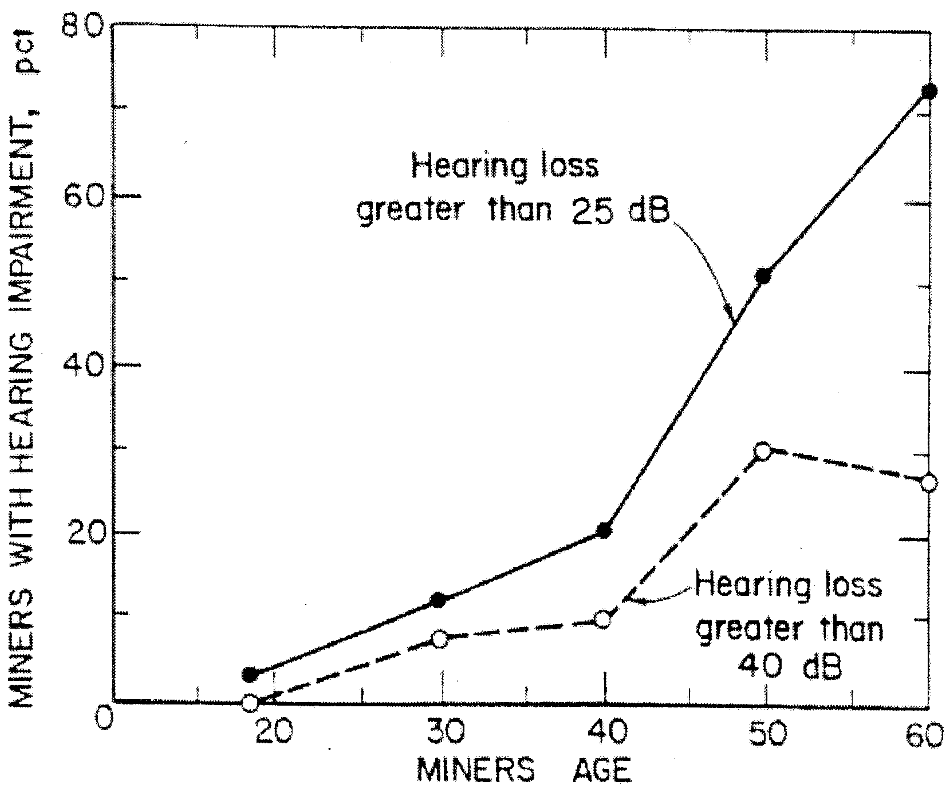

Figure 1: Hearing loss as a function of age (NIOSH, 1976).

Since the passage of the Federal Coal Mine Health and Safety Act of 1969, there has been some progress in controlling mining noise. Machinery manufacturers have incorporated design changes to reduce noise levels. At the same time, however, many of these gains have been diminished by the use of ever larger, more powerful, and sometimes noisier machines.

Thus, the number of miners overexposed to noise, as defined by federal regulations, still exceeds their overexposure to all other health hazards. Data from more than 60,000 full-shift MSHA noise surveys show that the noise exposure of selected occupations has decreased since the 1970s, although the percentage of miners overexposed to current MSHA noise regulations remains high (Seiler, et al. 1994). MSHA found that the percentage of coal miners with noise exposures exceeding federal regulations, and unadjusted for the wearing of hearing protection, was 26.5% and 21.6% for surface and underground mining, respectively. Table I lists recently published data from MSHA noise surveys of exposures in the coal and metal/nonmetal mining industries (Federal Register, 1999).

Table I - MSHA noise samples exceeding specified TWA_8 sound levels.

Industry segment	TWA_8 sound level, dBA[1]	90-dBA threshold		80-dBA threshold	
		Number of samples	Percent of samples	Number of samples	Percent of samples
Coal	90 (PEL)[2]	1075	25.3	------------	------------
	85 (Action Level)	--------------	--------------	3268	76.9
Metal/ Nonmetal	90 (PEL)	7360	17.4	------------	------------
	85 (Action Level)	--------------	--------------	28,250	66.9

[1]TWA_8 is the sound level, if constant over 8 hours, would result in the same noise dose as measured.
[2]Pel-Permissible exposure level

Despite the extensive work done in the 1970s and 1980s, NIHL is still a pervasive problem. MSHA has published new Noise Health Standards for Mining (Federal Register, 1999). One of the changes will be 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 (HCP) were adopted, hypothetically 78% of the coal miners surveyed would be required to be in a hearing conservation program (Seiler and Giardino, 1994). Based on full-shift time-resolved dosimeter measurements at six U.S. longwall operations, Bartholomae and Burks (1995) found that all the longwall face workers surveyed in these mines would be required to be in a hearing conservation program. These data are corroborated by data collected in the National Occupational Health Survey of Mining (NOHSM) during the 1980s (Greskevitch et al., 1996). Based on this survey, the projected mine workers potentially overexposed to noise was approximately 200,000 workers, or 73% of the workforce.

PERSONAL HEARING PROTECTION

At first glance, personal hearing protection devices (earplugs, earmuffs, etc.) seem to be a relatively cheap and simple solution to almost any noise problem. However, good industrial hygiene and safety practices suggest that hearing protectors should be considered only as an interim or secondary noise control solution and that engineering and/or administrative controls should be first employed. There are several reasons for this. First, earplugs and earmuffs generally do not provide the same degree of protection in the mining workplace as they do in the laboratory or other types of workplaces (NIOSH, 1996; and Giardino and Durkt, 1996). The use of personal hearing protection (PHP) was studied by Stewart and Burgi (1980) and Berger (1983), who found that earmuffs have serious limitations when worn under mine conditions. These include much less real work noise attenuation than that measured under laboratory conditions and the possibility of reduced hearing causing a safety hazard (AIHA, 1986). The effectiveness of PHP can be improved through proper fit, but the possible hazard from overprotection while wearing PHPs is unresolved.

Second, miners often refuse to wear hearing protectors because they are uncomfortable, annoying, or prevent them from perceiving signals such as the sounds that precede a roof fall ("roof talk") or backup alarms on moving equipment (NIOSH, 1996). Often miners simply do not appreciate the risk presented by excessive noise, nor do they believe that using PHPs will protect them.

Finally, spot surveys have shown that miners believe that they are wearing hearing protectors more than they really are. For example, a research group in New South Wales, Australia, surveyed one mine where 75% of the miners stated that they used hearing protectors "regularly" (55%) or "all the time" (20%). In fact, the investigators found that only 40% of the miners wore hearing protectors regularly and 20% wore them some of the time (O'Malley and O'Beirne, 1993).

The limitations of PHPs underscore the importance of using engineering and administrative controls to the fullest extent practicable. At the same time, however, PHPs can offer some reasonable measure of protection, especially when fit and worn correctly. As such, their importance in an overall hearing loss prevention program should not be underestimated.

HIGHLIGHTS OF NOISE REGULATIONS IN MINING

Regulation of noise in mining is covered in Title 30 of the Code of Federal Regulations (30 CFR). The Federal Coal Mine Health and Safety Act of 1969 established requirements for protecting coal miners from excessive noise and, subsequently, the Federal Mine Safety and Health Act of 1977 broadened the scope to include all miners, regardless of mineral type (CFR 30 1977). The regulations allowed a permissible exposure level PEL) of 90 dBA TWA over 8 hours (TWA_8). Exposure below the criterion of 90 dBA is unregulated, while continuous exposure to levels greater than 115 dBA is not permitted. Many noise sources are not continuous, and movement by the worker generally results in exposure to various levels of noise for differing periods of time. This problem of exposure versus duration of exposure is evaluated using the well-known noise exposure index (NEI); the worker is out o compliance if the NEI exceeds unity. In practice, the dose received is most often determined using a type 2 personal noise dosimeter, as defined by American National Standards Institute (ANSI) S1.25-1991(R1997) American National Standard for Personal Noise Dosimeters (ANSI, 1991). Despite allegations that personal noise dosimeters are not as accurate as sound level meters or that they read erroneously with impulse noises, research has found that they are as accurate as sound level meters (Valoski et al., 1995); moreover, they correctly weigh impulse levels (Evans et al., 1991).

The new rulemaking efforts undertaken by MSHA, adopted in September 1999 and scheduled to go into effect in September 2000, retain the PEL of 90 dBA TWA_8, and include a new action level which is a noise dose of 50%, or equivalently a TWA_8 of 85dBA. The new regulation requires the mine operator to enroll a miner in an HCP if, during any work shift, the miner's noise exposure equals or exceeds the action level. Moreover, the new rules establishes the primacy of engineering and administrative noise controls, and explicitly eliminates credit for the use of personal hearing protection. Additional criteria include, a dual hearing protection level of 105 dBA TWA_8, and no miner is permitted to be exposed to sound levels exceeding 115 dBA. Specific details of the new regulations are listed in Table II.

Table II - Details of Part 62 - Occupational noise exposure measurements.

Type	TWA_8, dBA	Dose	Sound levels integrated, dBA	Exchange rate, dB	Weighting	Response
Action level	85	50%	80 to 130	5	A	Slow
Permissible exposure level	90	100%	90 to 140	5	A	Slow

CROSS-SECTIONAL SURVEY OF NOISE EXPOSURE

Methods

NIOSH is conducting a study to obtain multi-shift worker noise exposure and equipment noise levels to develop an up-to-date comprehensive profile of miners' noise exposures as a function of equipment and activity-specific measures. This study is a crucial component in the effort to develop noise controls because it will define the sources of miners' dosages and the characteristics of those sources. Once this information is available, efforts can focus on the development and application of appropriate engineering and administrative control measures that will result in reduced exposures for mine workers. Data collection will be performed at underground and surface coal and metal/nonmetal mines and in mineral processing plants. Although an exact study population has not been defined at this time, it is necessary to survey all segments of the mining industry because workers across the industry continue to have a significant risk of hearing impairment, as illustrated by the MSHA inspector noise survey data published in the Federal Register (1999) (see Table III).

Table III - MSHA inspector noise samples exceeding specified TWA_8 sound levels.

Mining sector	Occupation	Number of samples	90-dBA threshold	80-dBA threshold
			Percent of samples >90 dBA (PEL)	Percent of samples $85 dBA (action level)
Metal/ Nonmetal	Front-End-Loader Oper	12,812	12.9	67.7
	Truck Driver	6,216	13.1	73.7
	Crusher Oper	5,357	19.9	65.1
	Bulldozer Oper	1,440	50.7	86.2
	Bagger	1,308	10.2	65.0
	Sizing/Washing Plant Oper	1,246	13.2	59.7
	Dredge/Barge Attendant	1,124	27.2	78.7
	Clean-up Person	927	19.3	71.3
	Dry Screen Oper	871	11.7	57.6
	Utility Worker	846	12.4	60.6
	Mechanic	761	3.8	43.9
	Supervisors/Administrators	730	9.0	32.2
	Laborer	642	17.1	65.7
	Dragline Oper	583	34.0	82.5
	Backhoe Oper	546	8.4	52.6
	Dryer/Kiln Oper	517	10.5	55.5
	Rotary Drill Oper. (electric/hydraulic)	543	39.6	83.1
	Rotary Drill Oper. (Pneumatic)	489	64.4	89.0
Coal	Continuous Miner Helper	68	33.8	88.2
	Continuous Miner Oper	262	49.6	96.2
	Roof Bolter Oper. (Single)	234	21.8	85.5
	Roof Bolter Oper. (Twin)	92	31.5	98.9
	Shuttle Car Oper	260	13.5	78.5
	Scoop Car oper	94	18.1	74.5
	Cutting Machine Oper	22	36.4	63.6
	Headgate Oper	20	40.0	100.0
	Longwall Oper	34	70.6	100.0
	Jack Setter (Longwall)	25	23.0	68.0
	Cleaning Plant Oper	107	36.4	77.6
	Bulldozer oper	225	48.9	94.2
	Front-End-Loader Oper	244	16.0	76.6
	Highwall Drill Oper	83	21.7	77.1
	Refuse/Backfill Truck Driver	162	13.6	78.4
	Coal Truck Driver	28	17.9	64.3

The plan of research is comprehensive and is designed to include all workers at each site investigated. The data collected will include worker noise dose, equipment noise, and other worker, mine, and equipment-specific information necessary for characterizing the noise sources. At each site, mine workers will wear time-resolved dosimeters. During the shift, a task-based exposure assessment methods (T-Beam) approach studies will be used to correlate each mine worker's tasks, the noise dose received, and the noise source responsible for that incremental contribution to the miner's total exposure. Noise profiling of mine machinery will be conducted using hand-held sound level meters. This will consist of A-Weighted Equivalent Continuous Sound Levels (Leq) measurements on a uniform grid pattern to develop detailed noise contours and "area sweeping" of mine machinery to calculate sound power. The instruments that will be used to make these measurements include Quest Technologies Model Q 400, Noise Dosimeters, and Quest Model 2900,Integrating and Logging Sound Level Meters (fig. 2). Finally, site-specific parameters, such as characteristics of the mine plan, will be documented to support subsequent analyses. The bulk of the data collection activities are completed over five shifts. Typically, one or two site visits are made in advance of the data collection to gather information for the design of the site-specific data-collection activities.

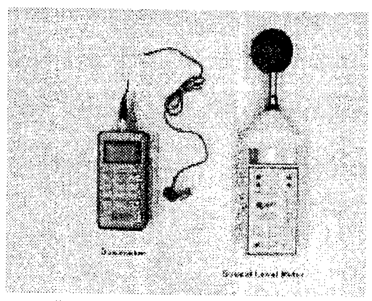

Figure 2: Dosimeter and sound level meter for conducting noise surveys.

Results

Progress to date includes completion of pilot studies at an underground coal mine and underground limestone mine, and a full-scale study conducted at a coal preparation plant. The pilot studies served both as training exercises for the field crews and for refining the data collection and analysis procedures. The study at the preparation plant included surveying the noise on all eight floors and a control room (fig. 3). The data collected included A-Weighted Leq , as well as Linear 1/3rd Octave Band Sound Pressure Levels (SPL's) around all major pieces of processing equipment.

The plant was a modern/multicircuit coal preparation plant. It was constructed of steel I-beams for internal support with corrugated steel walls (fig. 4), except for the first floor, which had walls constructed from concrete block. All floors were constructed of 4 inches of concrete, except on the second and sixth floors, which were made of open steel grating. In addition, there were many open spaces that extended from one floor to the next, or in some cases, from the ground floor to the top floor. The processing equipment included classifying cyclones, sieve bends, magnetic separators, flotation cells, banana screens, heavy media cyclones, D&R screens, coal spirals, centrifuges, clean coal and refuse conveyors, and pumps.

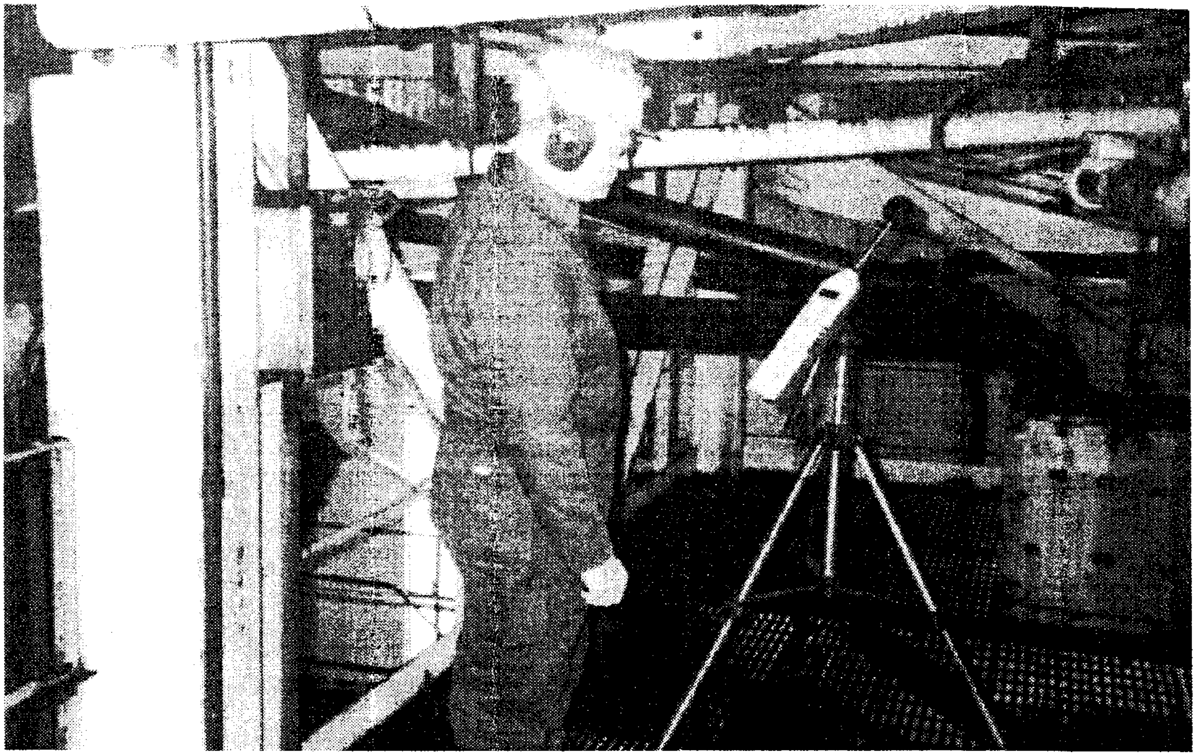

Figure 3: Noise measurement being made with a sound level meter.

Figure 4: Example of wall and building construction including open spaces.

The measured Leq levels ranged from 83 to 115 dBA, with most floors averaging in the upper 80s and above (see Table IV). Although Table IV lists the dominant noise sources, characterization of noise sources in the plant was a complicated task for several reasons. First, the sheer number of pieces of equipment and their close proximity to each other made separating specific noise sources extremely difficult, and process considerations made it impossible to operate equipment independently. Next, the openness of the building allowed noise to propagate between floors, as did the floor-to-floor connections of the equipment. Finally, the measured noise came from several sources, most often a combination of airborne and structure-borne noise paths (fig. 5). Airborne noise was present as direct sound, generated by the equipment, the process, and motors, and as reverberant sound reflected by the building's walls and floors. Structure-borne noise paths resulted from equipment vibration and transfer of that vibration to the building's structural components. The vibrant energy was then radiated as airborne sound into the surrounding area. An example of a contour plot of the noise levels is illustrated in Figure 6.

Table IV - Summary of Leq levels.

Floor	Leq Range, dBA	Major equipment	Dominant noise source (Leq, dA)
1	91 - 99	pumps, pump motors	classifying cyclone pump (99.4 dBA)
2	92 - 96	Conveyors	clean coal and refuse conveyors (93.5 dBA)
3	93 - 103	dewatering screens, centrifuges, mag separators,	fine refuse dewatering screen (101.6 dBA)
4	94 - 101	sieve bends, D&R screens, coal spirals	clean coal and refuse D&R screens (100.4 dBA)
5	91 - 101	heavy media cyclones, banana screens, flotation cells, sieve bend	raw coal banana screens (99.8 dBA)
6	89 - 115	sieve bends, cyclones	fine clean coal sieve bends (104.6 dBA)
7	89 - 92	raw coal conveyor, sieve bends, mag separator	None
8	88 - 91	Cyclones	15-inch dia. Classifying cyclones (91 dBA)
Control Room	74 (Inside) 90 (Outside)	plant controls, monitors, etc.	None

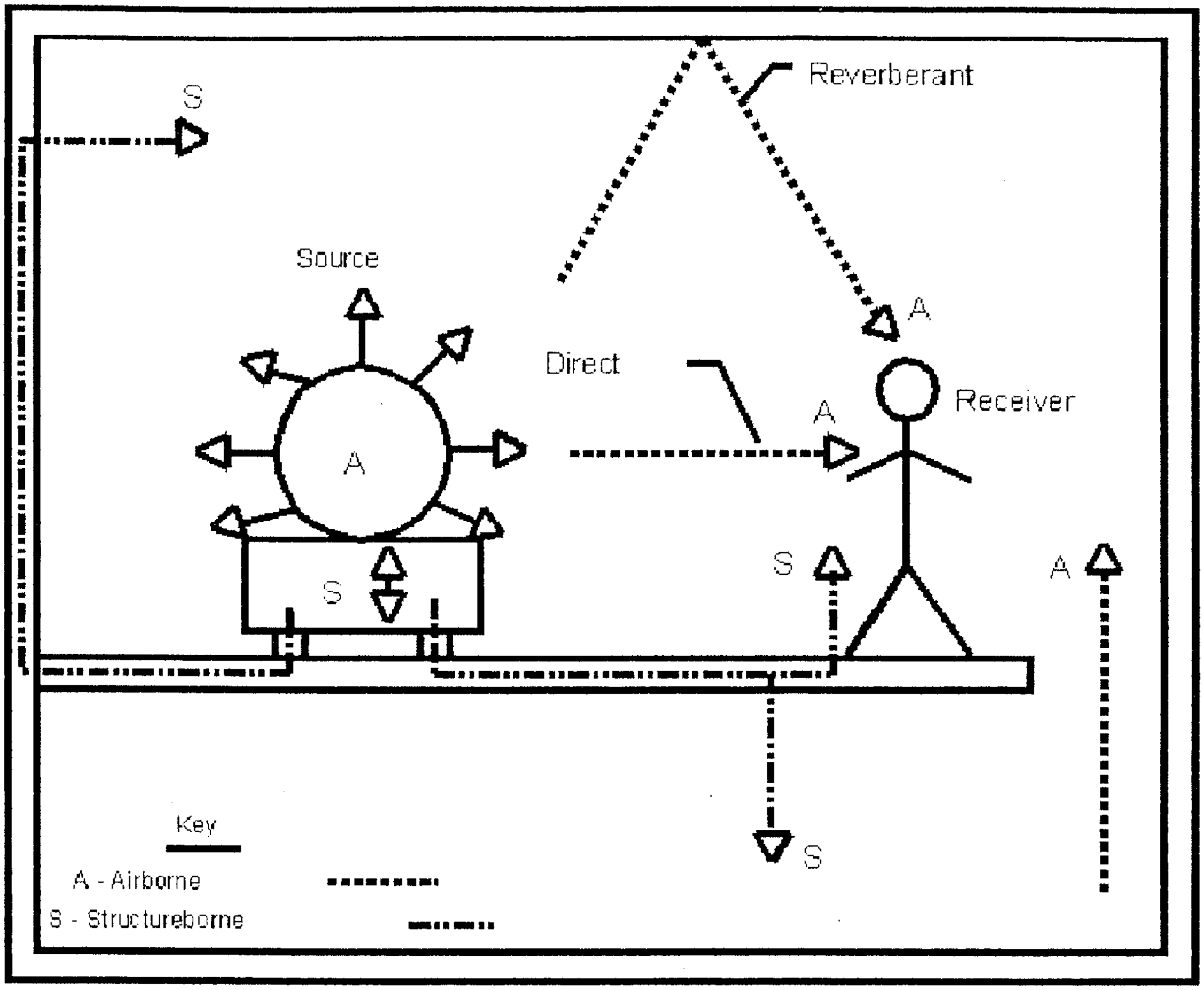

Figure 5: Example of airborne (A) and structureborne (S) noise paths.

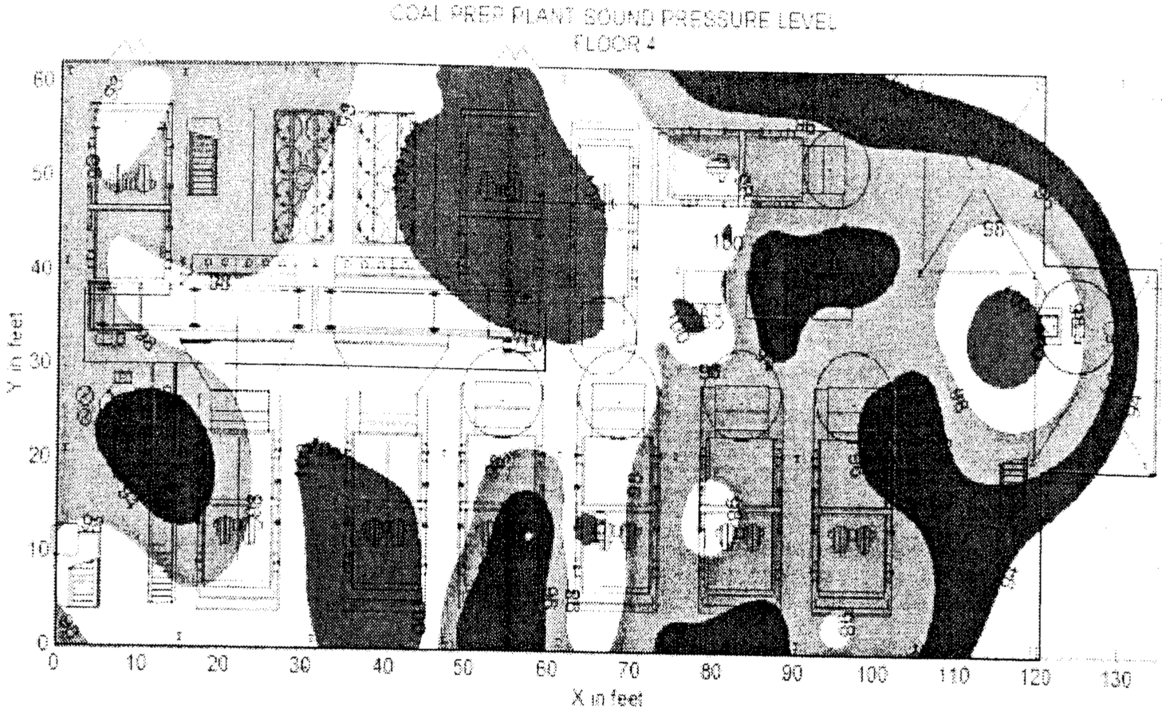

Figure 6: Example of noise contours in prep plant.

A few general observations of the noise levels on all floors can be made. (1) Although the highest noise levels were recorded on floor 6, floors 3 and 4 are considered to be the noisiest floors overall because the noise was consistent throughout the entire floors. (2) Vibration is certainly a factor in generation of noise throughout the plant. (3) Reverberant noise from the building walls is likely a significant component of the noise throughout the plant. (4) The openness and construction of the plant is conducive to noise propagation between floors. This likely resulted in "smearing" or "blending" of the noise from floor to floor.

In addition, several man-shifts were spent following the Plant Controls Man, documenting his work activities while he wore a personal dosimeter. He wore a personal dosimeter for parts of two shifts (8 a.m. to 3 p.m.), while a NIOSH Researcher performed a time and motion study as he traveled throughout the plant. Table V summarizes the Plant Control Man's location throughout the shifts. Table VI presents the projected dose and time-weighted average. The projected dose, in percent, is computed by measuring the dose for a specified time period (in this case, approximately 7 hrs) and extrapolating it to a different time period (8 hrs). The time-weighted average is the average sound level computed over an 8-hour time period.

Figure 7 is a plot of the cumulative dose for the measurement period. The sections of the graph with the steepest slope indicate the periods that the Plant Controls Man was in the plant and receiving most of his measured noise dosage. In contrast, the flat slope sections of the graph are the minimal dosages accumulated while he was in the control room or traveling between the control room and plant.

Table V - Location of Plant Controls Man			
Location	**Duration, min.**	**Time, pct.**	**Percent Dose**
Control Room	210.20	51	12[1]
Plant	189.25	46	88
Traveling between plant and control room	11.50	3	ND[2]
Total	**411**	**100**	**100**

[1]Although no control room was under 80 dBA, some higher noise levels occurred because of equipment and the door being opened.
[2]ND - Not determined. Since time period was small and because the old plant was not running, the dose is included in the Control Room dose

Table VI - Projected 8-Hour Dose for Plant Controls Man (one shift)		
MSHA Designation	Projected Dose, pct	Time Weighted Average (TWA_8), dBA
Action Level	159.96	93.4
Permissible Exposure Level	152.36	93.0

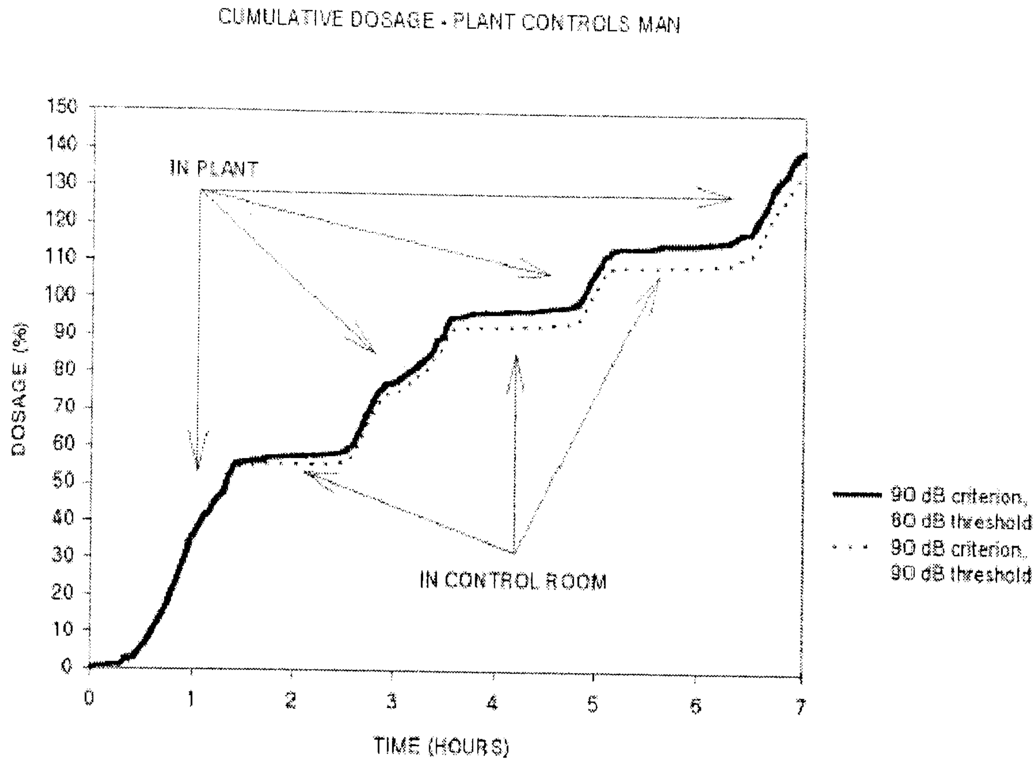

Figure 7: Plot of cumulative noise dose for plant controls man.

SUMMARY

Noise-induced hearing loss is a concern in the mining industry. One study revealed that more than of 90% of miners have a hearing impairment by the age of 50 (Franks, 1996). In addition, based on thousands of inspector noise samples, MSHA has suggested that miners in all sectors of mining and occupations continue to have a significant risk of NIHL over a working lifetime. Despite government and industry efforts over the past three decades, hearing loss remains relatively unchanged in the industry. It is apparent that it is a complex problem that will require an understanding of its underlying causes. Although engineering and administrative controls represent the desired means of protecting workers from excess exposure, it will be necessary to understand where mine workers receive their exposure and the specific characteristics (frequency, duration, level) of the offending noise sources. The NIOSH cross-sectional survey project will establish valid worker noise exposure and equipment noise level data for formulating intervention strategies that target high-risk equipment and activities with the noisiest exposures for mine workers.

The coal preparation plant study highlighted in this paper illustrates the nature of the study and the complexities of the data analysis. The ultimate value and application of the findings from this plant will be in aggregated form when it can be examined as part of a larger sample of plants and mines. However, there is specific value to these findings as well. Careful study and review of the contour plots revealed "hot spots" of higher noise levels. These can be the starting points for applying engineering and administrative controls in an attempt to reduce noise and worker exposures.

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