Identification of noise sources on longwall panels using multiple time-synchronized dosimeters

E.R. Spencer, D.R. Babich, L.A. Alcorn and A.K. Smith
Mining engineer, mining engineer, engineering technician and mechanical engineer, respectively, National Institute for Occupational Safety and Health (NIOSH), Pittsburgh, Pennsylvania.

Abstract

Noise is one of the most pervasive health hazards in mining. A compilation of Mine Safety and Health Administration (MSHA) noise survey data for fiscal year 1990 shows that approximately 40% of the total samples taken for longwall occupations exceeded the Permissible Exposure Limit (PEL) of 100% (Gigliotti et al., 1991). To effectively determine worker noise exposures on longwall coal mining systems, it is necessary to provide accurate baseline measurements for these mining systems. This research was designed to develop measurement methods and test procedures for identifying noise sources that are major contributors to the underground noise exposure of longwall coal mining system workers. The measurement system that was used to analyze the noise sources around a stageloader used stationary dosimeters in a documented repeatable pattern to record the sound pressure and dose levels. A time-motion study of the cutting cycle and stageloader operator's work cycle was done to correlate the sound levels at measurement locations and the resulting operator's daily dose with significant noise events. Results from the underground measurements show that the highest sound levels recorded were at the stageloader discharge segment and tailpiece controls, where sound levels remained about the same throughout the test.

Introduction

Despite 25 years of regulation, overexposure to noise remains a widespread, serious health hazard in the U.S. mining industries. Noise-induced hearing loss (NIHL) is the most common occupational illness in the United States today, with 30 million workers exposed to excessive noise levels (NIOSH, 1999). Noise doses (PEL) of up to 786% have been recorded for longwall coal mining system workers with job titles such as shearer operator, jacksetter, longwall foreman and head gate (stageloader) operator (Bauer et al., 2001). This study revealed that the sound levels around the longwall mining system ranged from 81 to 102 dB(A). The study also showed that stageloader operators were among the most exposed longwall coal mining system workers, with recorded PEL dose levels ranging from 142% to 386%.

This paper presents suggested measurement methods from research done by the NIOSH Pittsburgh Research Laboratory to reduce noise exposure in mining environments. The measurement methods used identify the noise sources that are major contributors to the underground noise exposure of longwall mining system workers. The procedures followed allow for accurate, repeatable measurements of the noise sources and for the development and evaluation of noise controls on longwall mining systems. Specifically, this paper concentrates on the noise emissions of a DBT America[1] longwall stageloader system. DBT America longwall stageloader systems make up approximately 40% of the stageloaders in use in underground coal mines (Coal Age, 2006) and thus are representative of industry usage. Mining equipment manufacturers, mining companies and MSHA intend this information for use for evaluating the effectiveness of engineering noise controls.

Background

2004 study. NIOSH researchers completed a study evaluating an engineering noise control on a JOY stageloader in New Mexico in 2004 (Bauer et al., 2005). The study was performed in three phases: precontrol, postcontrol and 6-month postcontrol. The noise control tested included sound-absorptive filled cavities on the crusher and gooseneck using bagged fiberglass

1 References to specific brand names do not imply endorsement by the National Institute for Occupational Safety and Health.

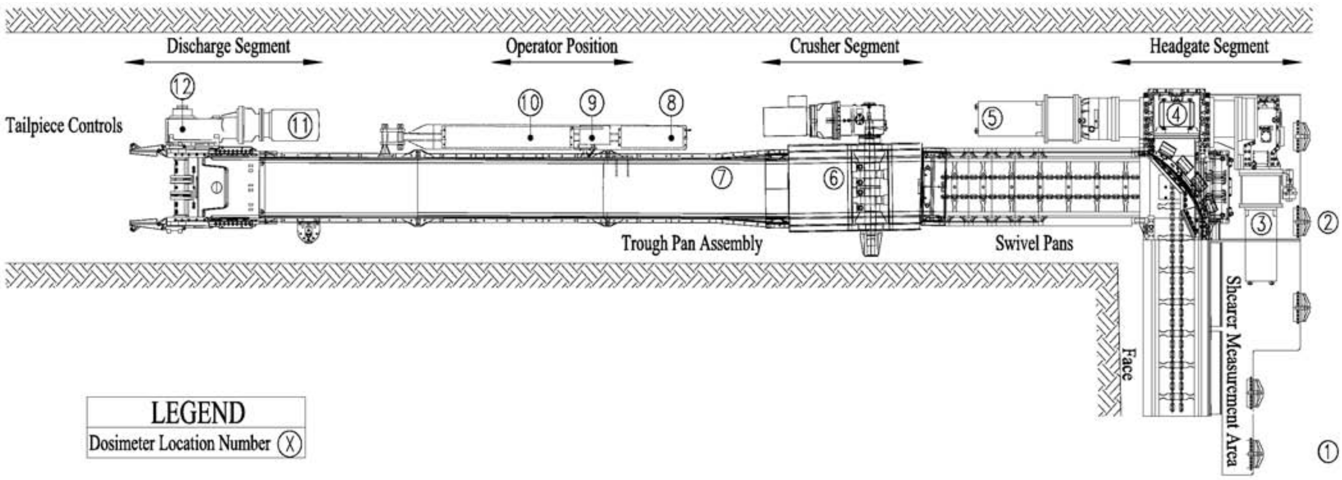

Figure 1 — Segments of the longwall head gate mining system (not to scale) with dosimeter locations.

covered with conveyor belting. The sound levels, worker noise exposure levels and four stationary dosimeter measurements were collected at similar locations and conditions for all phases. The sound level measurements made in the head gate area and along the length of the stageloader were taken at 30 locations using a sound-level meter set to average over a 30-second time period. A minimum 15-minute test period was required when mining conditions were constantly changing. The 6-month postcontrol sound levels were on average 2 to 3 dB lower than the initial postcontrol sound levels and nearly the same as the precontrol sound levels. Overall, it was not possible to determine if the implemented engineering noise control reduced the stageloader sound levels or the stageloader operator noise exposure.

In this 2004 study, although various types of measurements were conducted on the stageloader over several shifts, the test results varied and were inconclusive. At this study site, production levels varied greatly because of problems associated with hydrogen sulfide (H_2S). This resulted in widely varying amounts of coal in the stageloader because production was decreased or stopped when the concentration of H_2S in the environment reached a certain level. Thus, changing amounts of the coal being cut, crushed and conveyed was a major factor in the variability of the testing results. In addition, the movement of the longwall face in relation to the crosscuts and the varying size of the section caused deviations in the long-term or shift measurements. The high percentages of noise overexposures, wide ranges of dose levels and the inability to evaluate noise controls underground prompted NIOSH to perform follow-up research to determine methods and procedures for measuring the longwall mining systems underground.

Research approach to current study. In the 2004 study, research concentrated on exposure/dosage measurements and single sound-level measurements as indicators of excessive noise problems on longwall mining systems. The sound-level measurements made in the head gate area and along the length of the stageloader were taken at 30 locations and took more than 15-minutes to complete while mining conditions were constantly changing. The current study's approach to measurement methods included using time-synchronized stationary dosimeters for measuring sound levels of the longwall mining system and conducting a time-motion study. The time-motion study was used in conjunction with sound-level measurements to correlate operational events on the longwall stageloader mining system with periods of high noise generation. This allowed for repeatable and full-test period measurement of noise sources on longwall stageloader mining systems for prenoise and postnoise control evaluations.

Permissible dosimeters were used to record the sound levels and were placed on the stageloader and in the head gate area in a documented pattern (Fig. 1). Because of the size of the stageloader, the stationary dosimeters were placed at known noise sources on the machinery, (e.g., armored face conveyor (AFC), crusher and discharge). The dosimeters were fitted on magnetic stands with their microphones approximately 300 mm (12 in.) from the magnet base. Any height greater than this might have resulted in the instruments being knocked off or crushed because of the low clearances. Each dosimeter was set to record the equivalent sound level every 10 seconds using an exchange rate of a 3-dB, A-weighting, slow response, 40-dB threshold level and a 140-dB upper limit. Data recorded from the dosimeter provided the following information: an A-weighted sound pressure level, maximum and minimum sound levels, and absolute unweighted peak sound levels at each of the designated positions. To obtain the MSHA PEL and time-weighted average over 8 hours (TWA(8)), the dosimeters were also set to meet MSHA criteria, which included a 5-dB exchange rate, A-weighting, slow response, 90-dB threshold level, a 90-dB criteria level and a 140-dB upper limit (Code of Federal Regulations, 1999).

Two researchers conducted a time-motion study in conjunction with these measurements. One researcher was positioned at the head gate and was responsible for recording the shearer position and the status of the AFC (off or running empty, half-full or full) with the time of the shearer's cutting cycle and distance from the head gate. The other was positioned at the stageloader discharge area and was responsible for the stageloader armored conveyor (AC) status (off or running empty, half-full or full), the stageloader operator's position and the stageloader movement time and distance moved. The dosimeters and the watches used for the time-motion study were time synchronized.

Test plan. To determine effective dosimeter locations, distance measurements of the longwall stageloader mining system were made underground. These locations were marked and recorded with reference dosimeter numbers, as shown in Fig. 1. The 12 preprogrammed dosimeters were attached to magnetic stands then placed at the predetermined locations. Once all the dosimeters were in position and the researchers were positioned for the time-motion study, the testing then began.

Testing consisted of monitoring two complete passes (a pass consisted of the shearer cutting down to the tailgate and back) or cutting cycles of the longwall shearer. During a complete pass, the shearer traveled a distance of 615 m (2,000 ft) in 80 minutes, which correlates to an average cutting speed of about 7.7 m (25 ft) per minute. The cutting speed was less than 7.7 m (25 ft) per minute during cut-out and sump-in at the head and tail, and greater when traversing the remainder of the longwall face. After 4 hours, the dosimeters were removed from the longwall stageloader mining system and taken back to the lab for analysis. Each dosimeter was downloaded and saved as an Excel file. After all of the results were tabulated into an Excel spreadsheet and analyzed, relationships derived from the data were determined. A graph was generated for each test point plotting the equivalent sound level versus time. Finally, the time motion results were overlaid on each of the graphs. From these graphs, the maximum sound level for each location could be determined and related to the operation of the longwall mining system.

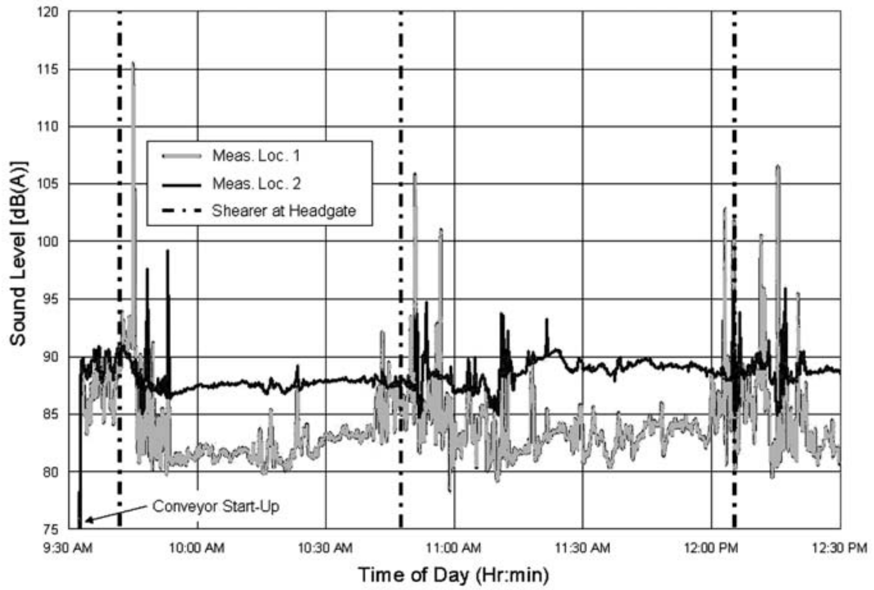

Figure 2 — Sound-level measurements at shearer measurement segment, Locations 1 and 2

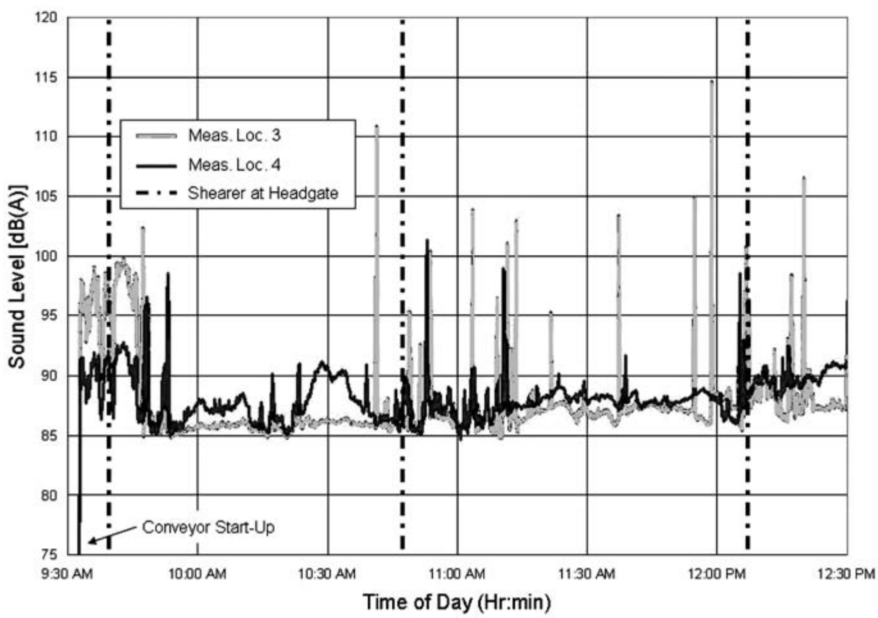

Figure 3 — Sound-level measurements at stageloader head gate segment, Locations 3 and 4.

Results

To analyze the complex longwall mining system, the head gate and stageloader were divided into six measurement segments: the shearer, stageloader head gate, swivel pans/crusher, trough pan assembly (stageloader body), stageloader operator position and discharge/ tailpiece controls. The data were then organized so that the sound levels in each segment could be examined as a function of time. Operational events that were noted during the time-motion study were analyzed on the same time scale as the stationary noise measurement instruments. Thus, insight was gained about the sound field as the longwall system operated.

Shearer measurement segment. Figure 2 depicts sound-level measurements for the shearer measurement area segment, Locations 1 and 2, which represents the shearer as it travels to the head gate, cuts out and sumps into the face and cuts back to the tailgate. Both locations have similar sound levels when the shearer is at the head gate area (dash-dot line), indicating that the shearer is the dominant noise source. The sound levels at Location 1 drop by 8 dB, 10 minutes after the shearer leaves the head gate area, at which time only the sound levels generated by the AFC are present. However, the sound levels at Location 2 stay consistently higher than at Location 1, except when the shearer is at the head gate. This indicates that Location 2 receives additional noise from the conveyor/head drive area section, which is the major noise contributor at Location 2 when the shearer is operating at a distance down the face from the head gate.

Stageloader head gate segment. Sound-level results for measurement Locations 3 and 4, which represent the stageloader head gate area, are shown in Fig. 3. This segment is where the AFC ends and the stageloader AC begins. The startup noise from the face AFC (head drive) and shearer can be seen at 9:32 AM in this graph and continues until 9:45 AM as the shearer cuts into the head gate. The startup noise diminishes

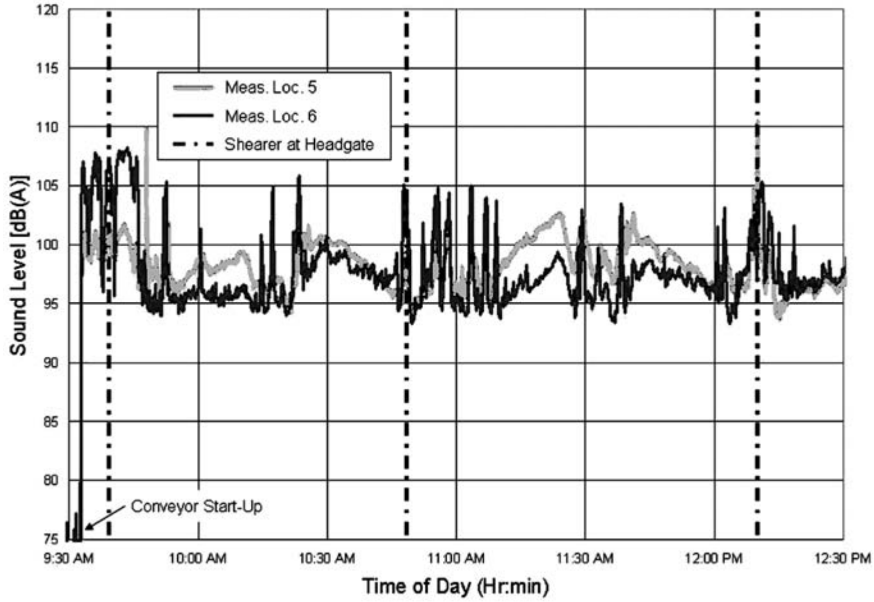

Figure 4 — Sound-level measurements at swivel pans/crusher segment, Locations 5 and 6.

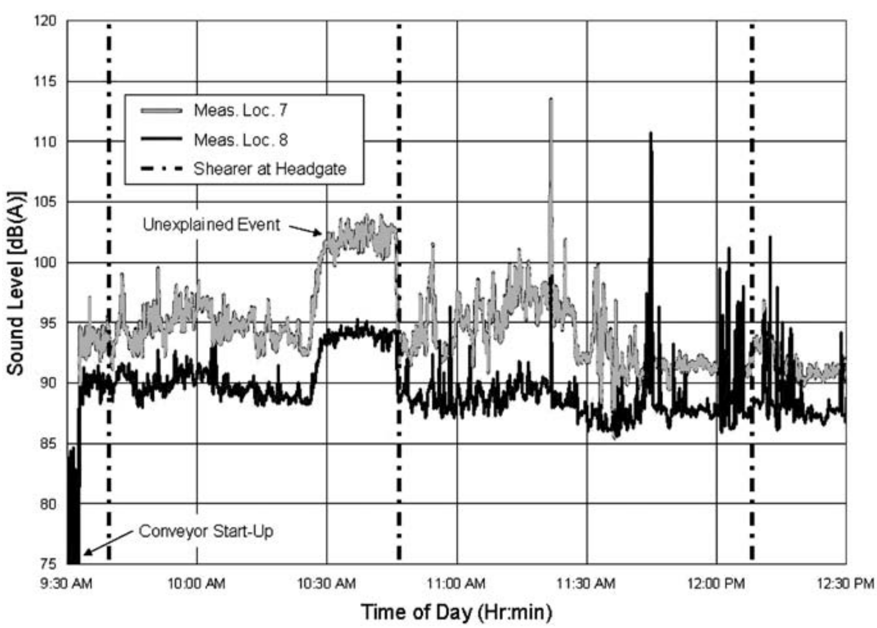

Figure 5 — Sound-level measurements at trough pan assembly segment, Locations 7 and 8.

as the conveyors fill and the machine "sumps in." High peaks occur at 9:48 AM, 10:51 AM, and 12:05 PM, when the shields push the stageloader forward. Other peaks at 10:45 AM and 11:59 AM correspond to the shearer cutting at the head gate. In general, the dominant noise sources in this case are when the shearer is at the head gate, when the stageloader is moved and finally, from the AFC head drive and the noise from both conveyors, after the shearer leaves this area.

Swivel pans/crusher segment. Figure 4 shows sound level results for Locations 5 and 6, which represent the area in front of (swivel pans) and on top of the crusher, respectively. The results show sound levels primarily ranging from 95 to 105 dB(A). Initially, when the conveyors went from empty to half-full to full, a corresponding rise in the sound levels was observed. However, as time went on, no correlation between increases in sound level and conveyor status (empty, half-full or full) could be determined. Furthermore, shearer location had little impact on noise levels observed at these measurement positions due to the distance from the shearer. In general, at these locations, the crushing and transport of material, along with the machinery noise, cause the dominant noise sources.

Trough pan assembly (stageloader body) segment. Figure 5 shows sound level results for Locations 7 and 8, which represent the area on the body of the stageloader at the trough pan assembly and nearby the stageloader body. The sudden increases at each location, occurring from 10:25 AM to 10:45 AM, cannot be explained by the time-motion observations. Further investigations are needed to determine the cause of this event. The approximate 4 to 5 dB difference in sound level between Locations 7 and 8 can be attributed to Location 7 being on the stageloader body and closer to the noise radiating from the enclosed body. At these locations, the crushing and transport of material, along with the machinery noise, cause the dominant noise sources.

Stageloader operator position segment. Figure 6 shows sound level results for measurement Locations 9 and 10, which represent the area at the stageloader operator's position. As Figure 6 shows, the stageloader operator spent about 50% of his time in this area (shaded area). Similar to what occurred at Locations 7 and 8, the sudden sound level increase at Location 9 from 10:25 AM to 10:45 AM cannot be explained by the time-motion observations. The total MSHA-defined dose during the total observational period at Location 10, taken directly from the dosimeter, was determined to be 28% with a time-weighted average (TWA(8)) of 81 dB(A). The dominant noise source in this area is caused by the transport of material radiating from the stageloader body.

Discharge/tailpiece controls segment. Sound level results for measurement Locations 11 and 12 are displayed in Fig. 7, and represent the area at the discharge segment of the stageloader. The controls for the crawler-mounted tailpiece are also located in this area. The dosimeter and magnetic stand at Location 11 fell off of the stageloader at 9:52 AM and were placed back into position at 10:04 AM. This measurement segment had the highest sound levels of all measurement locations along the stageloader, ranging from 105 to 111 dB(A). Although the operator did not spend a majority of his time in this area (shaded area), exposure levels would likely exceed the PEL in less than one hour at these sound levels using the MSHA Reference Duration Table 62-1. Using the MSHA criteria, the total accumulated dose during the cutting cycle between 10:46 AM and 12:10 PM at Location 12 is 1,195%, and the TWA(8) is 108 dB(A) for this cutting cycle. In general, the dominant noise was caused by the crusher noise and the stageloader AC noise traveling down the enclosed stageloader body, acting as a wave-guide and making it louder at the discharge. External to the discharge noise source are the tailpiece motor and gear box contributions.

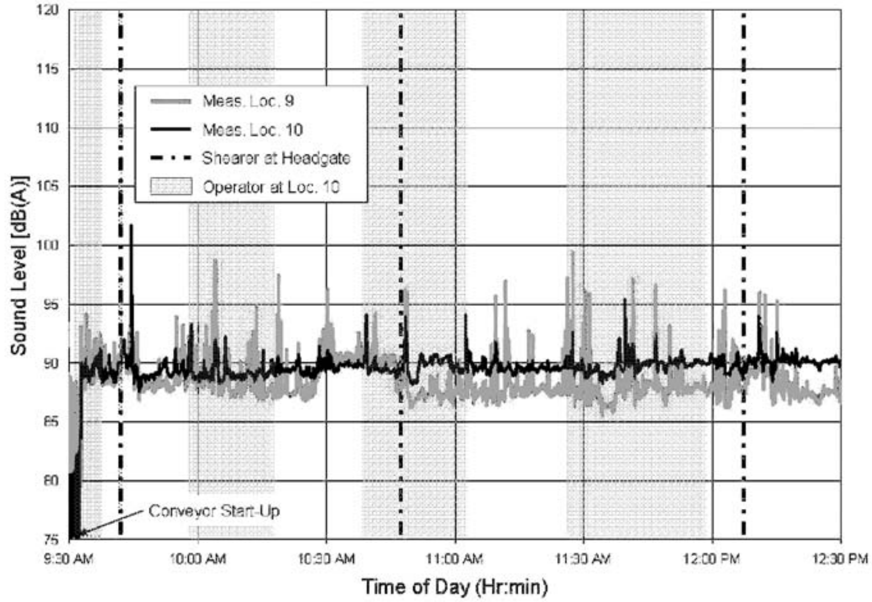

Figure 6 — Sound-level measurements at stageloader operator position segment, Locations 9 and 10.

Segment comparison analysis. Analysis of data from a cutting cycle between 10:46 AM and 12:10 PM is shown in Table 1. The results compare all the measurement locations by the MSHA dose, TWA(8), and overall equivalent sound level. The information presented in Table 1 is based strictly on the 1-hour 24-minute time period (cutting cycle), extrapolated to 8 hours, and assumes that the cutting cycle and associated sound levels repeat exactly the same for an 8-hr. period. When the shearer is at the head gate, sound levels peak above 105 dB(A) (Fig. 2); however, these peaks have a minimal effect on the calculated dose because of their short duration. It is not until the crusher segment area that the high dose levels and corresponding high dB(A) TWA(8) occur. The 14-dB difference between Locations 7 and 8 can be attributed to Location 7 being on the stageloader body and closer to the noise radiating from the enclosed body. The stageloader operator position, at the midpoint of the stageloader body, is a relatively quiet area for the operator. Thus, the operator should be encouraged to be in this area whenever other work tasks are completed to reduce the overexposure to noise.

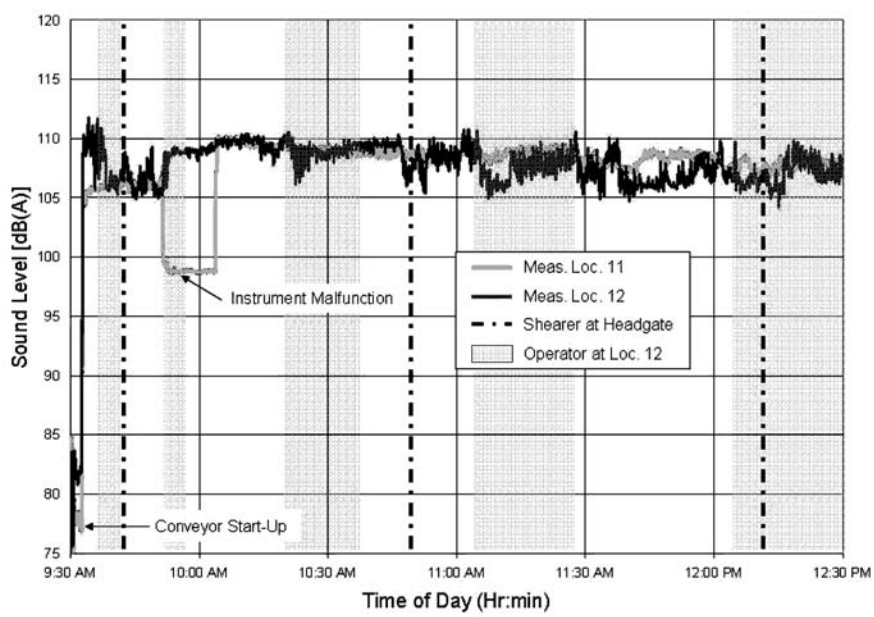

Figure 7 — Sound level measurements at discharge/tailpiece controls segment, Locations 11 and 12.

Unlike any other location along the stageloader, the discharge and the area around the tailpiece controls have excessively high sound levels during this cutting cycle, resulting in potentially high doses for workers located near this area during this cutting cycle. This noise at the discharge is mostly caused by the crusher noise and the stageloader AC noise traveling down the enclosed stageloader body, acting as a wave-guide and making it louder at the discharge, along with the tailpiece motor and gear box.

Summary

This paper presents suggested methods for repeatable measurements of noise levels of a longwall mining system for prenoise and postnoise control evaluations. In addition, the report documents research by NIOSH on a longwall mining system representative of industry usage. The study involved monitoring the head gate area and stageloader using stationary time-synchronized dosimeters set up to record sound levels. The synchronized dosimeters allowed for sound levels, dose and TWA(8) comparisons along the entire stageloader from each measurement location. A time-motion study of the shearer position, stageloader movement, stageloader operator position and amount of material on the conveyor was conducted to correlate operational events on the longwall mining system with periods of high noise generation. The shearer's position had minimal effect on the overall sound levels, as did the stageloader movement. The estimated MSHA 8-hr dose listed

Table 1 — Measurement results from cutting cycle between 10:46 AM and 12:10 PM.

Segment area	Measurement location	MSHA-defined dose, %	MSHA-defined TWA(8), dB(A)	Overall test Leq, dB(A)
Shearer measurement area	1	9	73	84
	2	10	74	89
Head gate	3	24	80	88
	4	6	70	88
Crusher	5	361	99	99
	6	308	97	97
Trough pan assembly	7	187	94	94
	8	26	80	87
Operator position	9	15	76	88
	10	35	82	90
Discharge and tailpiece controls	11	1,358	109	108
	12	1,195	108	107

in Table 1 indicates that the stageloader operator is not likely to be overexposed at the operator position, but when at the tailpiece controls the potential for overexposure is excessively high. Initially, when the stageloader AC went from empty to half-full to full, a corresponding rise in the sound levels was observed. However, as time went on, no correlation between increases in sound level and conveyor status (empty, half-full or full) could be determined.

Identifying noise sources is the first step toward developing engineering noise controls to reduce longwall mining system worker noise overexposure. In this study, the highest equivalent sound levels recorded are at the stageloader discharge segment and tailpiece controls; these remained at about the same level throughout the test. The next step in reducing overexposure is to identify the sources causing the noise at the discharge end of the stageloader, because during the cutting cycle it produced the highest calculated TWA of 109 dB(A). The noise at the discharge was caused by the crusher noise and the stageloader AC noise traveling down the enclosed stageloader body, acting as a wave-guide and making it louder at the discharge, along with the tailpiece motor and gear box. Because the discharge area has proven to have the highest sound levels, future engineering noise-control research by NIOSH will be concentrated in this area.

Disclaimer

The findings and conclusions in this report have not been formally disseminated by the National Institute for Occupational Safety and Health and should not be construed to represent any agency determination or policy.

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