Mining haul truck cab noise: an evaluation of three acoustical environments

S.B. BEALKO

S.B. Bealko, member SME, is mining engineer with the Pittsburgh Research Laboratory, National Institute for Occupational Safety and Health, Pittsburgh, PA.

Introduction

This study investigates haul truck cab noise in underground limestone mines that employ nearly 2,000 workers at 117 mines across the United States. In this industry, hazardous noise is present from drilling, blasting, rock crushing operations and the predominance of large and noisy equipment. Continued exposure of miners to high noise levels can cause damage to the inner ear. The result of this damage is a permanent shift in the hearing threshold, known as a noise-induced hearing loss (NIHL). A NIHL makes it difficult to hear and understand everyday speech and is irreversible.

Of special interest is the haul truck (Fig. 1) because it comprises of the largest class of equipment used in the underground limestone industry. With these trucks and most diesel-powered equipment, the engine is generally a major source of noise. Engine noise may emanate from the exhaust, the intake and the cooling fan. Other significant noise sources include the transmission, drive train and hydraulic system.

Noise from these sources reaches the ear via several paths, both directly, by airborne paths and indirectly, by reflections from various surfaces. In addition, sound in the form of vibrations may travel along or through structures (Daniel et al., 1981). An approach to eliminate or control noise at its source, engineering controls, is through the use of mufflers, gaskets and control of reflected noise. Another way to lower noise levels is to identify, isolate and treat the many paths along which noise travels with barriers, absorbers and dampers.

Control of haul truck cab noise is important because haul truck operators spend a majority of their time inside the cab. Most mine policies require haul truck operators to remain inside their cab throughout the entire shift except for restroom use, attendance at safety meetings, during maintenance and sometimes during lunch breaks. Therefore, it is typical for operators to spend almost the entire shift (eight to 10 hours) inside the haul truck cab.

According to Daniel et al., “Cab enclosures generally

Abstract

Mining haul trucks comprise the majority of the equipment used in underground limestone mining operations and are known to emit high levels of noise. A previous study conducted by the National Institute for Occupational Safety and Health (NIOSH) indicates that 70-90 % of all miners have a noise-induced hearing loss (NIHL) great enough to be classified as a hearing disability by retirement age. These results demonstrate the public health need to protect the hearing of workers in the mining industry, including haul truck drivers.

Cab enclosures present an opportunity to isolate the haul truck operator from both truck and other noise in the mining environment. A total of 25 haul truck cabs were studied. They were divided into three style (treatment) categories determined by soundproofing features and technology for noise reduction: old-, new- and retrofitted-style. This study examines the contribution of cab acoustics, operator performance and maintenance to noise reduction for each cab style. Dosimeters were used to measure eight-hour time weighted average sound pressure levels (TWA_8 SPLs) inside and outside the cabs. The main objective was to determine the noise levels inside of the three types of cabs (with different acoustical treatments) and determine if the noise levels were significantly different. Adherence to the Mine Safety and Health Administration (MSHA) permissible exposure limit (PEL) of 90 dB TWA_8 (with a 90 dB threshold) was used as the main indicator of overall noise reduction achieved. Dosimetery results indicated that all but two samples measured outside of the cab exceeded the MSHA PEL. However, only 2% of the samples measured inside of the cabs exceeded the PEL, but samples could still be reduced much further. Descriptive and comparative statistics indicate that noise levels inside the new-style cabs are significantly lower than the other two cab styles. Also, data suggest that there is no difference in noise exposures when comparing the old-style to retrofitted cab styles. Operator influence (opening doors and windows) was a significant factor for increasing noise exposure.

This paper demonstrates that properly designed cabs can achieve major noise reductions, but noise levels could still be reduced much further below the MSHA PEL. New-style cabs, equipped with modern noise-reduction treatments, exhibit much lower noise exposures than the other two cabs styles, and the effectiveness of the current noise-reduction treatments for retrofitted cabs is questionable. Haul truck driver observations indicate that improved noise exposure reduction training is needed. Finally, specific targets for future noise reduction research are suggested that will further contribute to the prevention of hearing loss for haul truck operators.

are the most efficient way to prevent the radiation of sound through the cab walls." The effectiveness of noise reduction is greater if the cab is lined with an acoustically absorptive material. Most newer haul truck cabs are manufactured with features that are designed specifically for noise reduction (new-style cabs). These features are typically not found as original components in cabs of older trucks (old-style cabs). Sound-proofing materials may be added to the older cabs to upgrade their noise reduction potential (retrofitted cabs).

This study examines noise exposure inside haul truck cabs experienced during a typical workday with normal operator practices, the effect of noise-reduction features inside the cab, the consequence of disabling noise controls (unnecessary open doors/ windows) and the significance of haul truck and cab maintenance factors. The objectives of this study were to:

- Determine if current haul truck cabs provide enough protection to prevent a noise overexposure (as defined by the MSHA PEL) during normal operations.
- Determine if there is a significant difference in the noise exposure as measured inside the old-style, new-style and retrofitted cabs.
- Analyze critical factors that contribute to the cab noise protection potential.
- Observe and consider haul truck operator activities (opening of doors or windows) relative to established operating procedures and to determine this effect on the noise exposure inside the cab.
- Suggest specific research areas to further improve noise reduction in haul truck mining cabs.

Federal regulation of noise exposure in mining

Efforts to combat NIHL in miners began in 1969 with the enactment of the Federal Coal Mine Safety and Health Act (Public Law 91-173). This law set forth requirements for protecting coal miners from among other hazards, exposure to excessive noise. Later, the Federal Mine Safety and Health Act of 1977 (Public Law 95-144) broadened the scope of the law to include noise protection for all miners of all mineral types (the Acts are detailed in 30 CFR, Subchapter O, Part 70, Subpart F, 1997). MSHA enforced a PEL that was an eight-hour, time-weighted average (TWA_8) of 90 dBA(slow) (with a 90 dB threshold), but a hearing conservation program was not mandated unless a citation was issued for overexposure (Joy and Middendorf, 2007).

On Sept. 13, 2000, there was further progress in controlling mining-related noise when MSHA established the new Health Standards for Occupational Noise Exposure (*Federal Register*, 1999). This standard adopted a provision similar to Occupational Safety and Health Administration's (OSHA's) Hearing Conservation Amendment (29 CFR 1910.95), where a miner is required to be enrolled in a hearing conservation program (HCP) if the full-shift noise exposure is at or above the action level (AL) of TWA_8 85 dBA (slow)(80 dBA threshold).

With the PEL remaining the same, other requirements of the new regulations included the primacy of engineering and administrative controls for noise exposure reduction, the implementation of a noise exposure monitoring system and the relegation of the use of hearing protection to

FIGURE 1

Haul truck and cab.

the hearing conservation program. The implementation of these regulations has served to reinforce the importance of noise reduction throughout the mining industry.

Methodology

Categorization of haul truck cabs. Presently, haul truck cabs are manufactured with built-in design features for noise reduction (new-style cabs) whereas cabs on older vehicles lack many such features (old-style cabs). There are also cases where the cab components have worn out before the haul truck is taken out of service. Often, to extend the life of the truck, the original components of these cabs are upgraded with materials (e.g. foam-materials on cab walls or new gaskets around doors and windows) to reduce noise exposures (retrofitted cabs). In order to compare the noise reduction characteristics for each cab style, criteria were established to divide cabs into the three cab styles or treatment groups. A description of each cab style, along with illustrations, follows.

New-style cabs: Noise control features for new-style cabs include sound absorption, vibration damping and sound barriers. Sound absorption materials are soft and porous materials (e.g., flexible polyurethane foam) where the amount of sound absorption is directly related to the amount of treated surface area. Vibration damping materials reduce the amount of vibration energy transmitted between surfaces and are constructed of rigid materials. Sound barrier materials combine mass and flexibility to

FIGURE 2

Examples of new-style cab, a) full-upholstery and window seals b) newer gaskets, door handles and window cranks.

FIGURE 3

Examples of old-style cab, a) and b) steel interior with older sealants and gaskets and c) older door handle.

reduce the sound energy passing between the noise source and the controlled area. Sound barriers, combined with sound absorption materials, can be very effective in controlling noise (Mohanty et al., 2000).

Besides new sound-proofing materials and technology, research has been conducted to reduce structure-borne noise by determining the best placement for sound-absorbing materials in cabs. Researchers created and tested cab designs using computer-aided-engineering methods. Some examples of the new-style cab characteristics are shown in Fig. 2. This figure demonstrates full-upholstery cabs that absorb noise and seals, gaskets and latches that minimize noise leakage and all-around cab vibration.

Old-style cabs: It is not uncommon to encounter haul trucks that are 20-years-old or older still in use at underground limestone mines. Needless to say, these cab enclosures lack some of the new technologies that reduce noise. A typical cab of this type has a hard steel interior that acts as a noise reflecting surface and there is little use of noise reducing materials. Because these cabs experience wear over time, the original components including cab sealants and gaskets may lose their effectiveness and allow noise leakage. In addition, cab integrity may deteriorate and increase cab noise due to the vibration of doors, windows or latches. Preserving the integrity of these components is crucial for noise reduction and thus requires a proactive maintenance program. Some examples of old-style cab characteristics are shown in Fig. 3. This figure illustrates steel interior cabs with noise reflective surfaces, and older-style latches, gaskets and seals.

FIGURE 4

Examples of retrofitted cab with foam sound-absorbing material with sealants and gaskets around a) doors, b) windows and c) walls.

Retrofitted-style cabs: This style cab has been upgraded with new technology or materials such as floor mats, insulation, special glass and other methods to reduce noise. The upgrade may be due to original component deterioration or wear from extensive usage. Figure 4 demonstrates an old-style cab that was upgraded with a material approved by MSHA. This foam material shown was engineered for use in high noise environments and meets the MSHA flammability standards (adopted UL 94 HF-1). It is faced with an aluminized polyester material layer that reflects radiant heat. The facing and foam were fused during processing to create a bond that resists delamination. This material is ideal for sound absorption in enclosed equipment, such as compressors, motors, generators, and pumps (TUFCOTE, 2006). This material is just one example of the many commercially available soundproofing products. There are also products that reduce noise echo, stop vibrations and lower noise transmission through glass.

Associated co-variables

This study was designed to evaluate cab noise exposure levels given the current maintenance condition, in the typical environmental noise surroundings, and with the haul truck operators performing as usual during a typical workday. Therefore, besides noise-reduction features in cabs, there are other variables that effect sound levels inside the cab. As part of the methodology, two of these variables referred to as co-variables, were monitored closely throughout the survey. These two co-variables are maintenance and operator performance. Other potential co-variables were considered including maintenance down time, extreme weather and road conditions, and shortened work shifts.

Maintenance: Although the effect of noise reduction for specific cab components is difficult to identify and measure, it is evident that improper maintenance of haul trucks and cab enclosures can lessen (or degrade) cab attenuation. Also, deteriorated door and window seals should be replaced and holes in the cab frame should be patched because air gaps and holes can also allow noise leakage. Figure 5 shows examples of cab degradation including inadequate sealing around doors, holes in the cab frame and the deterioration of soundproofing materials on the roof.

Another essential maintenance issue is a functional air conditioning system to sustain a comfortable and healthy work environment. If the system is in disrepair, haul truck operators will, out of necessity, open doors and windows to seek relief from the heat. When this occurs, the haul truck operators circumvent some of the protective cab features and allow outside noise, dust or diesel exhaust to enter the cab.

Operator influence: Haul truck operators are encouraged to follow safe operating practices. Most procedures require equipment operators to keep their windows and doors closed as much as possible. However, observations of haul truck drivers during operations reveal that some operators do not always adhere to these practices. One reason, which has already been mentioned, is to cope with malfunctioning air conditioning systems. Another reason is the preference for fresh wind and outside air, regardless of a guarantee for a noisier environment. Smoking and chewing tobacco use can also cause operators to frequently open their windows and doors.

Operators are also encouraged to stay inside the cab and away from noisy environments as much as possible and to report any maintenance needs. Adherence to good practices and procedures for equipment operation can help to reduce noise exposures.

Mine characteristics

Haul truck cab noise was studied at five underground limestone mines. The typical mining sequence for each mine included drilling the face, blasting the rock, and extraction using front-end loaders and haul trucks. The blasted material was transported to the crushing and screening facilities where it was processed into various sized aggregates. One mine had the crushing/screening plant located underground while the other mines had the facilities located outside the mine approximately 91 - 182 m (100 - 200 yards) from the mine portal.

Mine production ranged from 1.4 to 1.8 Mt/a (1.5 to 2 million stpy) of raw product and employment ranged from nine to 30 underground employees. Mining heights averaged 6.7 m (22 ft) and the mining widths were approximately 12 m (40 ft). Most of the underground equipment was diesel-powered with some smaller equipment powered by electricity.

Study procedure

Several tasks were completed prior to the start of the shift. Twenty-five haul trucks were examined and the cabs were categorized as follows: five old-style, 17 new-style and three retrofitted cabs. A pre-shift maintenance inspection of the cab was conducted, including noting the operational condition of the air conditioning unit and any obvious acoustic material maintenance needs.

Haul truck operators were then interviewed about their habits, activities and common practices. The company's operating procedures for haul trucks were discussed including the requirement to keep the windows and doors closed, reporting of any maintenance problems and proper radio volume. Additional information was collected including truck engine data (e.g., horsepower, year, make/model), weather or road conditions and planned maintenance activities.

Upon completion of the pre-shift tasks, noise dosimeters were attached at two locations inside and outside of the cabs. In all, there were 44 samples collected over the 13-shift study period. For each sample, two noise dosimeters measured noise (dBA TWA_8) using the MSHA PEL exposure criteria during the full shift. The dosimeter placed outside the cab to get some idea of how loud noise levels could be without the protective aid of the haul truck cab. In addition, operator activities were monitored and noted throughout the shift as closely as possible. However, researchers could only observe the haul trucks when they were outside of the mine. At the end of the shift, the noise dosimeters were recovered and the data recorded. Finally, a second interview of the haul truck operator was conducted to determine driver activities and other potential co-variables, discuss maintenance issues and to receive feedback or concerns about the noise study.

FIGURE 5

Examples of poor maintenance (a) inadequate sealing around roof, (b) hole in cab frame and (c) deteriorated roof materials.

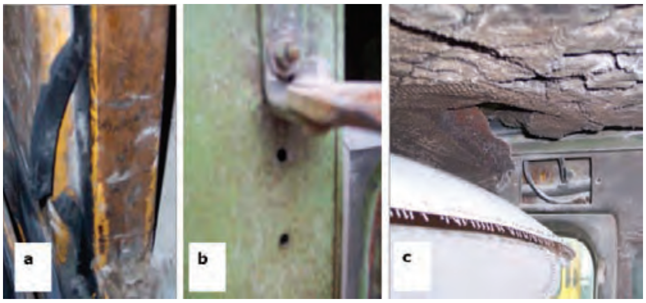


FIGURE 6

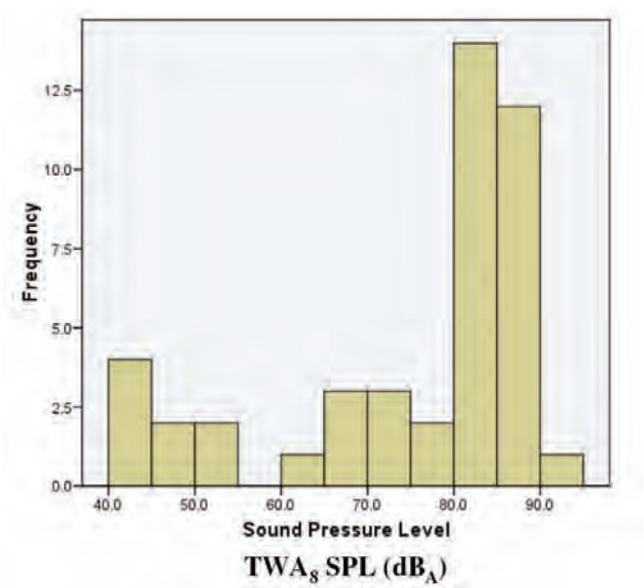
Dosimeter inside cab.

FIGURE 7

Dosimeter outside cab.

FIGURE 8

Histogram of the TWA_8 SPL sample data.



Instrumentation and data collection

Worker noise exposures were monitored using Quest Q-400 noise dosimeters. This instrument is preferred over a sound level meter when the noise levels must be measured over a lengthy period and vary due to intermittent nature. Most dosimeters available today provide outputs in dose or TWA_8 using various exchange rates (e.g. 5 dB), response rates (fast or slow), eight hour criterion levels, and sound measurement ranges.

Noise dosimeters are typically used to measure personal noise exposures of employees, but can also be used to measure noise exposures as area samples where the dosimeter stays in a stationary location. The dosimeters used in this study measured and stored the sound levels during a time period and computed the readout as a percent dose. Equation 1 below was used to convert the MSHA PEL dose percent to TWA_8 SPL.

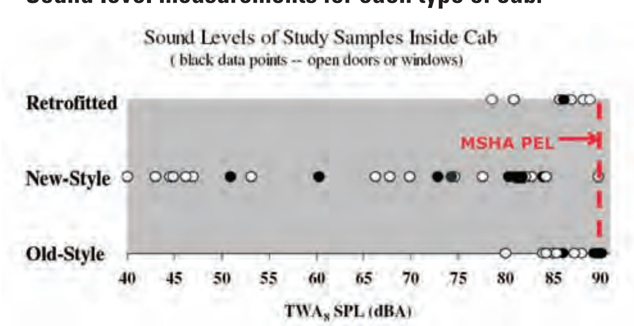
$$TWA_8 \text{ SPL (dBA)} = 16.6 \times \log10 (\text{Dose }\%/100) + 90 \quad (1)$$

Prior to the shift start, the noise dosimeters were calibrated and set to monitor an MSHA PEL of 100% or a TWA_8 of 90 dB Threshold, 5 dB Exchange Rate, a Slow Response, and a 140 dB Upper Limit. For uniformity, the dosimeter microphone inside the cab was placed as close to the operator's right ear as possible. As shown in Fig. 6, the microphone was placed 0.3 - 0.45 m (1 - 1.5 ft) to the right of the operator next to the engine-side window. Actions such as securing the microphone mount with tie wire/electrical tape, placing cloth or clothing around the dosimeter and utilizing microphone covers were taken to ensure the dosimeters or microphones did not vibrate or touch the window and produce structure-borne noise.

Measures were again also taken to protect the outside dosimeters and microphones from damage and vibration against the cab frame. Outside dosimeters were attached to the frame above the operator's door as shown in Fig. 7. This location was chosen to most closely represent the noise levels that the operator would experience if he/she did not have the protective measure of the cab and also out of convenience for fastening the dosimeters (handles and/or bars around or above the cab door in which to secure the dosimeter). There were a few occasions during the study where it was raining heavily. On these days, dosimeters were attached to the frame on the opposite side of the cab (engine-side) and were more directly exposed to engine noise than if they were located on the operator's side.

FIGURE 9

Sound level measurements for each type of cab.



Results

A histogram of the TWA_8 SPLs for all of the measurements inside the cab is shown in Fig. 8. The shape of the histogram (skewed left) suggests that the data may not be normally distributed, but perhaps a larger sample size would lead to a more normal or log-normal sample distribution. It could also be a bi-modal distribution where the high number of quieter cabs (new-style) represents the first peak and the larger group of noisier cabs (older and retrofitted) represents the second peak. Again, the normality characteristics of the histogram could be clarified with a larger sample size.

The descriptive statistics for all of the sample measurements are as follows: sample mean, 75.1; median, 81.3; standard deviation, 15.4; and 95% confidence intervals of the mean, 70.5 (lower limit) and 79.8 (upper limit). There was one extreme outlier (97.7 dBA) in the sample measurements that was not used in the data analysis. When compared to the highest measurement from the study data (90.1 dBA), the sound energy from the outlier was as much as four times greater. This reading was so high that it was improbable that the haul truck driver could have operated for a full shift without reporting discomfort from excessive cab noise levels. Therefore, this sample measurement is extremely unlikely. Researchers found no plausible explanation for this reading except that the dosimeter may have malfunctioned or it was not properly secured to the cab frame causing excessive vibration noise.

Figure 9 graphically represents the data as the TWA_8 SPLs for each sample collected inside the cab for each cab type. The black data points represent samples where the haul truck drivers had unnecessary intervals of open doors and windows. Figure 9 also shows the limits for the PEL (TWA_8 90 dBA) displayed in red. Only one out of the 44 sample measurements was above the MSHA PEL. However, 14 out of 44 (32%) did exceed levels of TWA_8 85 dBA, which may be considered hazardous. Furthermore, Fig. 9 shows that the new-style cab samples were fairly spread out, but only one sample came near to exceeding the MSHA PEL. In contrast, the measurements for the old-style cabs and retrofitted cabs were spread out only over the upper range (right side) of the graph that contained the higher noise level samples. Table 1 displays the descriptive statistics of the TWA_8 SPLs for each of the three cab styles including the mean, median, standard deviation, and 95% confidence interval of the mean.

Figure 10 depicts a box plot of the data showing the median, and upper and lower quartiles for each cab type. It appears that the median values of the MSHA PEL noise exposure for the old-style and retrofitted cabs are very similar, but both differ from the new-style cab median. The median value of the new cab style is much lower than the other two cab styles.

Because of questions regarding the underlying distribution of the sample data, the parametric ANOVA and non-parametric Kruskal-Wallis tests were performed to determine if there were significant differences in the TWA_8 SPLs inside the cab between the three cab styles. ANOVA tests were performed with Tukey post hoc comparisons. Although significance is usually set at alpha equal to 0.05, these tests were done to see if the p-values approached significance (p-value <0.05). Table 2 displays the results from all of these tests.

The null hypothesis for an ANOVA test is typically that there is no difference or effect among groups and a p-value close to zero signals that the null hypothesis is rejected. The ANOVA test of the sample data achieved a p-value of 0.0001, which achieves significance (p-value<0.05), suggesting that the null hypothesis should be rejected and that there is a difference in at least one of the three cab styles. As seen on Table 2, the Kruskal-Wallis test on the data achieved a p-value of 0.0001, which was the same as the ANOVA test. Results from the Tukey post hoc multiple comparison test on this data show that a p-value of 0.001 was achieved between the old-style and new-style cabs and a p-value of 0.007 was achieved between the retrofitted and new-style cabs. These two comparison tests indicate a significant difference between the groups for each test. The comparison for old-style and retrofitted cabs did not show significance (p-value = 0.987) that there was a difference between the groups.

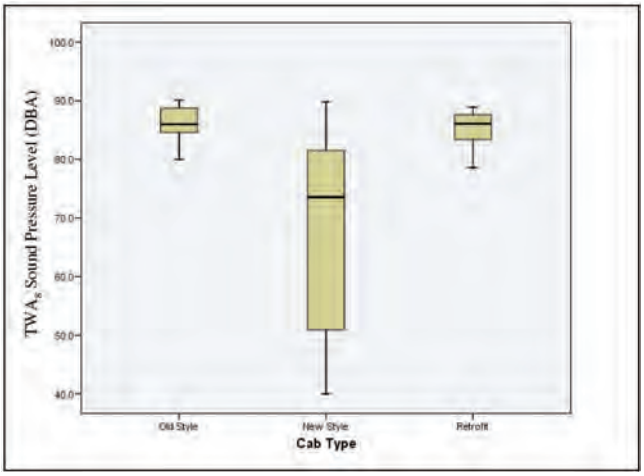
The outside dosimeter measurements (shown as a range of measurements in dB) are provided below. All but two of the data measurements were found to be above the MSHA PEL. Furthermore, the outside noise levels for the haul trucks with retrofitted cabs, overall, tended to be slightly lower than the trucks with new-style and old-style cabs. The measurements that were taken on the engine-side of the cabs were considerably higher than the ones taken on the operator's side of the cab.

- 89.3 – 93.8 dB for retrofitted cabs (driver-side measurements).
- 91.3 – 95.8 db for old-style cabs (driver-side measurements).
- 91.3 – 95.1 dB for new-style cabs (driver-side measurements).
- 97.5 – 99.5 dB for old-style cabs (engine-side measurements).
- 98.8 – 99.8 dB for new-style cabs (engine-side measurements).

The category of "open doors and windows" was determined if the operator admitted that he/she had doors or windows open (an inch or more) for unnecessary reasons or that this practice was observed by the researcher

FIGURE 10

Box plot of TWA_8 SPL for the 3 cab styles.



more than three times throughout the shift. The occurrence of unnecessary open doors or windows was observed in 13 out of the 44 samples (30%). These observations were seen in three out of the four highest noise levels measured during the study, including the highest measurement of 90.1 dBA. Table 3 shows the mean noise exposure for samples with open doors or windows versus the mean for samples where open doors or windows were not observed for each cab style. The increase in noise was 8.5 dBA for the new-style cabs, 4.0 dBA for the old-style cabs, and 1.2 dBA for the retrofitted cabs. This data shows a significant increase in noise for the new-style and old-style cabs. A broken air conditioning unit was the reason for the higher noise measurement in only one of the samples. Operators provided the following additional reasons why they opened their doors or windows: fogged interior windows, tobacco use, the preference for outside air and the need to hear the horn/signal from the front-end loader.

Good road conditions were noted throughout the study and normal weather conditions were observed. Some cab deterioration was visible in the old-style and retrofitted cabs, but little in the new-style cabs. Aside from wear and tear due to normal use, the seals, gaskets and latches were in fair to good condition.

Discussion and conclusions

The noise levels measured outside of the cab clearly indicate that most noise levels that would be experienced by the operator would be above the MSHA PEL had they

Table 1

Descriptive statistics for three cab styles.

	Retrofitted n=7 TWA_8 SPL (dB)	**New style** n = 26 TWA_8SPL (dB)	**Old style** n = 11 TWA_8SPL (dB)
Mean	85.1	67.7	86.3
Median	86.1	82.1	86.0
Standard deviation	3.86	16.2	3.0
95% CI on mean			
Lower	81.5	61.2	84.3
Upper	88.7	74.2	88.3

Table 2

Comparison statistics for three cab styles.

Parametric test	**F statistic**	**P-value**
ANOVA	10.7	0.0001
Tukey post hoct test (multiple comparisons)		
New-style vs. retrofitted		0.007
Old-Style vs. retrofitted		0.987
New-style vs. old-style		0.001
Non-Parametric Test	Chi-square statistic	P-value
Kruskall-Wallis	20.9	0.0001

not had the noise-reducing protection of a cab. The results from this study show that 43 out of 44 (98%) measurements inside cabs were below the MSHA PEL, regardless of open doors and windows, the cab maintenance condition or the cab style. However, noise reduction measures should be made to reduce noise even further to prevent NIHL.

Multiple comparison tests and descriptive data both show that there is a significant difference between the old-style and new-style cabs and the retrofitted and new-style cabs. Therefore, efforts to control noise inside the new-style cabs have been effective and mine management should continue their efforts to purchase haul trucks that have cabs equipped with these state-of-the-art noise-reduction features. Fortunately, as mines begin to replace old haul trucks with new haul trucks that have the new-style cabs, noise overexposures should become infrequent as long as operators keep the doors and windows closed.

Finally, multiple comparison tests and descriptive statistics suggest there is no difference between the old-style and retrofitted cab styles, highlighting the difficulty of designing and implementing retrofit noise controls. The multiple comparison tests show a lack of significant benefit from the retrofitted cabs, but with such a limited sample size, one cannot entirely rule out retrofits as a useful noise control strategy. The multiple comparison tests (Tukey post hoc tests) were sensitive to normality assumptions and without additional data measurements to test normality, making strong conclusions regarding the differences is somewhat questionable. Furthermore, some potential shortcomings were identified that, if corrected, could lead to more effective retrofits. Improved interventions to reduce door and window vibration could serve to further reduce these noise levels. Also, noise treatment of the cab floor could improve noise reduction significantly because of the relative proximity of the cab floor to the engine noise sources. Finally, treating the outside of the cab (engine side of the firewall and under the hood) with sound absorbing materials should also help to reduce the amount of noise inside the cab.

Table 3

Mean SPL for open vs. closed doors and windows for each cab style.

	Doors and windows	
	Open (dBA)	**Closed (dBA)**
New-style cabs	73.6 (n=8)	65.1 (n=18)
Old-style cabs	88.8 (n=4)	84.8 (n=7)
Retrofitted cabs*	86.1 (n=1)	84.9 (n=6)

Open doors and windows will increase the noise levels inside the cab and measures should be taken to encourage operators not to disable these protective cab features. Improved education and training of operators is needed regarding noise source awareness and noise overexposures. Furthermore, enforcement of noise policies should be strengthened. Technical interventions, such as alarms or lighted warnings that alert the operator when a window is open (similar to seat belt dash warnings), may heighten awareness that operators are at higher risk of a noise overexposure and encourage them to take appropriate action.

Three factors add a degree of uncertainty in this study. The first is the fairly small sample size for old-style and retrofitted cabs and the second is that the research was conducted at only five mine sites. Further studies of additional haul truck cabs (at a variety of mine sites) would enhance the certainty of the study results. In addition, the observations of operator activities could only be made while a haul truck was visible while on the surface and the activities that occurred underground could not be monitored. The collection of data on underground activities depended on the reliability of the information provided by the haul truck operator and could be affected by self-report bias and errors. More direct observation techniques, such as sensors around the windows or video cameras, could help alleviate this problem for future studies. Finally, no plausible explanation could be provided as to why the outside noise levels were lower for the trucks with retrofitted cabs except for that the majority of these vehicles had engines with lower horsepower than the other engines (old- and new-style), thus possibly producing less noise.

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.

References

Bauer, Eric R. and Daniel R. Babich (2004), "Administrative Controls for Reducing Worker Noise Exposures," SME Annual Meeting, February 23-25, Denver, CO), preprint 04-09, 9 pages.

Bauer, Eric R. and Daniel R. Babich (2006), "Limestone Mining – Is It Noisy or Not?" SME Annual Meeting, March 27–29, St. Louis, MO) preprint 06-017, 6 pages.

Daniel, J. Harrison, J. Alton Burks, Roy C. Bartholomae, R. Madden and E. E. Ungar(1981), "The Noise Exposure of Operators of Mobile Machines in U.S. Coal Mines," Bureau of Mines, U.S. Department of the Interior, Pittsburgh, PA), IC 8841, 24 p.

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, (September 13,) pp. 49548-49634.

Joy, Gerlad J. and Paul J. Middendorf. (2007), "Noise Exposure and Hearing Conservation in U.S. Coal Mines–A Surveillance Report," *Journal of Occupational and Environmental Hygiene,* January, Vol. 4: 26–35.

Mohanty, Amiya. R., Barry D. St. Pierre, and P. Suruli-Narayanasami (2000), "Structure-Borne Noise Reduction in a Truck Cab Interior Using Numerical Techniques," *Applied Acoustics*, January, Vol. 59, No. 1:1-17.

TUFCOTE (2006), "H-SM foams: E-A-R Acoustical Foams Meets UL Smoke and Flame Standard," http://www.earsc.com//HOME/products/BarriersandAbsorbers/AbsorbingFoams/index.asp?SID=314 (Dec).