# Underground evaluation of coated flight bars for a continuous mining machine.

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**ABSTRACT**

Noise induced hearing loss (NIHL) is the most common occupational disease among workers in the mining industry. Previous studies conducted by the National Institute for Occupational Safety and Health (NIOSH) have shown that approximately 90% of coal miners and 49% of metal/non-metal miners have a hearing impairment by age 50. The Mine Safety and Health Administration (MSHA) has determined that continuous mining machines rank first among all equipment in underground coal mining whose operators exceed 100% noise dosage. The conveying system is one of the principal noise sources on continuous mining machines, due to metal on metal impacts that occur between chain flights and the conveyor deck. A highly durable polyurethane coating has been developed for the chain flights to decrease noise generated by these impacts. A continuous mining machine retro-fitted with coated flight bars has achieved overall sound level reductions of 5-7 dB in a laboratory setting. This paper evaluates the effectiveness of this engineering noise control in reducing the noise exposure of continuous mining machine operators in an underground coal mine environment. The results show that the operator of a continuous mining machine utilizing the coated flights receives a predicted 35% reduction in total work shift noise dose.

## 1 INTRODUCTION

Noise-induced hearing loss is the second most common form of sensorineural hearing deficit, after presbycusis (age-related hearing loss) [1]. Hearing loss caused by exposure to occupational noise results in devastating hearing disability that is virtually 100 percent preventable. Occupational noise-induced hearing loss (NIHL) has been recognized by the National Occupational Research Agenda (NORA) as the most common job-related disease in the United States. An analysis of audiograms conducted by NIOSH shows that nearly 90% of coal miners and 49% of metal/non-metal miners had a hearing impairment by the age of 50, while only 10% of those who are not exposed to occupational noise experienced a hearing loss by the same age [1].

Overexposure to noise remains a health concern in the mining industry, in spite of 25 years of regulation. Sixty five percent of workers who were overexposed to noise operated one of

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seven types of equipment, according to MSHA Coal Noise Data collected from 2000 to 2002 [1]. Accounting for 35% of noise overexposures shown in Figure 1, the continuous mining machine produced the most noise overexposures of all surveyed mining equipment. Federal regulations require that a mine operator enroll workers in a hearing conservation program if they are exposed to an average sound level of 85 dB(A) or more during an eight-hour period. Furthermore, if a worker is exposed to more than the Permissible Exposure Level (PEL) of 90 dB(A), then the mine operator is required to implement all feasible engineering and administrative controls [2, 3].

Past research conducted at NIOSH's Pittsburgh Research Laboratory (PRL) has concentrated on developing engineering noise controls to abate unwanted sound caused by continuous mining machines. A coated flight bar design has been developed to suppress sound emissions caused by the continuous mining machine conveying system [4]. This paper presents results from underground case studies that examined the effectiveness of this noise control. Specifically, this paper evaluates the reduction of sound exposure during continuous mining machine operations using MSHA defined exposure limits. An underground comparison of A-weighted sound levels before and after the coated flight bar chain installation will also be examined.

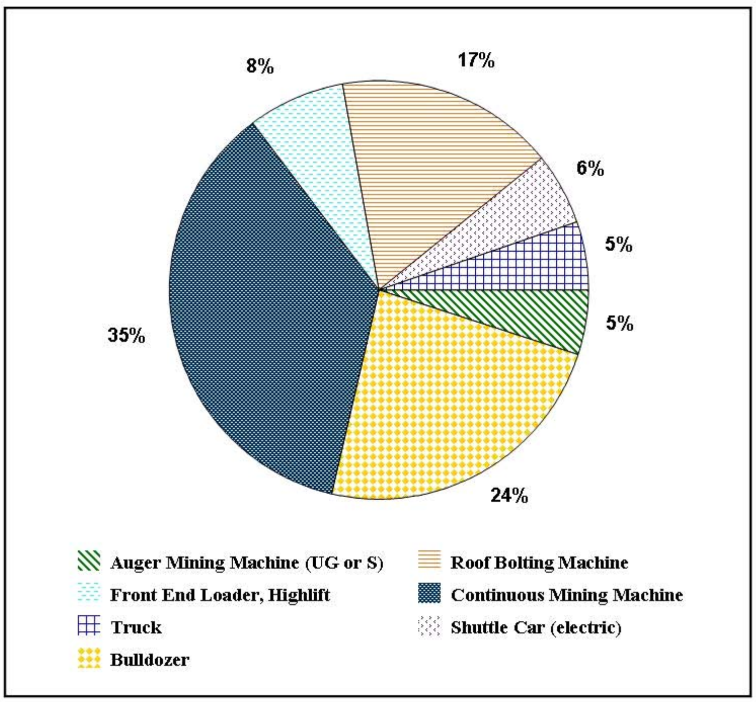


Figure 1: MSHA coal noise sample data - Percentage of equipment operators that exceeded 100% dose.

## 2 BACKGROUND

Continuous mining machines are one of the fundamental machines used to cut, gather, and remove coal and non-coal minerals from underground room and pillar mining operations. Each of these processes generates sound, which is the result of three subsystem machine components: the cutting-head drum, the conveying system, and the dust collection system. NIOSH, through its partnerships, has developed a novel engineering noise control to attenuate sound levels that are emitted from the conveying system. Steel bars that are perpendicular to the conveyor chain, called flights, span across the width of the conveyor and move the coal aggregate to the rear of the machine. A urethane coated flight bar has reduced the overall sound levels by 5-7 dB(A) in a laboratory setting [4]. Past underground investigations have evaluated the durability and sound level reductions of the urethane-coated conveyor flight bars [5]. However, this control has never been evaluated to determine the underground reductions in noise exposure to the machine operator. This study examines the underground performance of this noise treatment using dosimetry, as well as sound pressure level measurements.

Underground working environments create complex sound fields that make it challenging to determine the effectiveness of noise controls. Mine geometry, rock composition, and other working machines are variables that are difficult to quantify, and influence the observed overall sound levels. Thus, dosimetery can be used to evaluate the effectiveness of noise treatments in an underground environment. MSHA defines that 100% noise dosage is equivalent to a continuous noise exposure of 90 dB(A) for 8 hours, also known as the PEL. Using the MSHA 5 dB exchange rate, an average exposure of 95 dB(A) for four hours or 100 dB(A) exposure for two hours would yield a 100 % dose. Whereas, NIOSH defines a Recommended Exposure Limit (REL) for an 8 hour work shift as a Time-Weighted Average (TWA) of 85 dB(A) using a 3 dB exchange rate.

Underground mine workers, specifically continuous mining machine operators, are exposed to large amounts of acoustical noise. The source(s) of the noise that the workers are exposed to can originate from a host of different underground machinery. Worker exposure is also time-varying depending on the operation/task that is being performed. The contributions to an operators overall dose from multiple tasks can be estimated by determining the dose accumulated during specific operations. This approach is known as sound exposure profiling [6, 7]. Once the equivalent sound exposure levels have been determined for each task, the TWA can be estimated for an 8-hour work shift. This study utilizes a similar procedure to model a typical work shift for a continuous mining machine operator, based on the length of time the operator is performing a specific task. A model is computed and compared for both non-coated and coated conveyor flights to evaluate the performance of the noise treatment.

## 3 PROCEEDURE

Dosimetry determines the amount of acoustic noise that a worker is exposed to during a work shift. A Quest Technologies™ Q-400* dosimeter was chosen for this research because of its durability and underground permissibility. The dosimeter parameter settings were set to NIOSH and MSHA specifications, and are displayed in Table 1 [8]. The dosimeter determines the equivalent continuous A-weighted sound pressure level for a sample interval of 10 seconds. Then, knowing the allowed MSHA exposure time for the equivalent sound level, the incremental noise dose is determined. The incremental dose and TWA for the sample interval are stored in the device memory. The NIOSH settings were used for comparison with other past underground field investigations, since they capture sound levels below 90 dB(A).

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Table 1: Internal dosimeter settings.

| - | Dosimeter 1 | | Dosimeter 2 | |
|---|---|---|---|---|
| Parameters | Settings | Designation | Settings | Designation |
| Weighting | A | NIOSH Wide-Range Exposure Level | A | MSHA Permissible Exposure Level (PEL) |
| Threshold Level | 40 dB | | 90 dB | |
| Exchange Rate | 3 dB | | 5 dB | |
| Criterion Level | 85 dB | | 90 dB | |
| Response | Slow | | Slow | |
| Upper Limit | 140 dB | | 140 dB | |

Insight can be gained as to how the operator accumulates dose by utilizing time motion analysis. The subject is fitted with a dosimeter at the beginning of the work shift, and his activity is recorded on an event basis. When a task or phenomenon occurred, the observer logged the start and stop time, which was synchronized with the internal dosimeter clock. A Personal Digital Assistant (PDA) could not be used to facilitate this process as done with past NIOSH time motion studies [9], due to underground test equipment permissibility. Note that this method allows more than one event to occur and be logged at the same time. The total time spent for each operation was summed throughout the day, and averaged with other comparable days. The time motion data was used to compute the average dose from each task that the continuous mining machine operator was exposed to during the work shift.

## 4 RESULTS

All measurements were obtained at a single underground coal mine. Prior to the work shift, the continuous mining machine operator was fitted with a dosimeter. The dosimeter was calibrated prior to and after each shift measurement, and was attached to the midpoint of the operator's shoulder with the microphone diaphragm pointing up [8]. The dosimeter, machine type, manufacturer, model, and serial number were documented using hand written notes. The same continuous mining machine and operator were used for all underground measurements. The time that the dosimeter was installed and removed was also documented. Digital pictures were taken to document the installation of the coated conveyor chain flights, as shown in Figure 2.

Prior to the dosimeter survey, sound level measurements were taken to further assess the performance of the treated flight bars. A Quest Technologies™ 2900 sound level meter* with A-weighting and a slow time constant was used to compute the sound levels over ten-second averages. A 16 by 3 meter grid was constructed in middle of a 45 meter underground mine entry way. Measurements were taken on the grid at 1 meter intervals, at a horizontal plane 30 centimeters above the continuous mining machine. This was done for conveyor chain flight bars with and without the urethane coating. The continuous mining machine was run empty for both cases (no coal collection). The first 8 by 3 meters of the grid are displayed in Figure 3, and

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demonstrate a sound level reduction of 5-7 dB(A) between non-coated (top plot) and coated (bottom plot) conveyor flight bars.

Figure 2: Coated conveyor flight bars on a continuous mining machine.

An underground mining facility is a harsh environment with many variables that must be taken into consideration when attempting acoustic measurements. Production, safety, roof-bolting operation, and unexpected machine failure all had to be taken into consideration for this study. Due to variable conditions in the underground mining environment, only three surveys could be completed. Each noise survey comprised a full work shift that began as soon as the machine operator was fitted with the dosimeter. Two days of non-coated and one day of coated conveyor flight bar data were collected at the underground mining facility. Mechanical failure of the conveyor chain (not caused by the noise treatment) during the coated flight bar survey further complicated a direct portal to portal worker dose comparison. The accumulated noise dose of the continuous mining machine operator for each work shift can be seen in Figure 4. For the first work shift (solid-line) the continuous mining machine was performing overcast and floor cutting maintenance to an already established part of the mine. Data on the second (dashed-line) and third (dotted-line) work shifts was obtained at the working face of the mine. The coated flight bar conveyor (dotted-line) shows a promising initial reduction in noise dose compared to the non-coated flight bars (dashed-line and solid-line). However, sound exposure profiling must be used to objectively evaluate any reductions that are the result of the coated flight bars.

A time motion study was conducted in conjunction with the dosimeter measurements to evaluate the reduction in exposure achieved by the coated flight bars. Hand written notes were used to categorize different continuous miner operator tasks, as explained above. Table 2 shows the results of the sound exposure profiling for both non-coated and coated flight bars. Events/Tasks of the continuous mining machine operator were divided into five categories: man trip down, preparation time, cutting/conveying, lunch, and man trip out. For each work shift category the average task time, dose rate, and accumulated dose were computed. The time spent performing each task was averaged between all sampled work shifts to obtain an average task time. The dose rate was found by summing the noise dose associated with each operator task using the time motion notes, and dividing by the total time for that task. The dose rate was then used to determine the amount of accumulated dose the operator receives for each task based on the average task time.

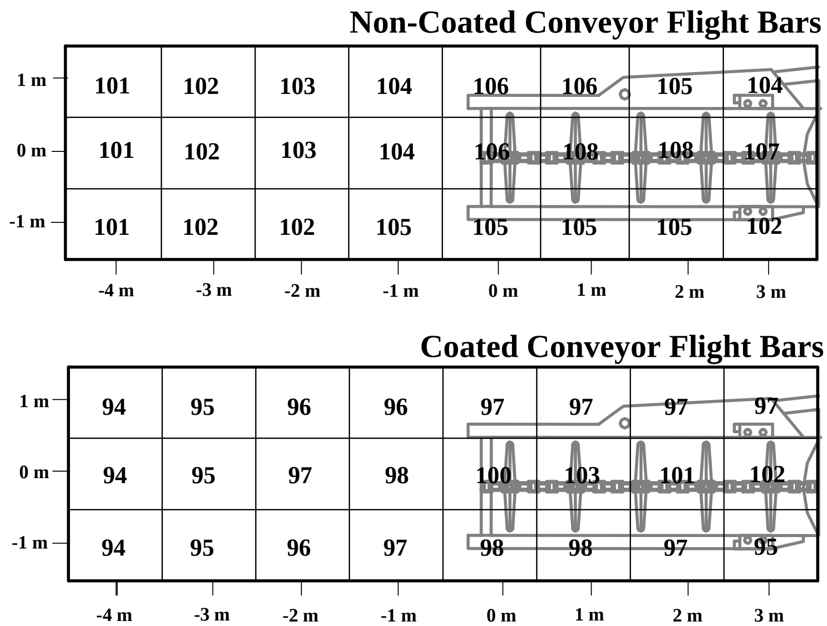


Figure 3: Non-coated vs. coated A-weighted sound levels.

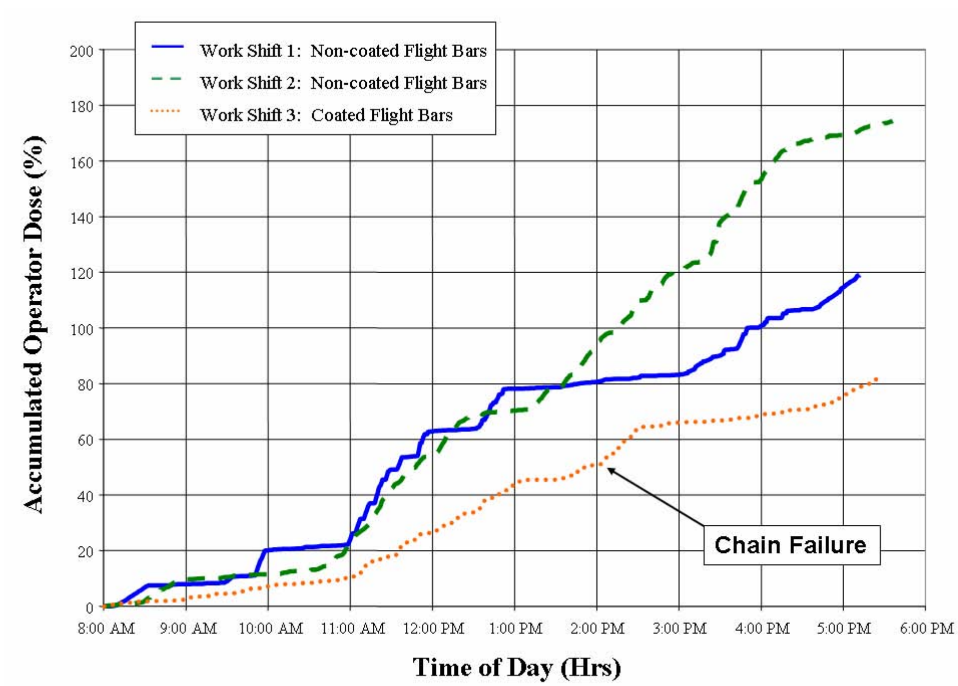


Figure 4: Accumulated operator work shift noise dose.

Table 2: Results of Sound Exposure Profiling.

| Operator Task | Average Task Time (min.) | Dose Rate (%/min) | Accumulated Dose (%) |
|---|---|---|---|
| Man-Trip Down | 43.3 | 0.15 | 6.34 |
| Prep. Time | 105.0 | 0.05 | 5.30 |
| Non-Coated Cutting\Conveying | 234.0* | 0.50 | 117.15 |
| Coated Cutting\Conveying | 177.2** | 0.30 | 51.89 |
| Lunch | 34.2 | 0.03 | 1.10 |
| Man-Trip Out | 37.2 | 0.24 | 9.00 |

* Average for two shifts
** Total cutting\conveying time for one shift until equipment breakdown

The results from sound exposure profiling were used to "model" reductions achieved by the coated conveyor flight bars. The average time spent performing each task was multiplied by the dose rate and combined to simulate the total dose that the continuous mining machine operator would receive during a typical work shift. A "model" to compare sound exposure of the continuous mining machine operator between coated and non-coated flight bar conveyors is shown in Figure 5. The projected accumulated dose of the non-coated conveyor chain case (solid-line) was found to be 178%, while the projected accumulated dose of the coated conveyor chain case (dashed-line) was reduced to 114%. This corresponds to a predicted 3 dB exposure in a full shift TWA using the MSHA exposure criteria.

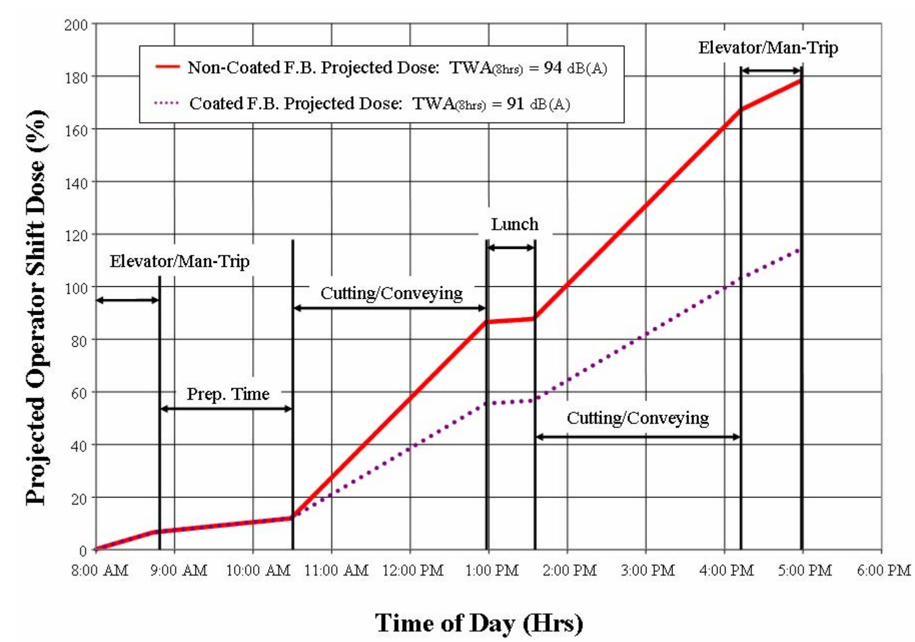


Figure 5: Projected operator work shift noise dose.

## 5 CONCLUSIONS

An underground investigation of the coated flight bar noise control was conducted on a continuous mining machine using sound pressure level and dosimeter measurements. A grid was constructed to measure sound levels at\around the continuous mining machine. These measurements showed a significant reduction of 5-7 dB near the cutting face of an underground coal mine. Dosimetry analysis was used to evaluate the noise exposure of continuous mining machine operators. The data was also used as a means to evaluate the performance of the coated flight bars. The dose rate of the operator was computed for various work tasks. The average amount of time spent doing these tasks was calculated, and an average work shift profile was formulated to compare exposure levels for both the coated and non-coated conveyor flight bar cases. Results demonstrated a 35% reduction in total work shift dose when the coated flight bar conveyor was used. The predicted eight hour TWA reduction in underground noise exposure was found to be 3 dB, using MSHA criteria. Use of the coated flight bar conveyor on a continuous mining machine will reduce exposure levels of the continuous mining machine operator, as well as all underground workers that are in the vicinity of the machine.

## 6 REFERENCES


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