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WEDNESDAY – 27 JULY 2011

Noise and Vibration Control for Research Laboratory Environments
10:00-11:20 am – Salon C

nc11_173 *Stability of vibration environments in laboratory settings*
Byron Davis and Tyler Rynberg
nc11_192 *Characterizing ambient noise and vibration in facilities designed for laboratory animal research*
Gary M. Glickman, Silas J. Bensing and Richard A. Carman
nc11_198 *Vibration sensitive facilities near rail lines: Considerations and mitigation*
Ramon E. Nugent and Jeffrey A. Zapfe
nc11_205 *A subtle "slab-curling" failure of a laboratory slab-on-grade floor*
Tyler J. Rynberg, Byron Davis and Ahmad Bayat

Mining Noise
10:00-12:00 am – Salon D

nc11_019 *The performance of badge-type noise dosimeters used in the mining industry*
John P. Homer
nc11_039 *Laboratory measurements of air carbon arcing sound power levels*
R.E. Miller and J. Shawn Peterson
nc11_123 *Theoretical active control analysis of low frequency noise in a mining vehicle cabin: Part 1*
C.L. Wilson, C.H. Hansen, R.R. Wareing and J.R. Pearce
nc11_145 *Evaluations of noise controls for roof bolting machineds used to drill 25-mm-diameter holes*
David S. Yantek, Lynn A. Alcorn and Amanda S. Azman
nc11_168 *Characterization of noise generated by mining equipment in an underground room and pillar coal mine*
Marek L. Szary, Yoginder P. Chugh and Joseph Hirschi
nc11_046 *Noise survey of aggregate industry vibrating system*
M. Jenae Lowe and David S. Yantek

Control and Prediction of Information Technology (IT) Product Noise
10:00-11:40 am – Salon B

nc11_095 *Flow impedance and acoustic performance parameters for notebook computer fan noise*
Eric Baugh
nc11_104 *Noise emission and power consumption estimation methods for fan-cooled equipment*
David A. Nelson

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Noise survey of aggregate industry vibrating screens

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Hearing loss was the second-most common illness reported to the Mine Safety and Health Administration (MSHA) in 2009. In the mining industry, the aggregate sector (stone, sand, and gravel) made up 79% of all mining facilities in 2009 and 52% of all surface employees. Through a series of field tests, researchers at the National Institute for Occupational Safety and Health set out to determine if the aggregate processing industry could benefit from ongoing research into noise controls for horizontal vibrating screens used in the coal processing industry. The results from this investigation show that noise exposure due to vibrating screens does not appear to be a concern for the plants that were surveyed. At the locations studied, 9-13% of plant personnel are affected by noise, while the remainder spend their work day in control booths or vehicle cabs where high noise levels are not present. Those personnel who are exposed to equipment noise spend limited time near operating vibrating screens. However, all screens surveyed include operator travel areas where sound levels exceed the threshold of 90 dB(A) used in the determination of the MSHA Permissible Exposure Level. Dosimetry and sound level data show that material size is the dominant factor in the noise produced by the inclined vibrating screens that are common in the aggregate industry. Screens with a larger material size (maximum feed size of 42 inches) have sound levels ranging from 91 to 118 dB(A), while screens with a smaller material size (maximum feed size of 1.5 inches) have sound levels ranging from 80 to 92 dB(A).

1 INTRODUCTION

1.1 Motivation

Of all occupational illnesses reported to the U.S. Bureau of Labor Statistics in 2004 and 2005, 11% were due to noise-induced hearing loss (NIHL)[1], making it one of the most common occupational illnesses in the United States[2]. As such, hearing loss prevention is one of twenty-

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one Priority Research Areas listed in the National Institute for Occupational Safety and Health (NIOSH) National Occupational Research Agenda[3]. Of all industries, mining has the highest prevalence of hazardous noise exposure, with 76% of employees reporting hazardous noise exposure on the job.[4] Despite leading the nation in reported hearing protector use[4], miners have the second-highest incidence of reported hearing difficulty of all occupations, with nearly one-fourth of all miners reporting a hearing difficulty[5]. Because hearing conservation programs alone do not solve the problem of NIHL, it is important to use engineering noise controls as the first line of defense[6], thus reducing harmful noise exposure for miners.

The aggregate industry, which produces stone, sand, and gravel, is heavily dependent upon vibrating screens for sizing and sorting its products. Given that the aggregate sector made up 79% of all mining facilities in 2009 and 52% of all surface employees[7], it was originally thought to be a high-potential industry to benefit from NIOSH's horizontal vibrating screen noise control research[8-10]. Consequently, NIOSH conducted a study to determine (1) whether vibrating screen noise is a problem in the aggregate industry and (2) whether NIOSH-developed noise controls for coal processing screens can be applied to stone processing screens. To answer these questions, NIOSH researchers conducted field tests at three aggregate processing facilities in Pennsylvania.

1.2 Screens in the Aggregate Industry

The final products of an aggregate processing facility are a blend of material sizes based upon standards for size ranges and aggregate quality. These standards vary from state to state. Inclined screens are used to size and separate material within an aggregate processing facility, which allows for the creation of the proper blends of material.

To accomplish this sizing and separation, material is directed to the feed end of a screen by a belt or vibrating feeder. Inclined screens are built at an angle such that the feed end of the screen is higher than the discharge end (Fig. 1). This allows gravity to do part of the work to move material along the screen, thus saving energy and reducing the expense of running the screen[11]. An inclined screen has one or more enclosed lobed shafts running through its middle which generate a circular motion in the screen. Coupled with gravitational force from the incline of the screen, the circular motion of the screen moves material down to the discharge end.

As the material passes from the feed end to the discharge end, it flows over the top of one or more screen decks stacked from top to bottom with various sizes of openings in the screens. The screen decks act as sieves, allowing smaller particles to fall through the screen openings and keeping larger particles on top of each screen deck. Each deck of the screen has a chute that collects the sized material that falls off of the discharge end of the screen and funnels it onto a conveyor which sends it further on in the process—typically either to another screen for finer sorting of the material or to a crusher which breaks the rock into smaller sizes. The various inclined screens at a facility have different names depending upon their function and order in the process flow. For instance, a scalping screen "scalps" most of the sand and gravel out of the raw material that comes from a mine or quarry, while a primary screen is in the first circuit of the process flow to size and sort the material. Overall, the material generally reduces to smaller sizes as it travels further in the sorting process.

2 DATA COLLECTION

NIOSH researchers traveled to three stone processing facilities in Pennsylvania during June and July of 2010. All of these facilities process limestone, which makes up 71% of the aggregate market in the United States. One mine also produces sandstone, which makes up less than 6% of the U.S. market[12]. At each mine, several screens were selected for noise studies that included dosimetry, time motion studies, and sound level meter recordings. The selected screens and the chosen measurement locations were based upon discussions with plant personnel about typical operator positions with respect to the machinery, the amount of time spent around the various screens, frequency of maintenance, and known noise issues.

NIOSH researchers wore dosimeters with the microphones positioned on the middle of their right shoulders per Mine Safety and Health Administration (MSHA) recommendations[13] to record noise exposure with respect to the MSHA Permissible Exposure Level (PEL). The dosimeters were activated prior to the beginning of the site visit to capture all noise associated with travel within the plant and noise exposure to various processing machinery. The dosimeters were configured to record A-weighted sound level data in one-second intervals. Recording observations of where a person wearing a dosimeter was and when they were there is known as a time-motion study. Synchronizing the time-motion studies with the dosimeter data allowed for the calculation of the percent dose per hour that each machine generates.

For each of the studied screens, A-weighted sound level measurements were used to characterize the noise in the area surrounding the equipment. First, the machine dimensions were measured to develop a plan drawing of the facility, including catwalks and stairwells. Next, a sound level meter was positioned with the microphone 1.5 m from the ground or catwalk floor to approximate the ear height of an average employee. Two 15-second readings were taken at each location. Locations were selected based on where an operator was likely to travel or perform maintenance, and were centered on the catwalks surrounding each screen. Catwalks in this study ranged from 0.45 to 2.45 m wide. Each measurement location was added to the equipment layout map to provide its location with respect to the machine.

3 DISCUSSION OF RESULTS

3.1 Observations

On the question of whether noise is a problem, the observations made at the stone processing plants visited as part of this research indicated that it is not. Most personnel are located within a vehicle cab or a control booth. Repairs to equipment are done when it is shut down, so the equipment is not a noise source at this time. Each facility has a small number (1-4) of ground laborers, who have potential for greater noise exposure than other employees. Ground laborers constitute between 9% and 13% of each mine’s total number of employees. They are responsible for cleaning up spillage from the belts and transfer points, performing routine maintenance, and helping to repair equipment when necessary. The time of exposure from these activities is not enough to cause a significant noise dose. Two of the facilities that were visited perform all maintenance when the equipment is shut down, and two perform some quick (5-10 minutes) cleaning and lubrication maintenance while the equipment is running. Administrative controls are in place at each facility to limit the ground laborers’ time around equipment and/or areas that are considered to be noisy, and all personnel are required to wear hearing protection. Among the three mines surveyed, only two noise violations were reported by the MSHA Mine Data Retrieval System, which listed the most recent violation as being in 2002[14].

The mine personnel listed screens, crushers, and tunnels as the loudest areas of the processing facilities. Material noise is considered to be louder than the screen running by itself, especially noise from rock hitting the screens from the feed belts or hitting the chutes from the screens. Subjective observations by NIOSH researchers in the field corroborated these opinions.

At the processing facilities, personnel are not stationed near any of the machines for any significant amount of time without being enclosed within an operator's booth. Any noise exposure is from cleanup, maintenance, or passing through the area where processing equipment is running.

3.2 Sound Measurements

The clearest trend shown by analysis of the field data is that the maximum feed size of the material loaded onto the screen has a bigger impact on the noise produced than the machinery noise of the screen itself. Maximum feed size is the largest dimension of a given piece of rock that is fed onto the screen. In the case of a brick-shaped piece of rock that dimension would be the length, and for a spherical rock it would be the diameter. The maximum allowable feed size is related to the screen mesh opening size and is specified by the manufacturer based upon the screen and application (i.e., wet or dry screening). Maximum feed size for each screen was provided by the plants.

The time-motion study and dosimetry results show that maximum feed size has a large influence on screen noise. Based on the time-motion studies, a percent dose per hour could be calculated to compare the noise generated by each machine encountered in this study. Percent dose per hour is the percentage of noise dose per the MSHA PEL that would be accumulated each hour an operator is working near a given machine. It allows for effective comparison of the dosimetry data from different screens on an equivalent basis, since the length of time spent near each machine varies. Using percent dose per hour also makes it easy to determine how long it would take for overexposure to occur. For example, by dividing 100% by the percent dose per hour calculated for the two NIOSH researchers involved in this study, the 8' X 20' Deister secondary screen data at Mine A predicts an overexposure in 4 to 4.5 hours if an employee were stationed there continuously. Table 1 shows the percent dose per hour for each researcher.

There is some difference in the noise dose that each of the two researchers accumulated, since during the course of the study they were working at different locations around the equipment at different times to take the necessary measurements. This led to differences in exposure duration to the noise sources in the area, and possible differences in exposure level as a result of non-continuous material flow. Researchers were not permitted to take measurements near the mountain screen at Mine A while stone was running through it due to safety concerns of falling rock at this location, so the reported value is machinery noise only. For both researchers, the greatest sources of percent noise dose per hour were the Mine B scalping screen, Mine B primary screen, and Mine C screens. The smallest source of percent dose per hour was the dual secondary screen setup at Mine A. This progression of decreasing percent dose per hour is generally from a larger to smaller feed size for the associated screens, suggesting that feed size is a main factor in the production of noise from inclined screens. To explore this trend in more detail, the percent dose per hour for each researcher and the highest average sound level recorded for each screen are plotted versus the feed size in Figs. 2 and 3.

As illustrated in Figs. 2 and 3, the trend shows that an increase in maximum feed size causes an increase in both percent dose per hour and the highest average A-weighted sound pressure level. These data and the subjective observations by NIOSH researchers and plant personnel cited above suggest that inclined vibrating screen noise is influenced more by the material passing over it than by noise generated by the machinery itself, and that a larger feed size will generate more noise.

To better determine the location of the greatest sound generation for each screen, plan view maps of the screens, nearby equipment, and measurement points were created to show the average A-weighted sound level measured at each position. Example plots are shown in Fig. 4. Additionally, readings were taken in operator control booths, which ranged from 70 to 77 dB(A). Based on these data, the time workers spend in control booths does not lead to dose accumulation since the sound levels are below the threshold level used in calculating noise exposure with respect to the MSHA PEL. In general, the highest sound level on each map is close to a chute, where the material falls from the inclined screen for further processing. This trend again suggests that material noise is the dominant factor by comparison to the noise generated by motion of the screen itself.

There are two exceptions to the above findings: the Simplicity scalping screen at Mine B (Fig. 5), and the dual Deister 7’ X 20’ secondary screens at Mine A (Fig. 6). The scalping screen has no chute but instead feeds directly into the primary crusher, and it is fed by a vibrating feeder above. The three locations at the scalping screen with the highest sound levels were the measurement points closest to the primary crusher and vibrating feeder, suggesting that these noise sources are primary contributors to the noise measured at these locations. For the Mine A dual Deister 7’ X 20’ screens, the measurement locations with the highest sound levels are near the motors, springs, and belt (the springs are located at the screen corners as in Fig. 1). As suggested by these data and noted in the earlier discussion about the influence of feed size on noise, at a small enough feed size the machinery noise begins to dominate over material noise. This explains why the sound map for this screen shows that the greatest sound levels were measured at locations close to the motors, springs, and belts.

Based on these findings, the best noise controls will vary by screen based upon the feed size. Screens with a larger feed size will require noise controls that focus on reducing impact noise from material hitting chutes and screen decks. For this purpose, rubber screen decks are already commercially available, as are rubber chute liners. Building chutes out of damped steel or using constrained layer damping on the screen sides[9] may also reduce impact noise. For screens with a smaller feed size, mechanism noise from motors, springs, and belts are the key noise sources to address. Motor noise may be attenuated with an enclosure or by changing to a motor design with reduced cooling requirements which would result in less fan noise. Spring chatter noise may be controlled with a plastic or rubber coating, or an insert, which is being developed at NIOSH, to keep the bottom spring coils separated. Mechanism noise may be further reduced with a damped pulley that is being developed at NIOSH for horizontal vibrating screens. Belt noise may be reduced by modifying the roller design through material or bearing changes.

4 CONCLUSIONS

Vibrating screen noise is not a large concern in the aggregate industry due to the small number (9-13%) of plant personnel subjected to screen noise and their limited exposure to it. At the plants surveyed, noise controls do not appear to be necessary at the present time. However, even the screens with the lowest sound levels include operator travel areas that were over 90 dB(A). There are potential means to reduce the noise levels below the 90 dB(A) threshold used for the PEL and consequently reduce noise dose. Given that material noise tends to dominate as a sound source for most inclined screens, noise controls that focus on reducing material impact noise in the chutes and on the screen decks would likely provide the greatest noise reduction. On screens with small feed sizes where mechanism noise begins to dominate, noise controls should focus on motors, springs and belts.

5 ACKNOWLEDGEMENTS

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Table 1 – Percent dose per hour for processing screens encountered by researchers.

Plant	Screen Size, Brand, and Name	Researcher 1 (% dose/hr)	Researcher 2 (% dose/hr)
Mine A	8' X 20' Deister mountain screen (running without stone)	15.1	9.2
	8' X 20' Deister secondary screen	22.4	24.5
	Dual 7' X 20' Deister secondary screens	1.4	1.3
Mine B	8' X 24' Simplicity secondary screen	17.8	24.4
	8' X 16' Simplicity primary screen	75.9	72.5
	6' X 12' Simplicity scalping screen	82.4	74.9
Mine C	Dual 8' X 24' Simplicity screens	35.8	44.5

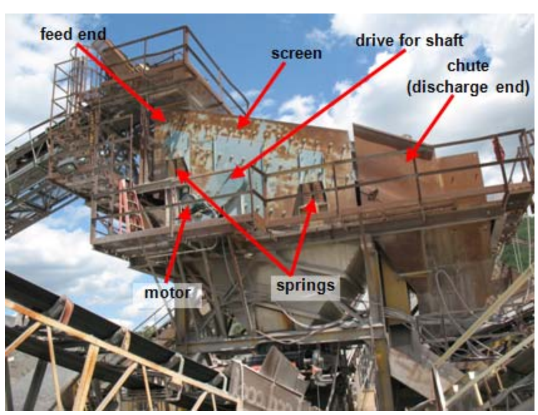


Fig. 1 – An inclined vibrating screen.

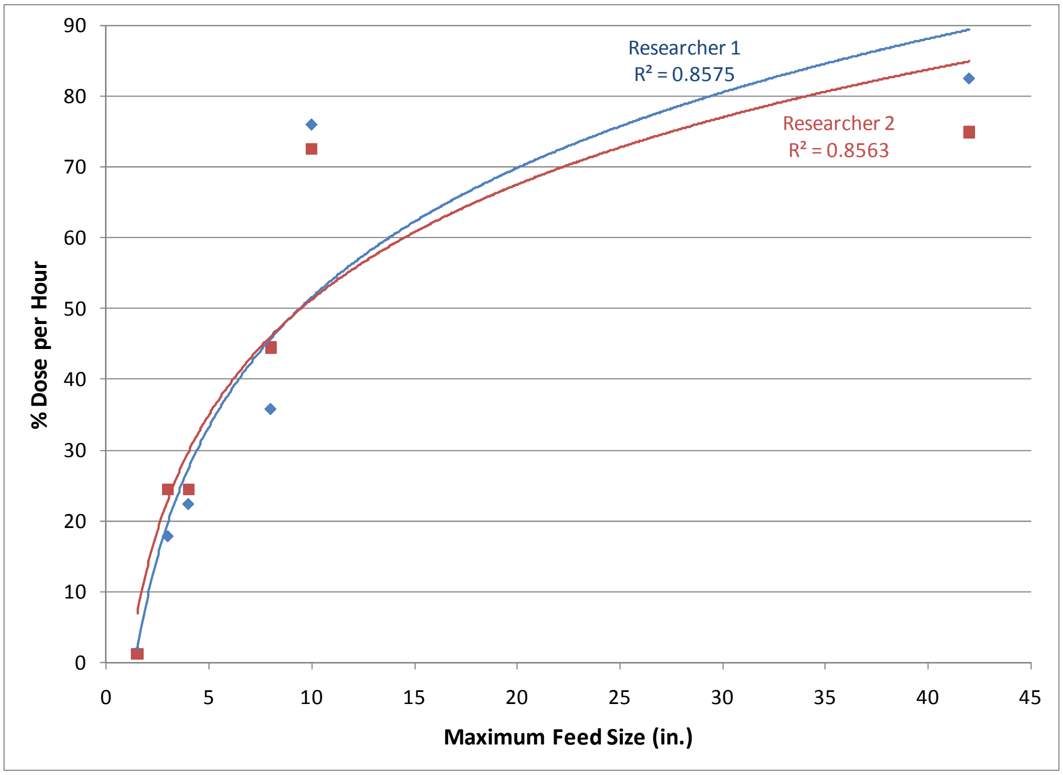


Fig. 2 – Percent dose per hour vs. maximum feed size for Researchers 1 and 2.

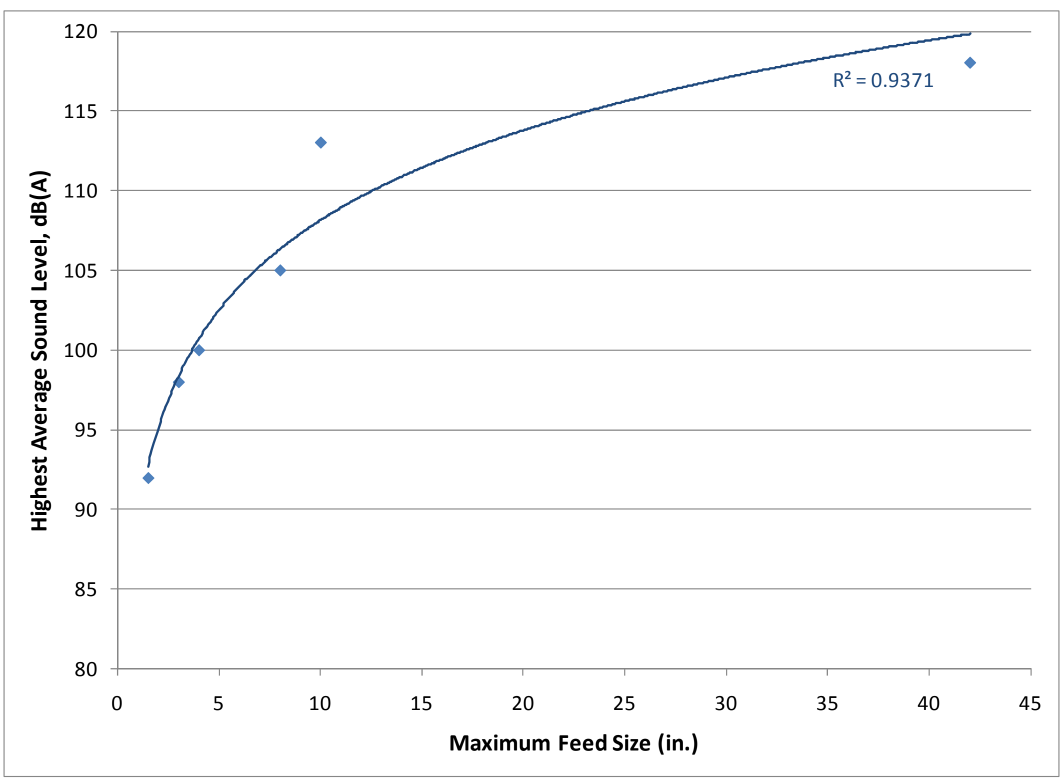


Fig. 3 – Highest average sound level for each screen vs. maximum feed size.

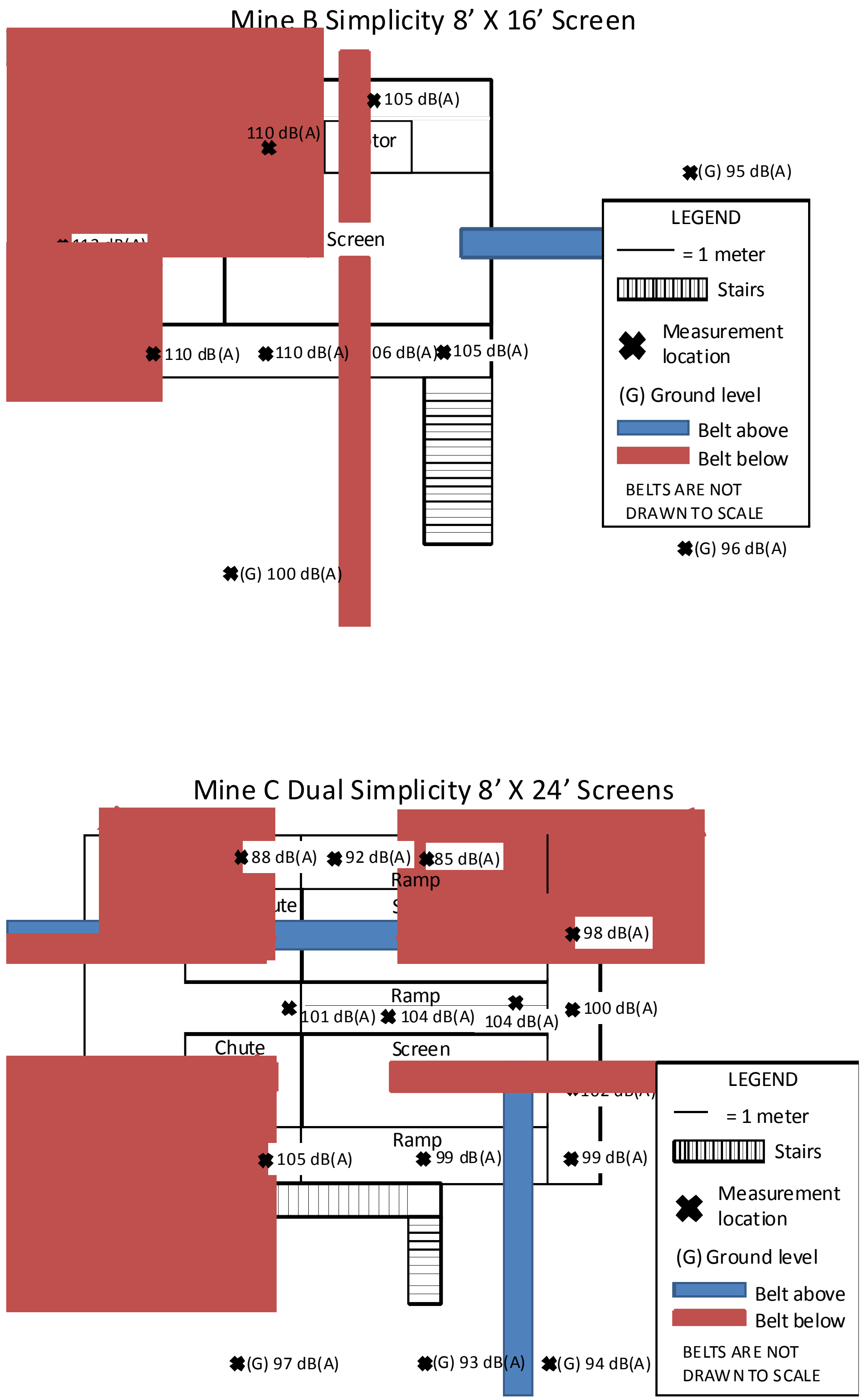


Fig. 4 – Example sound maps for inclined vibrating screens.

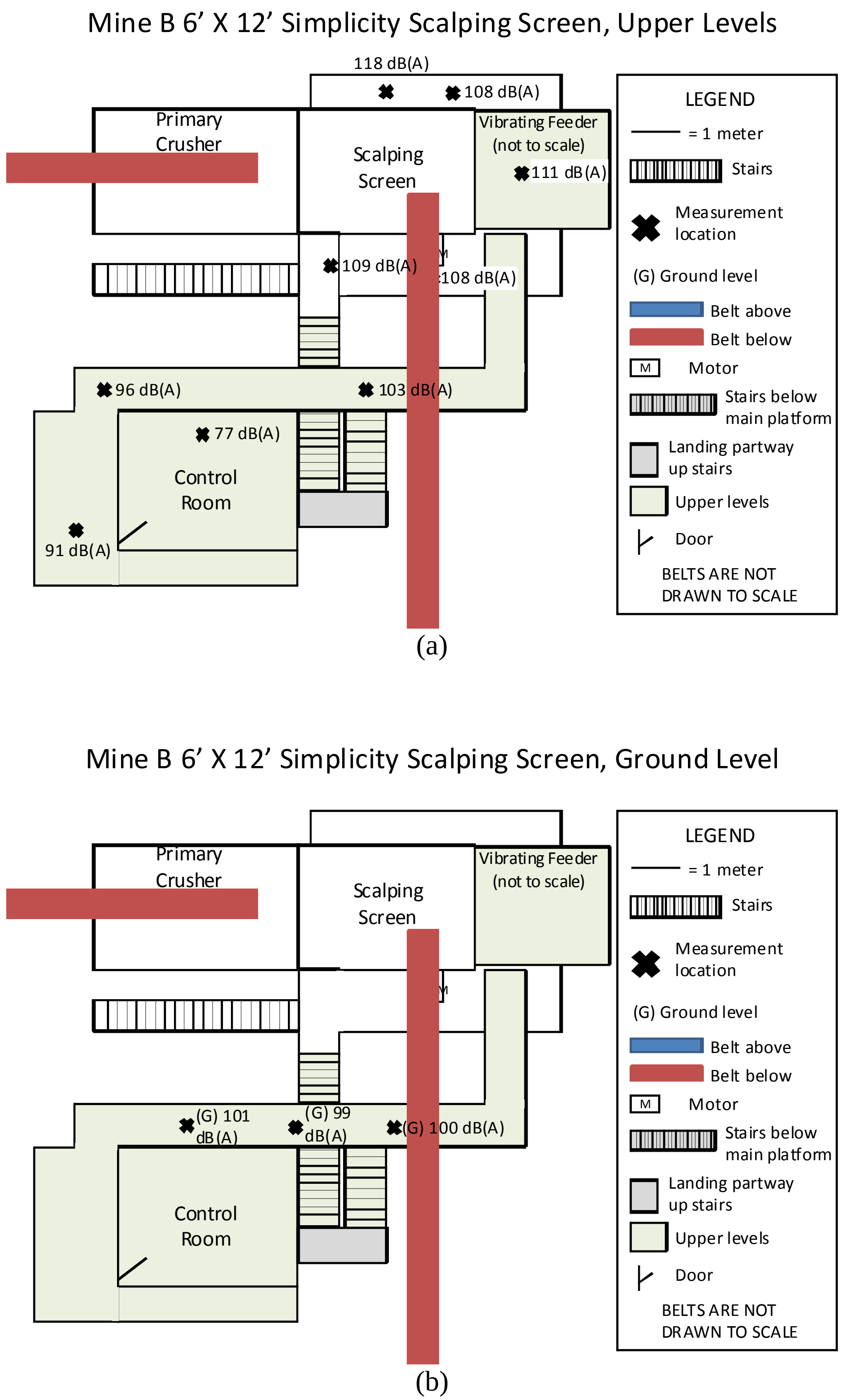
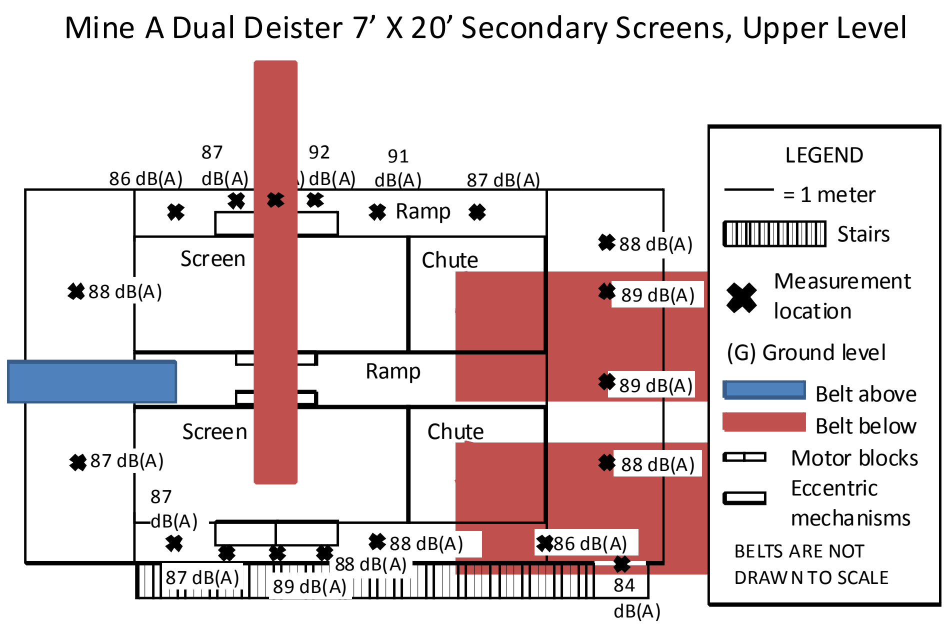
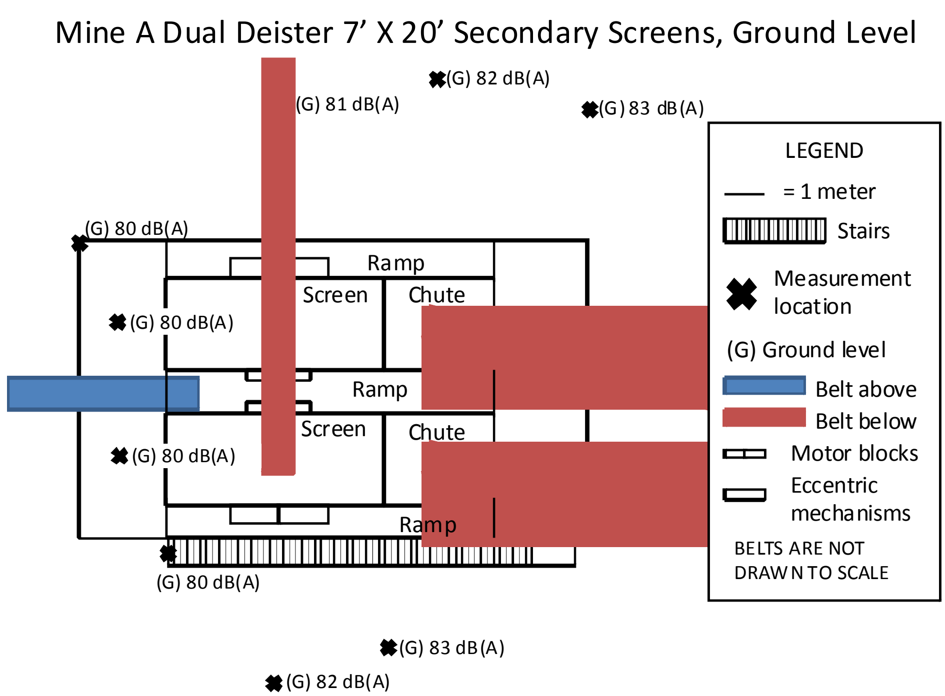


Fig. 5 – Sound maps for the Simplicity scalping screen at Mine B (a) upper levels and (b) ground level.



(a)



(b)

Fig. 6 – Sound maps for the dual Deister secondary screens at Mine A (a) upper level and (b) ground level.