Broadband Alarms: A Tangible Part of Memphis Stone & Gravel Company's Noise Reduction Strategy

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Introduction

Memphis Stone and Gravel Co. is a locally owned and operated aggregate supplier to West Tennessee and North Mississippi. In business since 1910, Memphis Stone & Gravel Company mines sand and gravel deposits and each year processes about five million tons at six wash plants. Typical equipment used at these operations consists of front-end loaders, articulated haul trucks, scrapers, tractors, bulldozers, draglines, water trucks, and hydraulic excavators. Additionally, Memphis Stone & Gravel Company's sister company Lehman-Roberts Company operates asphalt plant facilities at two of its wash plant operations.

Not unlike many aggregate mining companies, Memphis Stone & Gravel Company operates within close proximity to residential dwellings. It is not unusual to operate within three hundred feet of a house or other occupied structure. Noise or "the potential to cause noise" is frequently cited by stakeholders as a major (negative) issue associated with mining operations. Stakeholders include neighbors who live or work near operations and the property owners who lease land to the company. The Census Bureau reports that noise is Americans' top complaint about their neighborhoods, and the major reason they wish to move (NFA, 2007). Memphis Stone & Gravel Company follows a three phase strategy to reduce noise at its operations, including: 1) site planning, 2) effective use of noise barriers, and 3) noise source reduction. The information presented in this paper will describe practices Memphis Stone and Gravel Company use to control noise at the mine with particular emphasis on its use of broadband sound technology for its mobile equipment and conveyor systems.

Figure 1: A stakeholder residence near Memphis Stone and Gravel Company's Anderson Mine.

The Issue of Noise

In 1998 Memphis Stone & Gravel Company had an independent environmental assessment performed at one of its proposed operations in response to a request by the local land-use authority during the permitting process. The assessment analyzed the ambient noise and potential impact noise would have on the affected community near the proposed operation. The study determined that background noise levels were typically in the range of 50 dB(A) (decibels). It also determined that typical traffic noise in a rural setting would be about 70 dB(A) and conversational speech at a distance of three feet has a noise level of about 60 dB(A). The study concluded that the noise levels very near the source of the proposed mining operation would approach 90 dB(A). "However, the magnitude of the sound pressure waves is dissipated as they get farther from the source. This dissipation with distance coupled with the natural vegetation and artificial berms surrounding the facility will minimize off-site noise impacts" (Moore, 1998).

Noise is obviously a necessary element of mining and is not always a negative aspect of the mine. Noise when directed properly can be used as an effective safety tool. The Mine Safety and Health Administration (MSHA) has a requirement for self-propelled mobile surface equipment to have some type of system to alert a person exposed in or near the hazard area. As a consequence of this requirement, most mobile equipment used in mining are sold with an automatic reverse-activated signal alarm. The rules state that the alarm must be *audible above the surrounding noise levels*. Additionally, there is an MSHA standard for requiring an alarm on conveyor systems. Memphis Stone & Gravel Company has over five miles of over-land conveyor system to move raw materials from the pit to the plant. At each wash plant conveyors are an essential component of the production process. MSHA requires that when the entire length of the conveyor is not visible from the starting switch, a system which provides a visible *or audible warning* shall be installed and operated to warn persons that the conveyor will be started. The conveyor must be started within 30 seconds of the alarm or second warning must be given (MSHA, 1997).

Although operational noise can be controlled effectively (i.e., <60 dB(A)) within the permitted limits either by distance (site planning) and/or noise control barriers (berms), it is repeatedly noted as a major issue by our neighbors. Through observations at permit hearings and conversations with stakeholders, specific types of noise are generally cited as being most problematic. And empirical evidence suggests that noise with a repetitive nature is most noticeable. For example, complaints typically noted by residents living near Memphis Stone & Gravel Company operations are those from backup alarms and conveyor start-up sirens. Conventional narrowband backup alarms with the characteristic “beep-beep” sound are most often cited as the most recognizable noise coming from our operations. Conveyor start-up alarms employ a siren type sound similar to an emergency response vehicle.

Noise at the Mine

At Memphis Stone & Gravel Company’s North Plant facility, pit operations generally include one to two hydraulic excavating units, two to three loaders, a grizzly feeder and a series of piggy back conveyors. Mining typically occurs 20 to 40 feet below the original ground surface. Pit run material is transported to a stationary wash plant via over-land belt conveyor. Conveyoring units may be powered by diesel fueled generators or by stationary power. Overburden removal and reclamation is conducted concurrent to mining operations and is accomplished with a hydraulic excavator and three to five articulated haul trucks. One to two bulldozers, one grader, and a water wagon support the stripping and reclamation work. The wash plant and screening plants are above ground and are elevated. A mobile vertical impact crusher with generator is onsite intermittently. Often stockpiled material is stacked up to 30-40 feet high. Mobile equipment generating the highest level of noise are front-end loaders, haul trucks, bulldozers, and graders. These machines are in reverse mode more than other types of equipment and will sound repetitive noise alarms most often. Table 1 identifies typical operational noise levels by various activity and equipment.

Table 1: Typical Noise at the Mine

	Activity	Noise Levels
	Stripping	• 65 to 75 dB(A) (trucks and excavator at surface at ~50 feet away) • 80 to 85 dB(A) (tracking of dozer at ~50 feet) • 60 to 65 dB(A) (excavator loading truck one cut below surface at ~300 feet)
	Mining	• 75 to 80 dB(A) (3 loaders, 1 excavator in pit ~25 to 50 feet) • 70 to 75 dB(A)(at edge of pit 150 to 175 feet)
	Field Conveyor	• 65 to 70 dB(A) (~5 feet at middle of conveyor during normal operation, up to 75 dB(A) at conveyor repair splice. <60 dB(A) at ~100 feet away • 82 dB(A) at conveyor head section at ~10 feet. 65 dB(A) at conveyor head section at ~100 feet.
	Wash Plant	• 76 dB(A) (primary plant at ~50 feet) • 83 dB(A) (secondary plant at ~25 feet) • 82 dB(A) (between primary plant and secondary plant) • 70-75 dB(A) (load out area)
	Trucks	• 78-84 dB(A) (loaded trucks pulling away from scales to ticket office at ~10 feet
	Crusher	• 85 dB(A) (on same side as generator at ~50 feet)

	Generators	• 95 dB(A) (~15 feet from source) • 64 dB(A) (~300 feet from source)

Note: Noise levels recorded by a Simpson 884 Type S2A sound level meter. Distances were stepped off by foot and estimated.

A Noise Reduction Strategy

The Federal Highway Administration states that effective control of the undesirable effects of highway generated noise requires careful consideration of the following points (USDOT, 1974):

1. Source emission reduction
2. Improved highway design, and
3. Land use control near the highway

Memphis Stone and Gravel Company follows this model. Obviously Memphis Stone & Gravel Company cannot control land use of its neighbors. But it can attempt to improve its "mine design" and more effectively plan and control its operations. Memphis Stone & Gravel Company employs several physical controls to minimize noise caused by its equipment, particularly noise that is strident, which can cause complaints even at relatively low sound pressure. But ultimately a dynamic strategy must be promoted within operations to effectively control noise in mining situations because of the constant change taking place. Certainly, acute and chronic noise exposure to employees is of primary importance and proper personal protective equipment is utilized as circumstances warrant. Otherwise, operations within close proximity to residential or other areas used by the public prioritize noise abatement controls and practices.

Site Planning

Planning in itself can be the single most important factor in reducing noise. Distance reduces the effects of sound and it is well documented that doubling the distance from a noise source can reduce its intensity by as much as 6 dB(A) (USDOT, 1974), (Brigade, 2006). The manner in which you sequence the mining activity can have a positive or negative affect on noise. For example, mining away from the community, thus using the reclaimed land as an expanding buffer, can significantly affect the noise both physically and psychologically. At the beginning of the project, people are usually more frustrated with the situation and certainly know what is going on. Some comfort may result in knowing that the project is "moving away" from them. Other elements of planning should involve an analysis of the following:

- Prioritizing the noise sources (e.g., crushers, load out areas, offices)
- Site selection for loud equipment
- Type, size, and shape of noise barriers
- Phasing the activity to reduce the "foot print" of the operation
- Avoiding unnecessary destruction of existing vegetation
- Seasonal variations in vegetation
- Using natural topography to minimize noise

Noise Barriers

Noise barriers are obstructions strategically placed between noise sources and the affected community. "They do not *completely* block all noise, but reduce overall noise levels. Effective noise barriers typically reduce noise levels by 5 to 10 dB(A), cutting the loudness of traffic noise by as much as one half" (USDOT, 2001). Noise barriers can be walls, earth berms, stockpiled materials, or vegetative plantings.

Vegetated earth berms, are as common a fixture in Memphis Stone & Gravel Company's operation as the front-end loader. Berms are sinuous mounds of soil or earth materials, with a trapezoidal cross section built with 3:1 slopes then vegetated. The berm is placed around the perimeter of the operations to serve as visual screening device as well as an effective noise control (Figure 2). Earthen berms can reduce noise as much as 3 dB(A) more than a wall constructed at the same height.

Figure 2: Berm constructed around mining operations. Note the close proximity (~500 feet) from the nearby subdivision to the bottom-left of the photo.

Similar to berms, strategically placed stockpiles can be very effective. Memphis Stone & Gravel Company has measured up to a 30% reduction in decibel levels by placing stockpiled materials in front of noise sources (Figure 3).

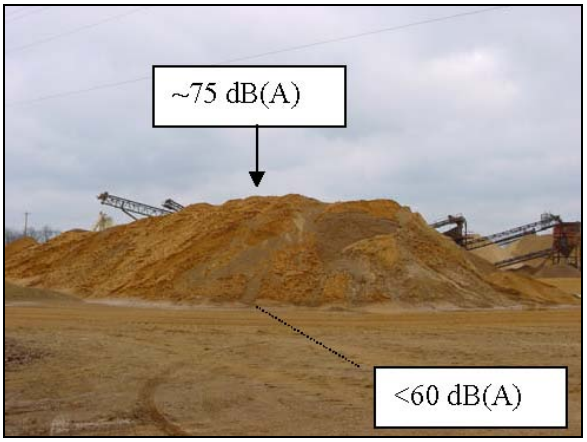

Figure 3: A stockpile of fill sand is placed between plant operations and the property boundary. The sound measures below background levels when measured on the side away from the plant.

Trees planted in rows are typically used more for aesthetic purposes than for noise control. However, a wide strip of trees with very thick undergrowth can lower noise levels. Memphis Stone & Gravel Company typically selects evergreen trees which have fast growth. Loblolly Pine and Leland Cypress are varieties most often used. The Federal Highway Administration suggests that 30 meters of dense vegetation can reduce noise by five dB(A) (USDOT, 2001).

Noise Source Reduction

Noise source reduction can involve something as simple as replacing a squeaky conveyor idler or an economic decision to eliminate an activity generating excessive noise. The idea is relatively simple, but as much as anything involves a culture change within the organization. Management should be proactive in communicating a philosophy that noise reduction has tangible benefits to the company, even when it is not a safety issue. Until recently, Memphis

Stone & Gravel Company had limited options for noise source reduction. This has changed with the use of broadband backup alarms.

Since 2005 Memphis Stone & Gravel Company has had an aggressive campaign to retrofit much of its mobile equipment with broadband directional backup alarms. The alarms have increased our noise reduction capabilities near the communities in which we operate while at the same time improving employee safety. Memphis Stone & Gravel Company has chosen broadband directional sound devices produced by Brigade Electronics Incorperated (Brigade) and marketed as bbs-tek® (broadband sound technology) back-up alarms. The success of the alarms regulatory acceptance can be measured in part by one of Memphis Stone and Gravel Company's local land use control agency's reaction to the idea of broadband alarms as a noise reduction strategy. The Memphis and Shelby County Office of Planning and Development recently required as one of its permit conditions the following: "backup alarms on vehicles and construction equipment shall emit a narrowly directed signal of white noise, as consistent with the latest technology, so as to eliminate the ambient warning noise activity as a significant nuisance for neighbors" (MSCOPD, 2006).

Broadband Sound Technology- A Closer Look

"Broadband sound is known colloquially as "white sound". The "white" description derives from white light which is composed of all the colors in the color spectrum. Broadband sound similarly, is composed of all frequencies in the audio spectrum. Therefore, broadband does not have to rely on high sound pressure dB(A) in order to be heard because, being multi-frequency, competing single frequencies cannot mask it" (Brigade, 2007). Figure 4illustrates how broadband at a lower dB(A) output compares to conventional narrowband alarm sound in the audio spectrum.

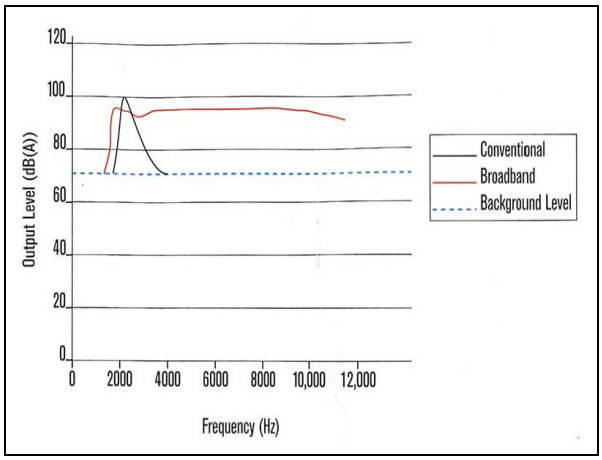

Figure 4: Frequency distribution of broadband sound versus narrowband sound (courtesy of Brigade Electronics, Inc).

Broadband sound has the unique characteristic of its source being instantly locatable. The sound is very directional as opposed to the more omni-directional character of narrowband sound. The "locatable" characteristic is a major factor in the broadband technology's appeal. It has two advantages when compared to narrowband alarms conventionally used in mobile equipment. First it makes those within the danger zone more easily recognize the direction of the alarm's source. Secondly, it reduces the sound for those that do not need nor want to hear it (Brigade, 2006). Instead of the conventional "beep-beep-beep" tonal sound so familiar to

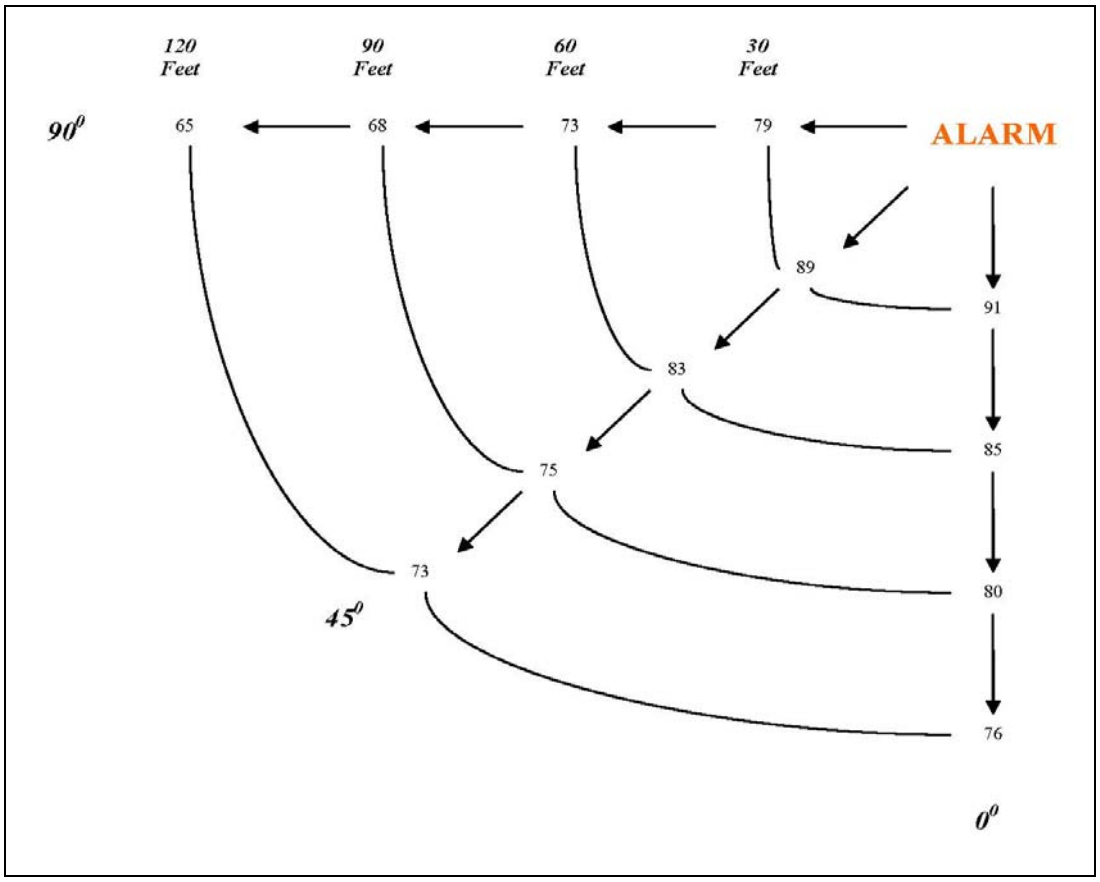

Figure 5: Sound dissipation map showing change in dB(A) measured at 30 feet intervals behind equipment. Equipment turned off and background noise less than 60 dB(A).

narrowband alarms, the broadband alarm "shhh-shhh-shhh" sound does not contain tones, so it is less strident. Figure 5 illustrates the directional characteristics of the alarm. A decrease of about 12 dB(A) was noted at 90 degrees to either side of the equipment.

Application

Memphis Stone and Gravel Company has determined that the bbs-tek® BBS-107 model alarm with a 107 db(A) output rating is best suited for its mobile equipment. Because the equipment is subject to movement from one location to another and thus varying conditions, the higher output model meets this challenge. The alarm meets the MSHA requirement of being *audible above the surrounding noise levels*. Field observations as measured with a Simpson 884 Type S2A sound level meter showed the alarm to be at the low 90 dB(A) level at approximately 30 feet away with the machine off and background noise levels <60 dB(A). Operational background levels inside a typical active pit measure at the 75-80 dB(A) level (about 25-50 feet away from equipment) and 75 to 83 dB(A) in proximity of a typical wash plant site. The broadband alarms were consistently measured above operational background noise. The alarms have proven to be relatively easy to install and require very little maintenance. One note of caution is to make certain installers understand that the broadband alarm must be

aligned with the front/rear axis and be pointed directly away from the machine in order to optimize the sound pressure (see Figures 6 and 7).

Figure 6: Photograph showing installation location of bbs-107 on a 966G loader. This location is not optimal and should be rearranged.

Figure 7: Photograph showing installation location of bbs-107 on a 980G loader.

The equipment targeted for the BBS-107 and the respective priority were the front-end loaders, dozers, graders, and haul trucks. Operations with sensitive conditions with respect to number of stakeholders impacted by noise were given priority. A plan to retrofit old equipment began in late 2005. Since early 2006 the company has installed these alarms on new equipment and to date approximately 50 to 60 percent of the company's entire fleet has been converted to broadband alarms. (Redden, 2007).

In addition to using broadband alarms on mobile equipment, Memphis Stone and Gravel Company initiated a pilot project with Brigade Electronics Incorporated in the summer of 2007 to evaluate broadband alarms on its conveyor systems. Conventional siren type alarms have historically proven to be safe and effective, but again in certain applications the desire to reduce sound can be a positive attribute. Memphis Stone and Gravel Company typically installs field-conveyor in 1000 feet segments with entire lengths up to two miles. Four to six "piggy-back" conveyors (shorter sections approximately 100 feet long) are used to feed materials from the pit to the field conveyor. The pilot study determined the following points:

- The company selected an alarm with a rapid pulse tone to distinguish the sound character from that which is installed on mobile equipment.

- The directional nature of the broadband alarm accompanies the linear structure of the conveyors. Brigade developed an alarm with a 117 dB(A) rated output in order to optimize the distance along the conveyor line. Brigade developed a cone for the alarms to further magnify the linear sound pressure. The alarm measured approximately 105 dB(A) ~10 feet away from the source.

- Memphis Stone and Gravel Company determined that no less than one alarm for each two piggy-back conveyors is necessary (Figure 8). This is required to accommodate the time sequence that alarms must

sound. Each conveyor starts independently of one another and the conveyor must start within 30 seconds after the signal sounds. Also, it is generally more noisy where piggy-back conveyors are used (i.e., inside the working pit) than other areas along the conveyor line. Background noise typically measured <60 to slightly above 60 dB(A), but can approach 80 dB(A) close to loading operations. The broadband alarms measured from 70 to 83 dB(A) at the points of maximum distance between alarms (~200 ft.). These levels appeared adequate to signal start-up, but it is necessary to have an alarm on the first conveyor from the feeder, as it is usually the area with the most background noise.

Figure 8: "Piggy-Back" conveyors are 100 feet conveyor segments designed to be easily reconfigured to move materials from the active pit to the field conveyor.

- The optimum distance between alarms for the field conveyors appears to be 300 to 400 feet. At this distance the alarms located at the 300 feet distance measured in the upper 60 dB(A) range and the alarm at the 400 feet distance measured in the mid to upper 70 dB(A) range. Figure 9 illustrates that Alarm 2 begins to positively influence the sound measured between the 300 and 400 feet interval. Typical background levels are 65-70 dB(A). Under normal circumstances the conveyor will be in the off position when the alarm sounds and during the most quiet background conditions these distances should be conservative. But if heavy activity occurs between alarms, any contingency will quickly diminish. Another factor to consider is potential wind interference and topography. Field conveyors are often placed in wide open places and are often placed on rolling terrain that can approach 3:1 slopes.

- The diesel powered generators often used along the conveyor line can greatly diminish the alarm's effectiveness if the generator sound emission source is oriented parallel to the conveyor. This can be minimized by orienting the generator perpendicular to the conveyor.

- Similar to the mobile equipment, alarm installation requires careful planning so the sound waves are not needlessly obstructed to a point which severely affects its performance. During the pilot testing it was noted that alarm 1 was inadvertently installed behind the take-up frame and resulted in a ~10 dB(A) reduction. This can be observed by comparing the dB(A) measured at Alarm 1 and Alarm 2 at the 100 feet intervals (Figure 9).

- Site specific characteristics such as the conveyor's distance to

stakeholders and start/stop frequency will be the major factor in determining the cost effectiveness of using broadband alarms on conveyor systems.

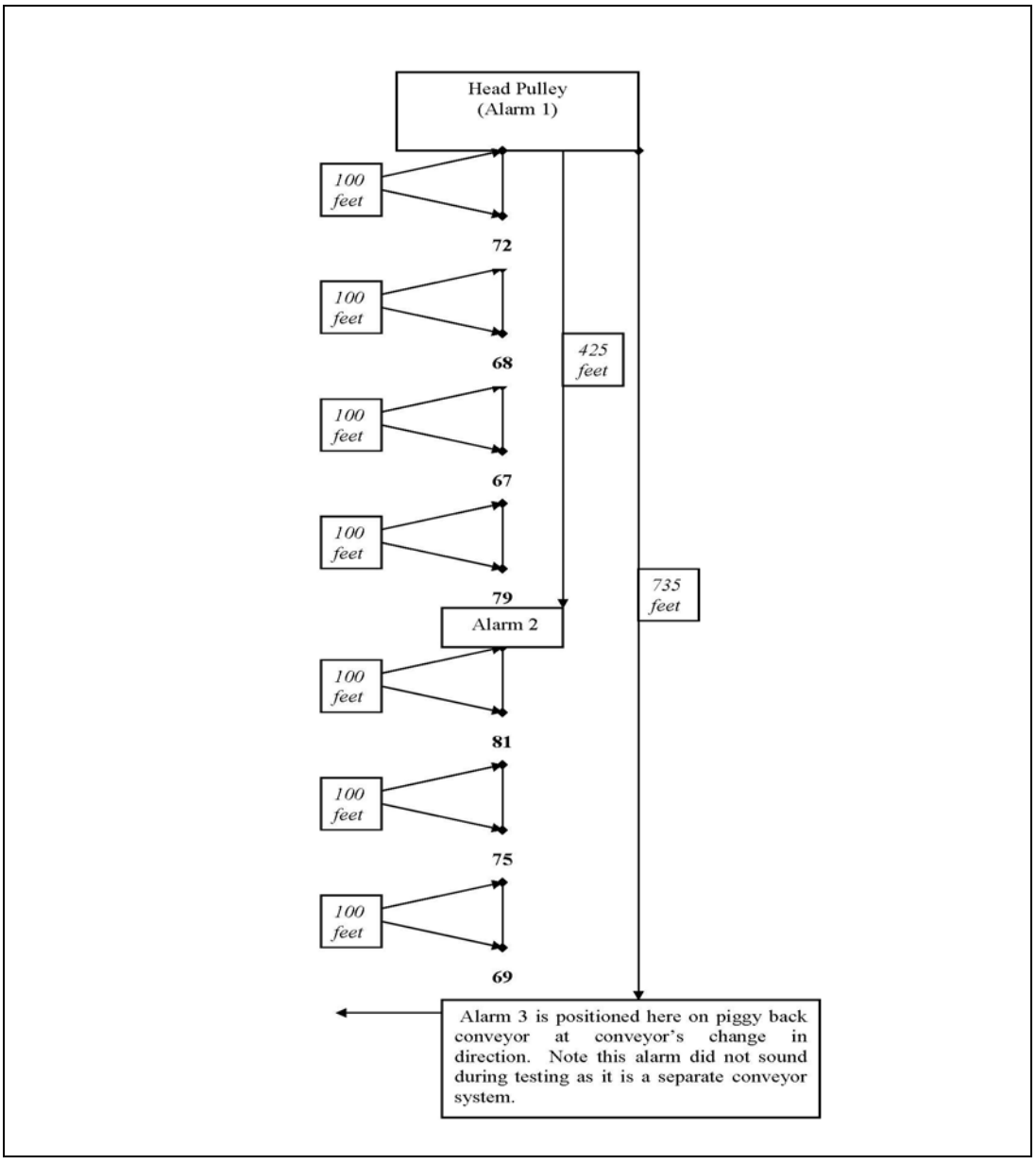

Figure 9: Field conveyor with two alarms. Note that the alarms sound simultaneously when started. Sound measured at 100 feet intervals. Distance stepped off by foot and estimated. All measurements in dB(A).

Conclusion

Whether perceived or real, noise is a major quality of life issue that aggregate operations should address in a systematic and proactive manner. Memphis Stone and Gravel Company controls noise at its operations by better planning its operations, effectively using noise barriers, and attempting to reduce noise at its source. It is important that management communicate to staff the benefits of reducing noise for its community relations. Those responsible for obtaining permits or maintaining harmony with stakeholders will find broadband alarms an effective tool in its noise source reduction strategy. Broadband alarms on mobile equipment have proven to be a sound investment and there use has now become a proactive measure taken by Memphis Stone and Gravel Company during the permitting process. The use of broadband alarms on conveyors is a feasible alternative to conventional sirens, but the costs may or may not be justified depending on the characteristics of the conveyors' start/stop cycles and the distance to stakeholders.

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