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**ACOUSTICAL CONSIDERATIONS IN THE DESIGN OF MINERALS
PROCESSING PLANTS**

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INTRODUCTION

It is well established that the best opportunity to address industrial noise control problems is during the design phase of new plants. Solutions at this stage are both economically and technically more effective than later retrofits. Thus, unique opportunities are often presented to management in the planning phase for new plants to make decisions that are also acoustically advantageous. A simple example of this was recently found in which a mining company, engaged in the processing of silica sand, had built two screening towers similar in function but with different constructions. To provide the mining industry with quantitative information to guide them in assessing the potential acoustical benefits of facility design, these mineral processing plants with similar operations, but contrasting designs, were studied. To characterize the acoustical environments in these facilities, the spatial distribution of sound levels in the two plants was measured and compared using an external sound source. The results of this study clearly show the advantages of an *open* plant design in achieving reduced worker noise exposure levels.

DESCRIPTION OF PLANTS

The two facilities rely on essentially the same processing equipment to screen and classify silica sand material by size, after the comminution process; however, one of the screening towers uses an "open" construction, i.e., it has no roof or walls. Both facilities are multi-storied (see Figures 1 and 2) with each floor equipped with numerous screens, conveyors, and chutes. While the heavy equipment is mounted on steel/concrete bases, much of the floor space is covered with open grating. Because of the mining company's concerns about the health effects of silica dust, all of the equipment is sealed or enclosed, usually with steel plate, to prevent the escape of dust into the workplace. Traditional building technology is employed in the other facility (Plant #2), with cement blocks and metal roofing for the walls and roof, respectively. From an acoustical perspective, both facilities are complex due to the distribution of equipment which serves to generate noise, as well as to reflect and absorb it.

DESCRIPTION OF ACOUSTICAL MEASUREMENTS

Experiments to measure the spatial distribution of sound levels were conducted in the two screening towers. In order to minimize background noise, plant operations were suspended during all testing.

Tests to measure the acoustic environment were performed using an external sound source with a known sound power level. In Plant #2, a building acoustic analyzer was also used to measure the reverberation time.

Tests were conducted in both plants utilizing a B&K 4205 Sound Power Source Type¹ and recording system. The unit consisted of two separate components, the generator containing the controls, filters, amplifiers and meters, and a HP 1001 Sound Source containing two loudspeakers and associated crossover networks. The generator unit was equipped with octave band filters ranging from 125 Hz to 8000 Hz. The sound power output of the HP 1001 was controlled by an attenuator with 40 dB range in 10 dB increments. A sound power level of 100 dB was selected for all experiments. The recording system consisted of a ½" B&K 4133 microphone fitted with a B&K 2615 pre-amplifier as input to a Nagra tape recorder. The recording microphone was mounted on a tripod at an elevation of approximately 66 inches above the floor. After the noise source which was located on the ground floor was energized, 45 seconds of noise level data were recorded for each of the seven octave bands from 125 Hz to 8000 Hz. Noise level data were recorded at each of the locations shown in Figure 1 and 2. The tape recorded noise level data from the two screening towers were subsequently analyzed in the laboratory with a digital frequency analyzer. A 32-second linear averaging time was used in calculating the one-third octave band spectra from 63 Hz to 8 kHz.

In Plant #2 reverberation time measurements were performed with a B&K 4418 Building Acoustics Analyzer.² The test signal from this unit was enhanced by a power amplifier and used to drive a loudspeaker located on the ground floor. Reverberation time measurements were conducted at the 5 recording locations on the 2nd and 3rd floor (Figure 3).

RESULTS AND DISCUSSION

The results of the sound level measurements conducted in the two facilities are summarized in Tables 1 and 2 below. Octave-band sound pressure level (SPL) data are presented as a function of distance (and location) relative to the sound source. Note that data from some of the more distant measurement locations shown in Figures 1 and 2 were not used in the final analysis due to interference from background noise. In addition, the reverberation time, T_{60} , measured in Plant #2 is shown in Figure 3. In order to better visualize trends in the data and facilitate analysis, SPL-versus-distance data from the two plants at selected frequencies of 125, 1000, and 4,000 Hz are plotted on a log scale in Figure 4. These data have also been overlaid with a straight line having a slope of 6 dB per doubling of distance, which is characteristic of a source located in a free field.

Table 1. Sound Pressure Level - dB; Plant #1- Open Environment

Octave-Band Center Frequency	2nd flr, loc #3 23 ft from source	2nd flr, loc #2 27 ft from source	2nd flr, loc #1 42 ft from source	3rd flr, loc #2 44 ft from source	3rd flr, loc #1 56 ft from source
125 Hz	78.8	78.8	75.4	74.9	74.1
250 Hz	78.4	78.0	74.1	72.1	72.3
500 Hz	76.3	75.9	72.3	69.8	69.7
1000 Hz	75.1	73.4	71.7	67.6	67.9
2000 Hz	74.3	74.6	70.8	66.1	65.6
4000 Hz	72.7	73.5	68.0	64.4	62.2
8000 Hz	70.5	70.6	64.2	58.2	55.6

Table 2. Sound Pressure Level - dB; Plant #2 - Reverberant Environment

Octave-Band Center Frequency	2nd flr, loc #3 28 ft from source	2nd flr, loc #2 38 ft from source	3rd flr, loc #1 45 ft from source	3rd flr, loc #2 60 ft from source	2nd flr, loc #1 60 ft from source	4th flr, loc #2 68 ft from source	4th flr, loc #1 79 ft from source
125 Hz	84.3	84.8	82.7	81.3	79.3	77.9	77.8
250 Hz	81.3	82.6	81.4	78.1	78.9	76.7	76.0
500 Hz	80.7	79.4	78.8	76.3	76.8	77.3	72.9
1000 Hz	80.1	77.7	76.6	73.8	73.4	70.9	68.5
2000 Hz	77.4	74.8	75.7	70.8	71.2	69.6	65.7
4000 Hz	76.3	73.4	72.9	68.5	69.4	66.6	63.6
8000 Hz	75.2	71.4	71.9	65.6	66.6	66.7	59.1

From these data it can be seen that the sound fields in both plants decrease in level with increasing distance from the source. The open environment of Plant #1 appears to approximate, acoustically, that of a free field. In the reverberant environment of Plant #2 the level of the sound field tends to be about 5-8 dB higher than the level in Plant #1, at comparable distances from the source. What is surprising at first, in view of the reverberant environment in Plant #2, is that after an initial increase in SPL near the source, the level falls off with increasing distance much like the free field case. However, this is qualitatively consistent with the results of previous studies to predict the propagation of sound in fitted rooms.³ In general, when a large number of machines, or fittings, are distributed in an enclosed space like a plant or factory, the resulting noise level is higher near the source, but much lower at greater distance from the source. The fittings also serve to positively influence the absorption in the space by creating a more diffuse sound field with more opportunities for the sound field to interact with absorbent surfaces.

A rough approximation of the difference between the measured and expected SPL's in Plant #2 can be obtained using the measured reverberation time (Figure 3) and the following basic relationships:

$$\text{Equation 1. } T_{60} = \frac{.049V}{S\bar{\alpha}} \quad , \text{where}$$

T_{60} = reverberation time (sec)
 V = volume (ft³)
 $S\bar{\alpha}$ = Sabins of absorption (ft²)

$$\text{Equation 2. } SPL = PWL + 10 \log_{10} \left[\frac{Q}{4\pi r^2} + \frac{4}{S\bar{\alpha}} \right] + 10 \text{ dB} \quad , \text{where}$$

SPL = sound pressure level, dB
 re 20 uPa
 PWL = sound power level, dB
 re 10⁻¹² watt
 Q = directivity factor
 r = distance from source (ft)

First, based on a volume of 100,000 ft³ Equation 1 is used to calculate a value for $S\bar{\alpha}$ at a given frequency; after substituting this value in Equation 2, the expected SPL in the reverberant field (for PWL = 100 dB, Q = 2 and r = 79 ft) can be computed. Using this approach it is found that the expected reverberant SPL (in a room with the same volume and T_{60} , but no fittings) overestimates the measured SPL in Plant #2 at all frequencies, and ranges from 3 dB at 125 Hz to 20 dB at 8,000 Hz. It should be noted that excess attenuation due to molecular absorption in the air was not significant.⁴

CONCLUSIONS

The distribution of equipment in Plant #2 served to create a complex sound field not readily predictable. However, the results of this study quantified the acoustical advantage associated with an "open" plant construction. A 5 - 8 dB difference between the open and reverberant environments in Plant #1 and #2, respectively, was observed even though this difference was considerably less than what was expected, i.e. based on a similar reverberant space, but with no fittings. Thus, it is concluded that the choice of plant construction can have a significant impact on the noise exposure level of workers, which of course also depends on the amount of exposure time.

REFERENCES

1. Bruel & Kjaer Instruction Manual, *Sound Power Source Type 4205* (1981)
2. Bruel & Kjaer Instruction Manual, *Building Acoustics Analyzer Type 4418* (1982)
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4. L.L. Beranek: *Noise Control* (McGraw Hill, New York, 1960)

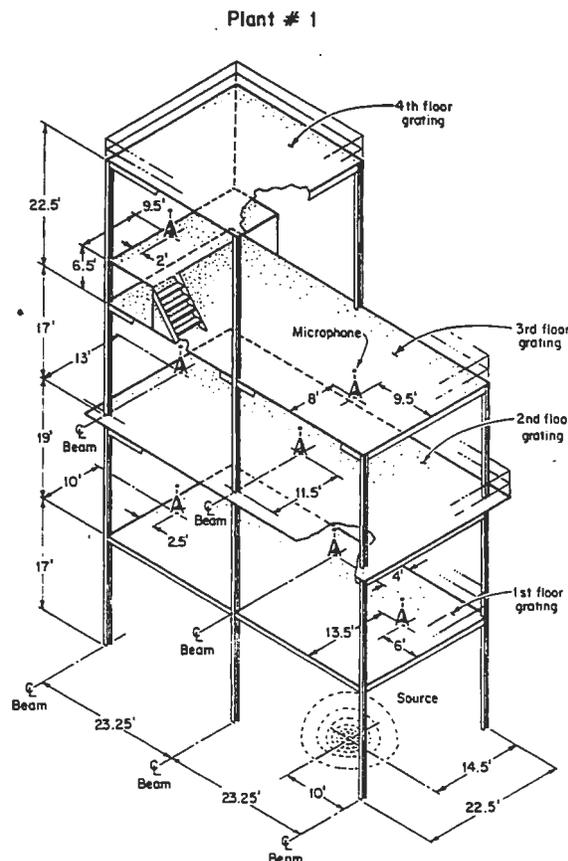


Figure 1. Plant #1 - Noise Measurement Locations

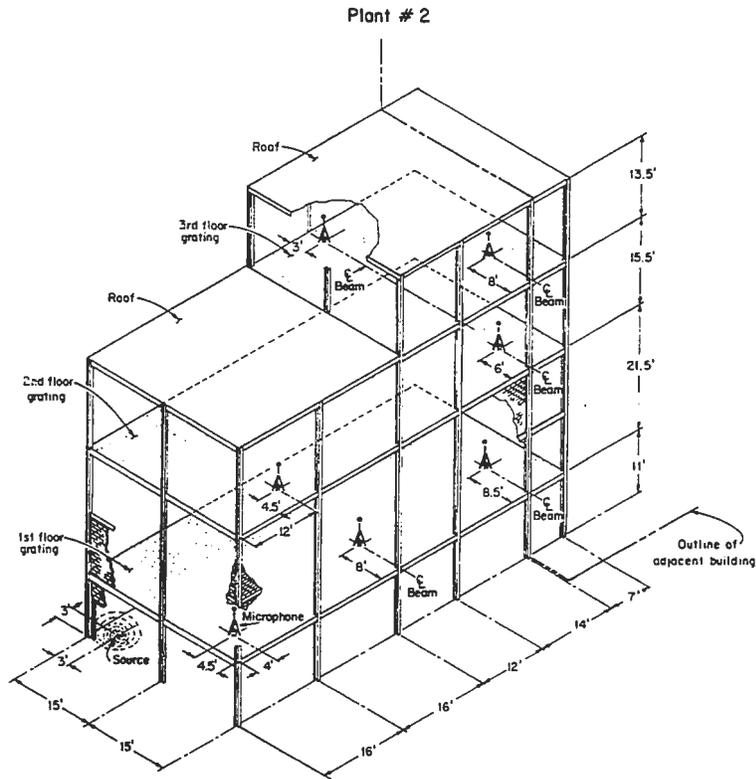


Figure 2. Plant #2 - Noise Measurement Locations

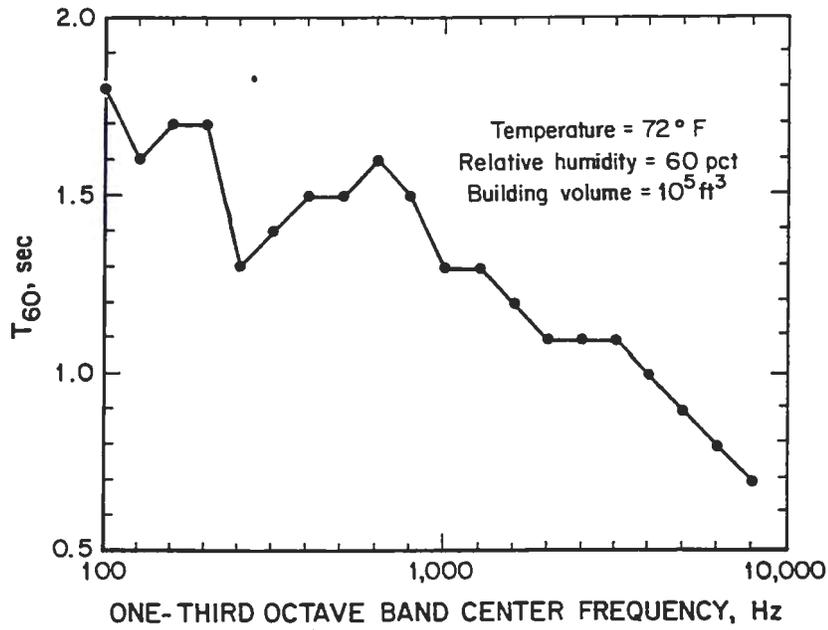
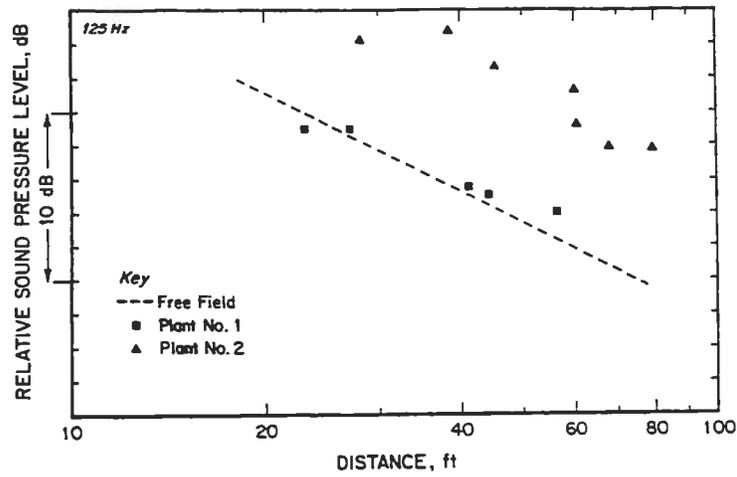
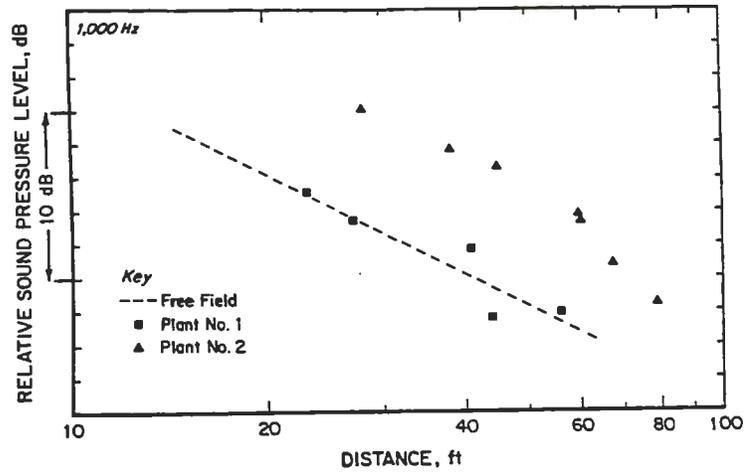


Figure 3. Reverberation Time in Plant #2



(a)



(b)

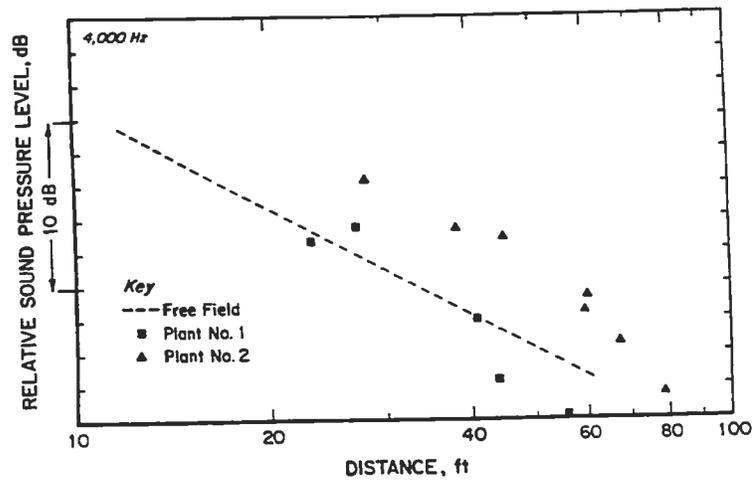


Figure 4. Octave Band Sound Pressure Levels in Plants #1 and #2

(c)

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