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# ESTIMATING COMMUNITY NOISE LEVELS FROM OUTDOOR CONDENSING UNITS

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## INTRODUCTION

Noise propagated from cooling towers and condensing units into adjoining residential neighborhoods is becoming an increasing problem in developing areas of the country. Population growth and an expanding economy have combined to have educational, commercial, recreational and industrial facilities in close proximity to residential areas. The large air-conditioning plants that are part of these facilities operate all day and through the night sometime causing noise disturbances in the residences especially during early morning hours.

It is difficult to accurately predict the noise levels that will be reached at the residential properties during the design stage of a project because of the complex geometry and lack of algorithms in the literature for the enclosures that often surround the towers and condensing units. The enclosures might be near walls from the building itself or a lower equipment courtyard wall may surround the equipment. Manufacturers typically provide sound power levels for outdoor condensing units and sound pressure levels at 5 ft (1.5m) and 50 (15m) ft distances for cooling towers. The sound pressure level measurements for the cooling towers are typically taken outdoors over a ground surface. Actual installations of this equipment are rarely in open areas away from buildings and other enclosing elements.

It is necessary to accurately account for the acoustical effects of partial enclosures and the effects of reverberant sound build-up within more complete enclosures on sound levels at locations away from condensing units to accurately predict the resulting sound levels at adjoining properties. There are only a few cases in the literature on this topic. At this time, most of the knowledge in this area is in the hands of consulting firms who have worked on actual projects and in manufacturers of noise mitigation devices such as silencers that have successfully completed projects.

## PHYSICAL ACOUSTICAL MODEL TESTS

### Construction of the Scale Model

A 1:10 scale model of a typical condensing unit was built. Cut sheets of condensing units and cooling towers of several projects were reviewed to find an average size for the scale model. The condensing unit model was built to represent a 15’ (4.6m) x 8’ (2.4m) x 7.8’ (2.4m) actual unit at a scale of 1:10. The model was constructed of ½" (1.3cm) thick, 6 layer, interior finish plywood panels. They were joined together to form a box. After forming the box, six loudspeakers were installed on the front, rear, and upper faces of the model, so sound would be propagated both upwards and to the sides of the model. Three of the loudspeakers were 4" (10.2cm) full-range speakers which propagated sound in the 80 – 15,000 Hz frequency range. The 4" (10.2cm) full-range speaker was used to produce low frequency sounds. The other three loudspeakers were 3½" (8.9cm) super horn tweeter speakers. This loudspeaker propagated sound from 4,000 – 27,000 Hz. The 3½ " (8.9cm) loudspeaker was used to produce high frequency sounds.

**Basis of Acoustical Modeling**

As the linear dimensions of a model are reduced relative to the prototype or full size situation, the wavelength and frequency of the sound waves must be scaled as well Table 1. provides a summary of the acoustical scaling process. With a scale 1:10 model, all the frequencies used in the model must be ten times higher than the frequencies measured in the full size measurement. The frequency range in the full size case studies of 63 - 2000 Hz is shifted to 630 - 20000 Hz in the model test. 10,000 Hz has a wavelength of approximately 0.1 ft (Cremer & Muller, 1978, p.178).

*Table 1. Summary of Acoustical Scale Model Principles*

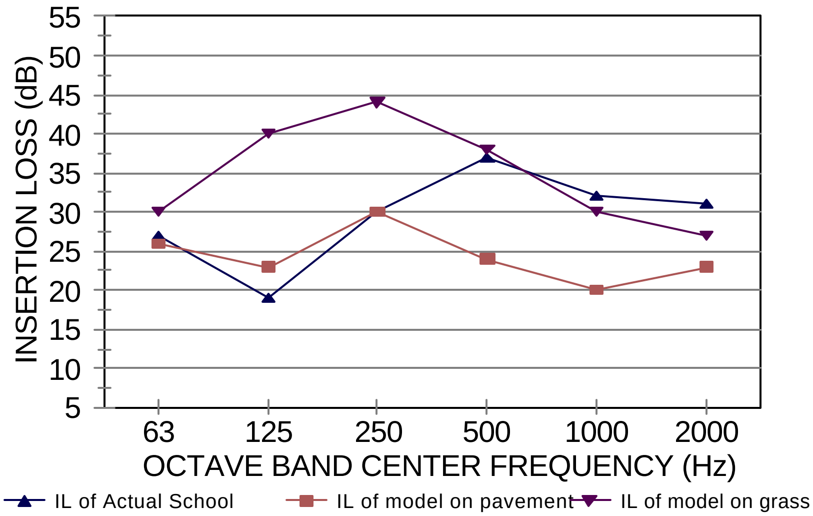
| | PROTOTYPE | MODEL |
|---|---|---|
| SCALE | 1 : 1 | 1 : 10 |
| LINEAR DIMENSIONS | 350 feet (106m) | 35 feet (10.6m) |
| FREQUENCY | 1000 Hz | 10,000Hz |
| WAVELENGTH | 1.13 feet (0.3m) | 0.113 feet (0.03m) |
| ABS. COEFFICIENTS | $\alpha$ at 1000 Hz | $\alpha$ at 10,000 Hz |

The model was wired to an amplifier, Crown Com-Tech 200. The amplifier was wired to an Parasound EQ300 equalizer,. An Ivie IE-84 pink noise generator was used as a sound source. The pink noise generator was connected to the equalizer where the spectrum was shaped to approximate the condensing unit noise. A ½" (1.3cm) condenser microphone, Ivie 1134 RP, was set 7" (17.8cm) above the ground at each measurement point. Measurements gathered with a ¼" (0.6cm) Larson Davis microphone, B&K pre-amp and B&K model 2804 power supply were identical to those recorded with the ½" (1.3cm) microphone. An IV PC-40, audio spectrum analyzer, was used to measure and record sound levels.

**The Model Test**

*Experiment 1. Middle School Chiller Levels.* A middle school in Gainesville was selected for Experiment 1. The site was selected because there were four large chillers behind the school building. There is a flat field extending from the chiller to a distance of approximately 400ft (122m). Sound levels were measured at 5ft (1.5m), 10ft (3m), 15ft (4.5m), 20ft (6m), 100ft (30m), 200ft (60m), 300ft (91.4m), and 350 FT (106.7m) the chillers at the school. A scale model of this situation was tested. A large reflecting panel made of plywood was constructed to simulate the school building. The model test was also performed at the scaled distances from the model chiller, 6in (15cm), 1ft (30cm), 18in (45m), 2ft (0.6m), 10ft (3m), 20ft (6m), 30ft (9m), and 35ft (10.7m). The model tests were performed on pavement and grass. The results of the measurements of the model tests and the full size tests at the middle school are shown in Figure 1. The measurements are compared based on the insertion loss provided between a near field measurement at 5ft (1.5m) from the chiller to the sound level measured at each distance. The insertion loss included the combined effects of distance, air and barrier (if present) attenuations.

*Figure 1. Comparison of the Insertion Losses of the Middle School Chiller*




The results were interesting because in the low frequency range, the Insertion Loss (IL) measured at the middle school was close (0 to -4 dB) to the model test on pavement. In the high frequency range, the IL measured at the school was quite close (+4 to -1 dB) to the model test on grass.

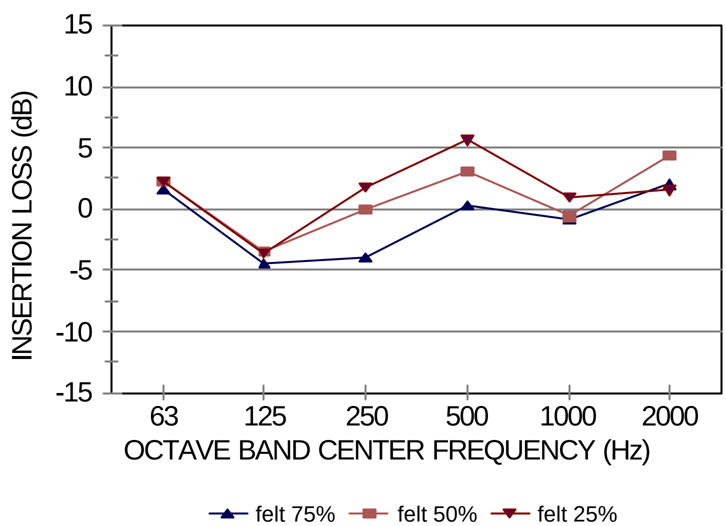
*Experiment 2. Model tests on mixed ground conditions*. The mid-point between the IL of the model tests on pavement and the IL of the model tests on grass would be a better result. This meant that a mixed ground condition was required to more closely approximate the hard dirt, pavement and grass surfaces at the full size school. Two tests were performed to reflect this condition. In the first test, with the microphone placed at a distance of 35 feet (10.7m) from the source, five-5ft (1.5m) felt strips were spaced equally with 2.5 ft between the felt strips. The second test consisted of eighteen 1 ft (0.3m) strips of felt spaced 1 ft (0.3m) apart. The model tests were performed on pavement covered with 75%, 50%, and 25% felt. The results of the model tests were compared with the measurements taken at the middle school data. The results of these tests are shown in Figure 2.

In the Figure 2, the value of IL error is the IL of the model tests subtracted from the IL of the measurement made at the middle school. Negative values mean that the ground condition in the model test resulted in more sound absorption than in the actual situation. Most values lie between the range of ±5dB. The test with 50% felt has the lowest average IL error range (2.31 dB).

*Table 2. Insertion loss error of the middle school and model tests on pavement covered with 75%, 50%, and 25% felt.*

| Frequency (Hz) | 63 | 125 | 250 | 500 | 1000 | 2000 | AVG. |
|---|---|---|---|---|---|---|---|
| felt 75% | 1.6 | -4.4 | -3.9 | 0.3 | -0.9 | 2.0 | 2.2 |
| Felt 50% | 2.3 | -3.5 | 0.0 | 3.1 | -0.6 | 4.4 | 2.3 |
| Felt 25% | 2.2 | -3.6 | 1.8 | 5.6 | 1.0 | 1.5 | 2.6 |

*Figure 2. Insertion loss error of middle school chillers and the model tests on pavement covered with 75%, 50%, and 25% felt.*




*Experiment 3. Model tests in a plywood platform.* A platform was constructed on which the model tests could be conducted. If the platform is constructed of plywood, it can possibly reduce the IL error because it was hypothesized that most of the error points lie above the zero line. It was reasoned that the pavement with felt did not absorb nearly as much sound as the actual conditions. The platform was constructed to verify these two effects. The platform was constructed of five ½” (1.3cm) thick 4’ (1.2m) x 8’ (2.4m) plywood panels on frames constructed of 2” (5cm) x 4” (10cm) pressure treated lumber. The five plywood boards were placed on the grass and leveled. The platform was covered with as much as 60% felt.

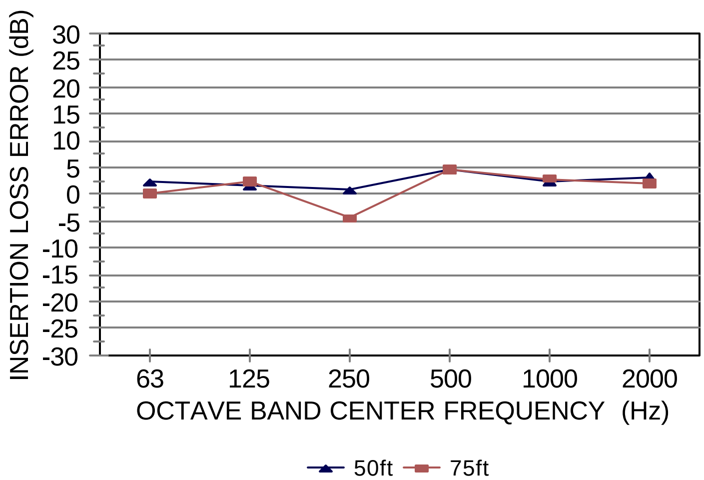
*Experiment 4. Community College Chiller tests.* A case study of chiller noise at a local community college was also selected to compare field measurements at the actual chiller with model tests. Chiller noise was propagating into neighborhoods from the community college building. The chillers were located behind the school building. The chiller was enclosed by a wall that was approximately the same height of the chillers on three sides. There was a large wall of the building located behind the chillers. The ground around the chillers was pavement. Sound levels were measured inside the enclosure, on all 4 sides of the chillers and at distances of 50 feet (15m), 75 feet (23m), 100 feet (30m), and 124 feet (38m) from the chiller.

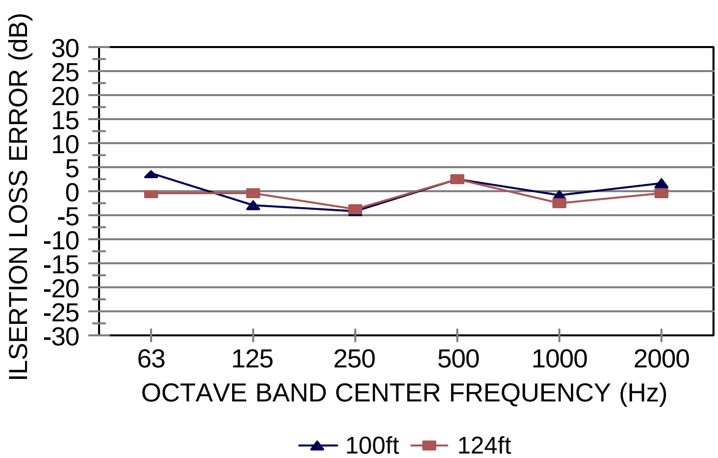
The model was set on pavement. A 3.3' (1m) X 8' (2.4m) size wall was constructed to simulate the sound reflecting effect of the building wall. An enclosure wall was also constructed on the other 3 sides of the chiller model to the height of the model chiller. A ¼" (0.6cm) microphone was set 7" (17.8cm) off the ground. Sound levels were also measured inside the model enclosure, and at distances of 5 feet (1.5m), 7.5 feet (2.3m), 10 feet (3m), and 12.4 feet (3.8m) at 1:10 scale.

*Table 3. IL error of community college chiller and the model test on pavement.*

| Frequency (Hz) | 63 | 125 | 250 | 500 | 1000 | 2000 | Avg. |
|---|---|---|---|---|---|---|---|
| 50ft | 2.2 | 1.5 | 0.7 | 4.7 | 2.4 | 3.1 | 2.4 |
| 75ft | 0.2 | 2.3 | -4.5 | 4.6 | 2.9 | 1.9 | 2.7 |
| 100ft | 3.7 | -2.9 | -4.2 | 2.6 | -0.9 | 1.8 | 2.7 |
| 124ft | -0.5 | -0.2 | -3.8 | 2.6 | -2.5 | -0.2 | 1.6 |

*Figure 3. IL error of the community college chiller and the model tests on pavement.*




All values of IL error lie between the range of positive and negative 5dB. The average of the IL error at 124 ft (38m) is 1.6 dB. This means that the model test could predict noise levels from the noise source to a receiver position for an enclosed chiller with a reasonable degree of accuracy in frequencies of interest.

## SUMMARY

A physical acoustical model using miniature loudspeakers for the sound source was constructed at a scale of 1:10. Experiments were conducted to estimate sound levels from the noise source to receiver positions. The model tests predicted noise levels from the noise source to a receiver position for an enclosed chiller or without an enclosure with a reasonable degree of accuracy in frequencies of interest.

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## REFERENCES

1. C. Ebbing and W. Blazier, *Application of Manufacturers' Sound Data* (American Society of Heating and Air-Conditioning Engineering, Inc., 1998)
2. C. M. Harris, *Handbook of Acoustical Measurements and Noise Control* (McGraw-Hill, Inc. 1991)
3. D. M. Egan, *Architectural Acoustics* (McGraw-Hill, Inc., 1988)
4. L. Cremer and H. A. Muller, *Principles and Applications of Room Acoustics Vol. 1* (Applied Science Publishers, London and New York, 1978)
5. L. N. Miller, *Noise Control for Buildings and Manufacturing Plants* (Bolt Beranek and Newman Inc., 1981)
6. "Issues in Mechanical Draft Cooling Tower Noise," R. W. Jameson, *NOISE-CON 97*, The Pennsylvania State University Park, (1997)
7. "Induced Draft Cooling Tower Noise and Its Control," J.S. Wang, *Cooling Tower Institute Annual Meeting, paper* TP161A, (1977)
8. "Noise Control for Reciprocating and Turbine Engines driven by Natural Gas and Liquid Fuel,", *AGA S20069, Am.* Gas Assn (1969)
9. "Standard Values of Atmospheric Absorption as a Function of Temperature and Humidity," *Society of Automotive Engineers, Aerospace Recommended Practice (ARP)* No. 866A, (1975)
10. "On the Attenuation of Sound as it Propagates through the Atmosphere," I.A. Dneprovskaya, V.K. Iofe, and F.I Levitas, *Soviet Physics – Acoustics*, Vol. 8, No. 3, (1963)