# INDUSTRIAL BUILDING ABSORPTION COEFFICIENT – POWER PLANT CASE STUDY

**Galen Wong[1] and Ji Cao[2]**

[1]ATCO Structures and Logistics, 100 – 170 Laurier Ave West, Ottawa, Ontario KIP 5V5, galen.wong@atcosl.com

[2]ATCO Structures and Logistics, 1243 McKnight Blvd NE, Calgary T2E 5T1, jason.cao@atcosl.com

## 1. INTRODUCTION

Building interior noise levels have been a growing concern for many industrial projects as it directly relates to worker occupational noise exposure levels. Generally, a continuous noise exposure level of 85 dBA over an 8-hour work shift is the provincial or territorial regulatory limit in Canada (CCOHS, 2011), and many companies are now working to meet that limit in their new projects. This evaluation of the interior noise levels during the project planning stage can help to identify potential noise exposure levels for future staff, and noise mitigation can be integrated into the plant design, thus avoiding more expensive future retrofit and replacement costs in trying to meet the noise exposure limits retroactively.

In the acoustical measurement and modeling of existing building interior noise levels, large differences were found between the model and measurement results. It was found that the absorption coefficient specifications for the building interior surfaces did not match those of the lab-tested specifications for those materials.

## 2. INDUSTRIAL BUILDINGS

Typical industrial buildings are constructed with a solid metal inner liner for the walls and roof, and a concrete floor, which are all acoustically reflective surfaces. With several noise sources in the room (also consisting of metal surfaces), a highly acoustically reverberant field exists. For a simple steady-state point noise source, the sound pressure level, $L_p$, in the room can be calculated via the room equation which is based on Sabine/Eyring diffuse field theories, $L_p = L_w + 10\log[(Q/4\pi r^2) + (4/R)]$ (Beranek, 1988), where $L_w$ is the source sound power level, Q is the directivity of the source, r is the distance from the source to the receptor, and R is the room constant, $R = S\alpha/(1-\alpha)$, where S is the surface area of the room and all interior objects and $\alpha$ is the area averaged absorption coefficient of the room. While the room equation allows calculation of the $L_p$ in a simple room, for more complex geometry rooms with many obstructions, complex sound sources, and absorptive surfaces which are not evenly distributed throughout the room, a computer model of the building can help to more accurately determine the noise levels within the building.

## 3. STUDY AREA

The power plant consists of six diesel engine gensets in the building. Four engines are normally in operation, with two engines as backup units. The gensets were housed in a metal building consisting of a 4” insulated wall with a solid corrugated inner liner. The roof interior panel also consisted of solid corrugated inner liner and the floor was concrete. The building dimensions were 49 m L x 35 m W x 20 m H peak, with the eave height at 18 m. In the building the six gensets were situated parallel to each other, along the centre length of the room, with six large heat recovery unit tanks situated at the exhaust end. A maintenance shop, control room and electrical room lined one length of the building, with a mezzanine floor above, containing six make-up air units. Figure 1 shows the building layout as modeled.

Significant noise sources associated with the equipment in the room included the engine air inlets and engine casing breakout. Other less significant noise sources included the engine exhaust piping and heat exchangers, the make-up air units, glycol and water pumps and other ancillary equipment in the room.

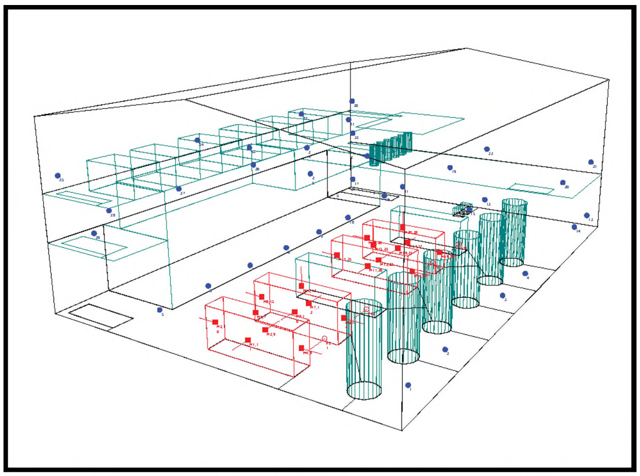

**Figure 1. Odeon 3D Model of the Power Plant**

## 4. ACOUSTIC MODEL

Odeon 10 Industrial, a ray-tracing program for room acoustical modeling, was used in this study of a power plant building. The model employs a combination of image-source, ray-tracing and ray radiosity methods to calculate the sound levels in a room (Christensen, 2009). Reflections are taken into account based on the room and obstacle geometry and the scattering and absorption coefficients. Source noise levels are input either as line, point or area sources.

Nearfield $L_p$ measurements of four of the diesel gensets were taken at the plant for the purposes of determining their $L_w$ (as per ISO 3744) for input to the model, with appropriate corrections made for the reverberant noise in the room. Thirty-five $L_p$ measurements throughout the facility were taken to be used in verifying the model results.

## 5. RESULTS

$L_p$ throughout the building ranged from 96 dBA far from the gensets, to 105 dBA at 1m from the genset engine casing. The average sound pressure level in the open areas of the building was 100 dBA.

The initial Odeon model was completed with the input of lab-tested absorption coefficients for the room materials (Bies, 2003). These absorption coefficients are listed in Table 1 below.

**Table 1. Initial Surface Absorption Coefficients**

| Surface | Octave Band Centre Frequency [Hz] | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 63 | 125 | 250 | 500 | 1k | 2k | 4k | 8k |
| Concrete Floor | 0.01 | 0.01 | 0.01 | 0.02 | 0.02 | 0.02 | 0.05 | 0.05 |
| Equipment, Building Walls | 0.10 | 0.13 | 0.09 | 0.08 | 0.09 | 0.11 | 0.11 | 0.10 |

With the above absorption coefficients, the model predicted significantly higher sound pressure levels within the building - up to 12 dB higher than the measured levels in several octave bands. The average difference per octave band is given in Table 2 below in the row "Initial α".

**Table 2. Differences between Model Results and Measurement Data**

| Average Difference in $L_p$, Model Prediction minus Measurement [dB] | Octave Band Centre Frequency [Hz] | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 63 | 125 | 250 | 500 | 1k | 2k | 4k | 8k |
| Initial α | 12 | 11 | 12 | 12 | 12 | 12 | 11 | 7 |
| Limited α | 11 | 9 | 10 | 10 | 10 | 10 | 10 | 7 |
| Adjusted α | 0.3 | 0.6 | 0.2 | 0.0 | 0.2 | 0.2 | 0.1 | 0.1 |

Odeon recommends limiting the absorption coefficient to between 0.1 and 0.9 (Christensen, 2003) to avoid excessive reflection and absorption in the calculation. Applying these limits to the model, the average difference between the model predicted results and the measured levels are about 10 dB, a slight improvement over the initial model results. The differences with these absorption coefficients per octave band are given in Table 2 under the row "Limited α".

Further adjustments to the absorption coefficient of the room and equipment surfaces were made to determine the appropriate values in order to bring the model results closer to the measured levels. The average difference between the model and measurement have been reduced to less than 1 dB, as shown in Table 2 under the row, "Adjusted α". The adjusted surface absorption coefficients are listed in Table 3 below.

**Table 3. Adjusted Surface Absorption Coefficients**

| Surface | Octave Band Centre Frequency [Hz] | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 63 | 125 | 250 | 500 | 1k | 2k | 4k | 8k |
| All Interior Reflective Surfaces | 0.55 | 0.55 | 0.50 | 0.48 | 0.48 | 0.52 | 0.58 | 0.50 |

## 6. DISCUSSION AND CONCLUSIONS

The modeling results generated by the Odeon software show that the room surface absorption coefficients must be specified much higher than the actual lab-tested levels in order for the model to correlate with the measured sound levels in the building. Surface absorption coefficients in other models of similar facilities with hard surfaces may also need to be adjusted in order to more accurately model the space and determine noise levels.

While simple, moderately absorptive rooms may model well in Odeon, some obstacles and low-absorption rooms may cause problems due to their high reflectivity and very diffuse fields. An expected diffuse sound field created in the model may not be created in actual industrial buildings. Absorption or other noise decay factors may be involved. In such cases, adjustments to lab-tested absorption coefficients may need to be performed in order to more accurately model the room.

In validating the model, more appropriate absorption coefficients have been found to accurately predict the sound pressure levels in the room. Noise mitigation treatment in the form of increased absorption to reduce the reflected noise may not be predicted accurately in the model and care must be taken in order to not underestimate the amount of absorption necessary. Local noise barriers situated around the noisy equipment may be more effective in reducing overall noise levels if the direct and first-order reflected noise are the dominant noise sources.

## REFERENCES


Beranek, L.L. (Ed.), (1988) *Noise and Vibration Control*, Revised Edition, Institute of Noise Control Engineering.

Bies, D.A., Hansen, C.H (2003) *Engineering Noise Control*, Third Edition, Spon Press.

CCOHS Canadian Centre for Occupational Health and Safety (2011) *Noise: Occupational Exposure Limits in Canada*. Retrieved from http://www.ccohs.ca/oshanswers/phys_agents/exposure_can.html

Christensen, C.L. *Odeon Room Acoustic Program Manual Version 10 Industrial, Auditorium and Combined Editions* 2009

ISO 3744:2010 Acoustics -- *Determination of sound power levels and sound energy levels of noise sources using sound pressure -- Engineering methods for an essentially free field over a reflecting plane*