

PREDICTING FAR FIELD SOUND LEVELS OF LARGE INDUSTRIAL NOISE SOURCES USING POINT SOURCE RADIATION MODELS

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INTRODUCTION

Community noise predictions involving industrial facilities begin with sound power levels of the industrial equipment components. The sound power levels are input to far field radiation models that account for atmospheric absorption, ground effects, barrier effects and reflections.

Sound power levels of industrial equipment are largely based on near field sound pressure level measurements that envelope the equipment surfaces. The methods most often specified for determining sound power are ISO 3745 (Precision method), ISO 3744 (Engineering method), and ISO 3746 (Survey method). When dealing with large industrial equipment applications, ISO 3744 and ISO 3746 are typically used because no limitations are placed on the equipment size nor whether the equipment is located inside or outside of buildings. The sound power levels are then used in various prediction models for determining community noise or noise within buildings. In many cases, the sound power levels based on these types of measurements are used to predict environmental noise with point source radiation models. Predicted far field sound levels are often imperfect. Typically, sound levels are over or under predicted by 3 or more decibels. This effect appears even when the source to observer distances are well beyond the minimum distance necessary to be considered in the sound source's far field.

Obtaining good agreement between predictions and far field measurements is imperative when designing optimized noise control features. Predicting far field sound levels significantly higher than those measured when the facility is actually operational not only wastes money spent in the initial noise control features and design, but can also affect the long term efficiency of the equipment when noise control design contributes to larger than necessary pressure drops and other mechanical losses. Under predicting sound levels relative to the actual operational sound levels is even more significant in terms of retrofit design time, cost and frustration of the facility's owner/operator.

Often, industrial facility noise models ignore obvious factors, such as partial screening or reflection of large sound sources, but also ignore directivity effects and the physical source dimensions as well.

This paper addresses these typically ignored effects that are uniquely important to large industrial equipment.

HOW MANY POINTS IS ENOUGH?

Often acoustical analyses are not performed “perfectly.” Many times the engineer or consultant is asked to calculate the noise from an industrial facility at a position closer to the source than a point source model would justify. Various guidelines, such as those provided in ISO 9613 part 2¹, clearly state that a source should be broken up into multiple sub point sources if the calculation distance is ≤ 2 times the largest source dimension. While most engineers and consultants understand the need to break sources up into such multiple semi-sources, time constraints and computer resources can limit their ability to “do it right.” The large size of some industrial equipment might require days of calculation setup times and lengthy processing times. The question too often, is not “how many points do I need to produce an accurate result”, but “how few points can I get away with and still have *an acceptable result.*” To evaluate the effect of using the single point source over simplification, a numerical investigation was performed. A large source was simulated by breaking it down into multiple point-sources distributed on it’s surface. The results of various densities of points representing the surface were then compared to a single point source calculation.

The surface source selected was a wall, 90 meters long x 30 meters high.

Four distributions of point sources were considered:

1. 6x18 grid, 5 meter point spacing
2. 3x9 grid, 10 meter point spacing
3. 3x3 grid, 10 meter vertical spacing, 30 meter horizontal spacing
4. a single point source representing the wall, centered on the surface

The distributed sources used are shown below in figure 1.

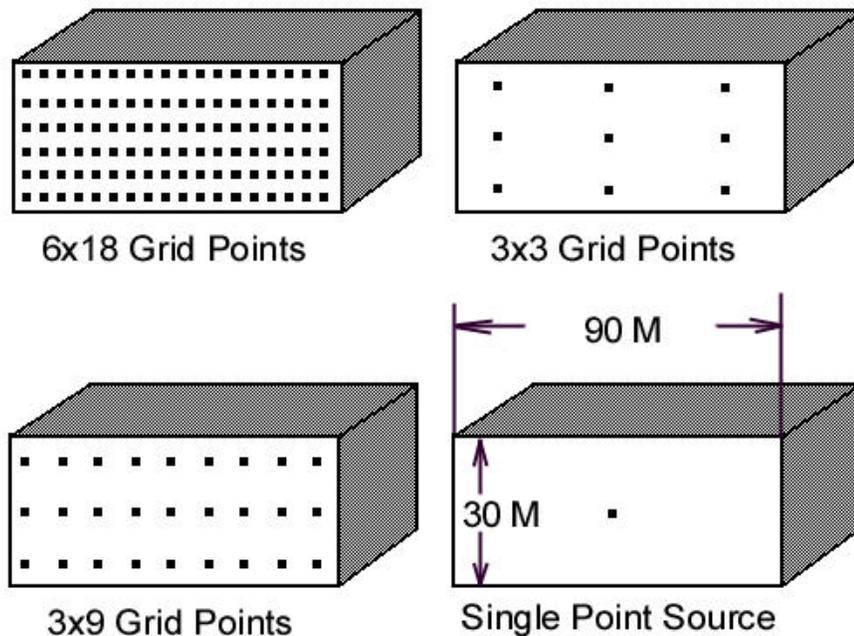


Figure 1. Sound Source Level Distribution

An observer was placed at distances of 10 m, 20 m, 40 m, 80 m, 160 m and 320 m perpendicular to the center of the surface source. The 6x18 grid of points is adequate to define points every five (5) meters. The 10 meter position then meets the criteria of being 2 times the largest source dimension. The 6x18 grid is defined as the norm. Accuracy within one decibel (1 dB) of the accepted norm was considered adequate.

Shown in Figure 2 is the calculated sound pressure level as a function of the perpendicular distance from the center of the source for four different point source distributions.

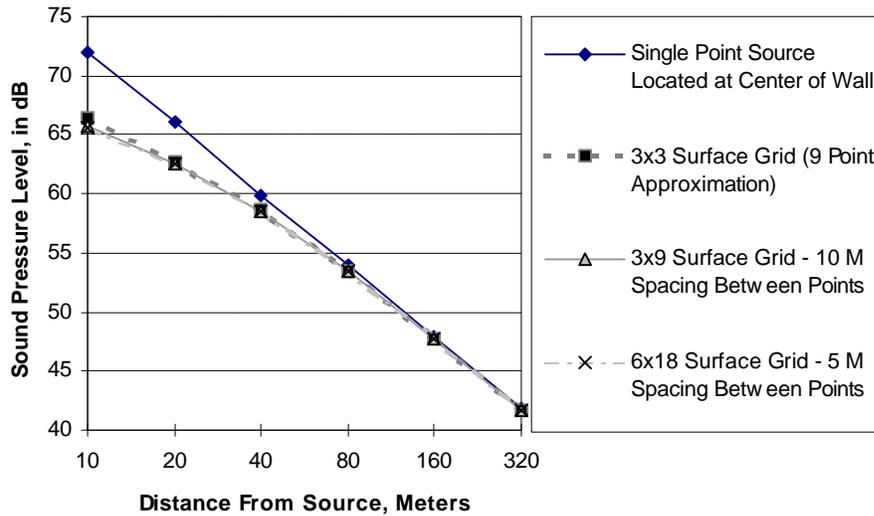


Figure 2. Sound Level As A Function Of Perpendicular Distance From A 90 Meter Long X 30 Meter High Wall ($L_w = 100$ dB)

It is clear that at distances closer than about 160 meters (approximately 1.8 x the largest source dimension) the point source significantly departs from the 6x18 grid norm. However, the simple 3x3 grid approximates the 6x18 grid within 1 dB to distances as near as 10 meters of the source.

Shown in Figure 3 is the calculated sound pressure level as a function of distance parallel to the face of the source for four different point source distributions. Again the 6x18 grid is considered adequate to meet the dimensional criteria. An observer was placed in the plane of the surface source 10 m, 20 m, 40 m, 80 m, 160 m and 320 m from the source's edge. Again, accuracy within one decibel (1 dB) of the accepted norm was considered adequate.

While figure 3 shows the single point diverges from the norm at distances closer than about 80 meters, a simple 3x3 grid is shown to approximate the 6x18 grid quite closely (within 1 dB) to distances as near as 10 meters of the source's edge. It appears that an accuracy of ± 1 dB can be obtained with a simple 3x3 surface grid to distances as close as $1/9$ the source's largest physical dimension. This is consistent with Rathe's findings showing planar sound sources can be approximated as *single point sources* at distances as close as L/p , where "L" is the largest planar source dimension. With the largest dimension cut to $L/3$ (3x3 grid), the closest distance the source can adequately be approximated is: $L/3p$ ($\cong L/9.42$).

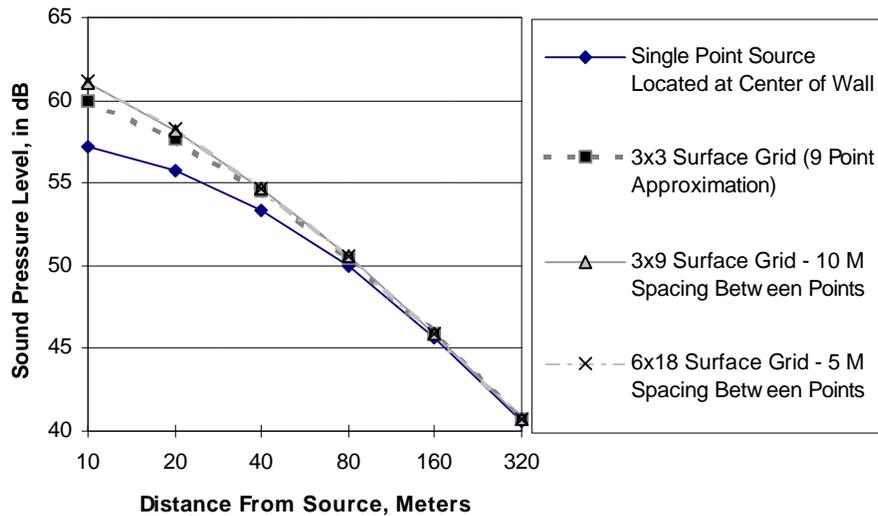


Figure 3. Sound Level As A Function Of Parallel Distance From A 90 Meter Long X 30 Meter High Wall ($L_w = 100$ dB)

DIRECTIVITY EFFECTS

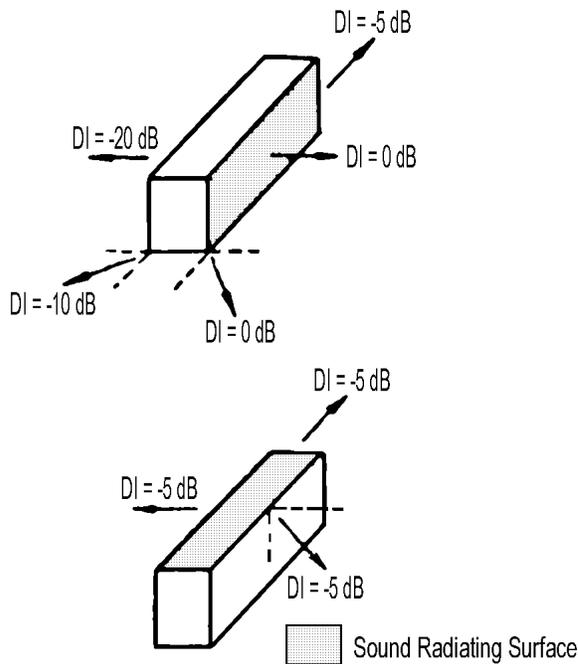


Figure 4. Directivity Indices of Sound Sources Located on Building Walls

The large size of some industrial equipment enclosures can justify modeling them as “buildings.” A typical gas turbine enclosure can be 13 meters long, 8 meters wide and 6 meters tall. This is more of a building than an “enclosure.” However, many far field noise calculations ignore the size implications and model this “building” as a point source radiating from the center of the enclosure. The point source modeling not only introduces the uncertainty associated with partial barrier and reflective effects, but many times the directivity effect is also ignored.

The directivity indices (DI) of sound sources radiating from building facades and roofs has been generalized in Beranek and Ver² to be that shown in figure 4. No limitations are provided in terms of frequency or building size. The text does state that the DI values do incorporate the effect of shielding from the building itself but not the impact of the solid angle effect of the nearby surface. Assuming the majority of the indices are

dominated by shielding effects, the user would expect significant frequency dependence. The generalization does not leave the user with a strong feeling of confidence that his calculations will be accurate. In addition, as the building dimensions become comparable to the wavelengths of the sound source, the building's ability to provide shielding diminishes. No guidance is provided for determining the appropriateness of these simplified indices.

To estimate the impact of the actual size of a building, a computer simulation was designed to model surface sources on one wall of a typical building. The sources were located approximately 2 centimeters off the physical front wall surface. Each of the four building walls was modeled as a barrier. The barrier attenuation (including multiple barriers) was modeled in accordance with ISO 9613 part 2. All observer directions were located 200 meters from the geometric center of the wall surface modeled.

Two building sizes were evaluated:

1. A 90 meter long by 45 meter wide by 30 meter tall building. One 90 m x 30 m wall surface was modeled as the noise source.
2. A 12 meter long by 4 meter wide by 4 meter tall building. One 12 m x 4 m wall surface was modeled as the noise source.

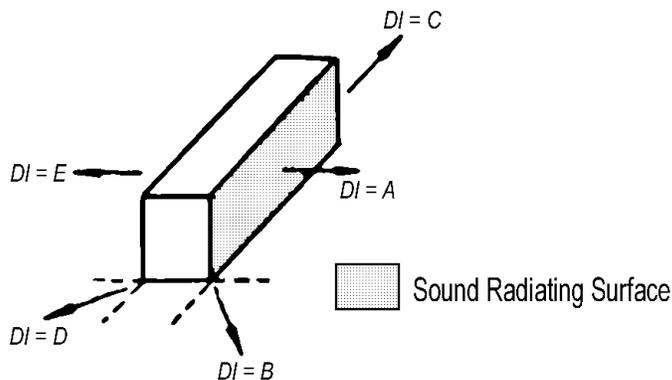


Figure 5. Directivity Reference

indices are significant once the line of sight is broken to the source. It can be seen that the large dimensions of the building shown in table 1 provides some sound level reduction even at 31.5 Hz while estimates of the smaller building, shown in table 2, would provide much less or no low frequency reduction. As the building or enclosure approaches negligible size, the directivity indices would approach 0 dB in all directions.

Shown in figure 5 is the directional frame of reference used in the data presentation. The results of the calculations performed for a large 90 m x 30 m surface are shown in Table 1 and the results of the smaller 12 m x 4 m surface are shown in Table 2. Modeled in this fashion, it is clear that significant frequency dependency is observed.

While directivity indices off the front surface (directions A and B) are similar to the indices presented in Beranek, the other directions depart from the generalization rapidly. Directivity

Table 1. Estimated DI, in dB, of a 90 meter long x 45 meter wide x 30 meter tall building.

	Octave Band Center Frequency, Hertz								
	31.5	63	125	250	500	1000	2000	4000	8000
(One 90 m x 30 m horizontal wall is radiating the noise)									
DI = A	0	0	0	0	0	0	0	0	0
DI = B	0	0	0	0	0	0	0	0	0
DI = C	-7	-10	-15	-21	-25	-25	-25	-25	-25
DI = D	-7	-11	-17	-22	-25	-25	-25	-25	-25
DI = E	-8	-12	-18	-23	-25	-25	-25	-25	-25

Table 2. Estimated DI, in dB, of a 12 meter long x 4 meter wide x 4 meter tall building wall

	Octave Band Center Frequency, Hertz								
	31.5	63	125	250	500	1000	2000	4000	8000
(One 12 m x 4 m horizontal wall is radiating the noise)									
DI = A	0	0	0	0	0	0	0	0	0
DI = B	0	0	0	0	0	0	0	0	0
DI = C	0	0	-1	-2	-3	-4	-4	-4	-4
DI = D	0	-6	-8	-13	-19	-24	-25	-25	-25
DI = E	0	-6	-8	-13	-19	-24	-25	-25	-25

SUMMARY

The sound level of large industrial equipment can be adequately modeled by breaking the sound power level down into many small sub-sources radiating from the surface of the equipment. A surface represented by a course 3x3 grid of point sources appears to produce a reasonable representation (± 1 dB) of a surface source at distances as close as $1/9$ the source's largest physical dimension. This is consistent with Rathe's findings showing planar sound sources can be approximated as single point sources at distances as close as L/p , where "L" is the largest planar source dimension. With the largest dimension cut to $L/3$ (3x3 grid), the closest distance the source can adequately be approximated is: $L/3p @ L/9.42$.

The effects of the sound source acting as a partial barrier to itself should be considered when modeling large noise sources, such as enclosures or buildings.

REFERENCES

- 1.) ISO 9613-2:1996(E), *Acoustics - Attenuation of Sound During Propagation Outdoors*.
- 2.) L.L. Beranek and I. Ver, *Noise and Vibration Control Engineering*, (John Wiley, 1992), p117
- 3.) E. J. Rathe, *Note on Two Common Problems of Sound Propagation*, J. Sound and Vibration, 10(3), 472-476 (1969)



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