NEWPORT BEACH, CALIFORNIA
NOISE-CON 2000
2000 DECEMBER 03-05

USING A PREDICTION MODEL TO ALLOCATE ALLOWABLE NOISE BETWEEN SOURCES AND ESTABLISH EQUIPMENT NOISE LIMITS

David J. Parzych, PE, INCE.Bd.Cert
Power Acoustics, Inc.
12472 Lake Underhill Rd. #302
Orlando, FL 32828

INTRODUCTION

Power generation facilities typically require customized noise abatement features to achieve various local and state noise regulations. Differing equipment or equipment arrangements, size and placement of equipment on the plant owner's property, and location within a community can all affect the amount of noise control necessary for a given facility. Selecting the correct amount of silencing for each piece of plant equipment is essential when optimizing for reduced cost of the overall noise control treatments. To achieve the overall plant noise goals, an analytical noise prediction model of the facility is developed and exercised with various equipment options until the desired criteria or goal is achieved.

This paper describes methods of using a noise prediction model to allocate noise "budgets" among sources, and using the model to establish noise criteria. The discussion addresses the overall effects of starting with poorly defined data, as well as imprecise or erroneous noise source data supplied by equipment manufacturers. Estimating reasonable and achievable noise goals for the equipment is also addressed.

UNDERSTANDING THE BASICS OF ENVIRONMENTAL NOISE MODELING

The details of physically setting up a complex computerized environmental acoustical model are beyond the scope of this paper. Nonetheless, it is essential to establish the basics to understand the allocation process of setting equipment limits. Setting up a noise model consists of the following steps:

1.) Determine the facility noise criteria based on state regulations, local ordinances or "quality of life" standards such as the US EPA guidelines, at property lines or critical receiver positions.

2.) Define the spatial relationships of the observers and noise sources (x,y,z coordinates) to be modeled.
3.) Define sound barriers, obstacles and sound reflectors within the model's spatial representation.
4.) Develop reasonable sound power levels of the equipment being modeled based on manufacturers data, empirical databases or with prediction methods.
5.) Assign the appropriate sound power levels to the spatial position of the modeled equipment sound sources.
6.) Exercise the acoustical prediction software model to determine the sound pressure levels at the receptor locations.
7.) Modify the sound power level data and/or define additional sound barriers (steps 3 & 4) until the desired sound pressure level is achieved.

Shown in Figure 1 is a representation of a combined cycle gas turbine facility spatially defined with observers located along property boundaries. Care should be given to assure the equipment is spatially located where the engineer expects. A stray minus sign in the x,y plane can put equipment or receivers several hundred feet from their actual locations. The acoustical engineer or consultant should use all available graphical capability of his computer model to assure the equipment is correctly spatially defined.

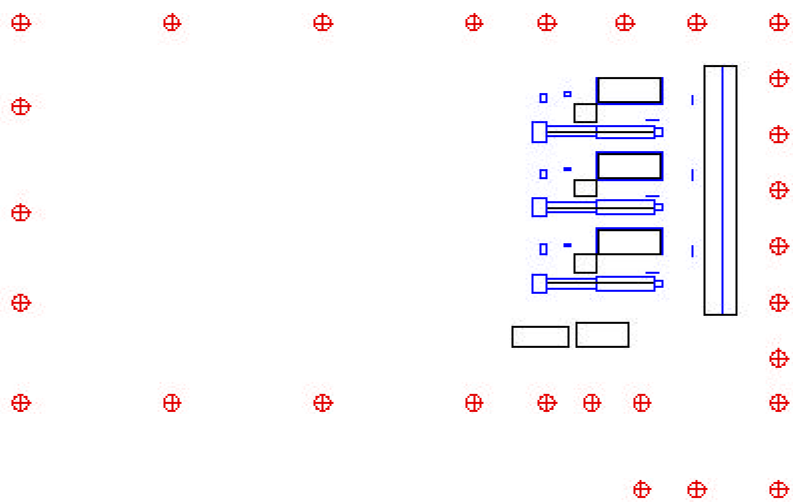

Figure 1. ***Spatial Representation of Observers and Combined Cycle Power Plant Equipment***

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. A single point source model can introduce uncertainty associated with partial barrier and reflective effects of large equipment and does not adequately distribute the sound over the actual large surface. Various references[1,2,3] exist to help define appropriate spatial relationships of equipment as well as to determine how many point sources are necessary to define a reasonable representation of large power generation equipment.

ALLOCATING NOISE TO EQUIPMENT

The allocation of allowable noise to equipment components is straight forward; determine the allowable sound level of the facility, then ration a portion of that sound to each of the individual sources of noise. Computerized environmental acoustic models exist to "add up" the equipment's individual sound contribution and determine the overall noise of the facility at any given location. The computerization of this task provides the appearance that the acoustical engineer's or designer's job is trivial. However, it is often overlooked that the task of designing the facility's noise control is not just making the numbers add up, but in determining a reasonable requirement for the particular equipment and what combination of treatments will produce the minimized cost of the facility's overall noise abatement. A good acoustical designer can significantly reduce the overall cost of the facility, while also increasing the likelihood the facility will actually achieve it's desired noise goals.

Several methods can be used to allocate noise. The typical approach is exercising a computer method to determine if a facility utilizing standard noise control achieves the desired level at the critical locations. If the criteria are achieved with standard equipment, the acoustical design is complete. This first step requires the use of sound power or pressure level data from the acoustical engineer's database or data supplied by the facility's developer reflecting the vendor's estimates or guarantees of the equipment the developer has purchased. If the facility doesn't achieve the noise goals, what's next?

The simplest, but not optimum, way of determining equipment requirements is to find the deficiency between the desired sound level and the sound level resulting from the sum of the standard equipment. This difference can then be applied as a delta to all of the facility's equipment. As an example, the combined cycle gas turbine facility shown in Figure 1 can be assumed to have a criteria equal to a maximum of 65 dB(A) at the property line. If the facility with all standard noise control misses the required sound level by "x" dB(A), then all the equipment could be specified to be "x" dB(A) quieter than what the standard equipment yields. This approach, however, needlessly places a burden on some equipment to be over designed while also creating the possibility that an unrealistic and unobtainable requirement is placed on other equipment.

Table 1 presents a typical breakdown of component contributions at the maximum receiver location found on the eastern property line of the sample facility shown in Figure 1. The total of all sources is provided first and the individual contributions of each source are sorted according to it's A-weighted sound level. The first source in the list has the largest impact or contribution to the overall sound of the facility, while the last has the least impact to the overall sound at that particular location.

Table 1. Component Sound Pressure Levels of a Facility Sorted by A-Weighted Contribution

	Octave Band Center Frequency, Hertz										
	31.5	**63**	**125**	**250**	**500**	**1000**	**2000**	**4000**	**8000**	**dB(A)**	**dB(C)**
Total of Sources	**78.6**	**82.8**	**81.2**	**75.5**	**66.7**	**64.8**	**63.6**	**61.8**	**61.1**	**73**	**85.7**
Cooling Tower Waterfall	41.4	50.5	51.9	50.9	53.8	59.7	58.4	60.4	60.7	66.3	65.7
Stack Exit #2	69.9	74.9	73.9	68.8	56.7	53.5	40.1	29.5	17.5	63.5	77.9
Stack Exit #3	69.1	74.1	73.1	68	55.9	52.7	39.3	28.5	15.9	62.7	77.1
HRSG Walls #2	71.3	76.2	74.2	67.1	53.1	50.3	42.9	24.1	0.2	62.4	78.6
Stack Exit # 1	68.1	73.1	72.1	67	54.8	51.6	38.1	27.2	13.7	61.7	76.1
Turbine Enclosure #2	62.6	63.5	61.6	57.7	55.4	53.8	57.4	51.1	35.8	61.5	67.8
HRSG Walls #3	68.8	74.4	73.1	66.3	52.2	49	41.4	22.4	0	61.4	77.1
Cooling Tower Fans	71.2	70.2	66.4	61.4	60.3	47.2	46	48	48.6	60.5	73.5
HRSG Walls #1	69.2	74.4	72.3	65.2	51	47.8	40.2	21.1	0	60.4	76.7
Boiler Feed Pumps #2	46.5	46.5	46.5	46.4	50.7	53.5	53.9	47.8	37.1	58.3	58.9
Turbine Enclosure #3	53.4	54	55.7	55.3	53.8	50.5	52.8	46.1	30.2	57.6	62
Transformer (365MVA) #2	51.1	51.6	53.2	55.9	57.3	51.1	45.3	37.3	18.8	57	61.7
Boiler Feed Pumps #3	45.2	45.2	45.2	45.1	48.8	51.5	51	45	34.1	55.9	56.7
Boiler Feed Pumps #1	44.8	44.8	44.9	44.8	48	50.8	50.3	44.3	33.3	55.2	56.1
Circ Water Pumps #2	51.5	45.1	50.1	52	49.5	49.3	49.1	41.8	34.3	54.5	57.9
Circ Water Pumps #1	49.8	44.4	49.4	52.1	49	48.8	48.4	40.8	32	53.9	57.4
Circ Water Pumps #3	48.2	41.2	46.2	49.9	46.8	46.6	46.2	38.4	28.9	51.7	55.1
Turbine Enclosure #1	51	49.5	44.5	37.3	33.5	44	46.9	39.7	21.4	50.1	54
Transformer (365MVA) #1	41	44.3	42.6	49.4	49	42.6	36.8	28.5	9.3	48.9	53.7
Steam Turbine Building #1	60.2	59.9	54	45	38.9	29.7	24	18.6	8.5	42.7	62.1
Steam Turbine Building #2	59.9	59.9	53.7	43.3	37.1	27.9	22.2	16.5	5.1	41.7	61.9
Transformer (365MVA) #3	44.5	49.2	49.8	42.9	40.6	32.1	24.1	14.5	0	41.2	53.2
Steam Turbine Building #3	57.1	57.8	50.8	39.4	31.6	20.6	13.2	7.6	0	38.3	59.4
Inlet Filter #2	48.7	52.6	45.5	41	32.6	25.1	22.7	28.6	12.5	37.4	53.8
Inlet Filter #3	40.4	43.1	33.9	27.4	29.8	21.4	16.5	21.3	4	30.2	44.2
Inlet Filter #1	40	42.4	32.9	24.9	13.9	2.8	0	0	0	21.9	43.4
15 MVA Transformer #2	10.6	1.7	0	0	0	0	0	3.5	0	5.1	10.3
15 MVA Transformer # 1	11.1	2.8	11.4	5.4	0	0	0	0.5	0	3.9	14.1
15 MVA Transformer #3	8.8	0	0	0	0	0	0	0	0	0	7.5

It can be seen that the individual contributions of the sources vary greatly. While applying a constant noise reduction of 8 dB(A) to each piece of equipment would allow the 65 dB(A) criteria to be achieved, forcing additional noise control to be applied to sources 20 dB(A) or more below the criteria is unnecessary and costly.

A better approach is to treat only the noisiest equipment or equipment who's sound pressure level contribution at a particular observer location is the greatest. Available computer environmental sound propagation models generally enable the user to sort data according to sound level effortlessly. The sorted data provided in Table 1 shows at a glance that the cooling tower waterfall noise alone causes the 65 dB(A) criteria to be exceed. The sound radiated from the exhaust stack exits, and HRSG walls are also shown to be at or near the required sound level limit.

Focusing only on equipment whose sound level contributes the most assures that smaller, quieter equipment are not needlessly fitted with additional noise abatement that can escalate the cost of the given facility.

DEFINING RESONABLE SOUND LEVEL REQUIREMENTS

Too often sound level criteria of equipment are arbitrarily selected based on what's necessary to make the acoustical model work and not necessarily to reflect currently available technology or practical noise controls. Allocation should start with the application of available treatments to the major noise sources. For instance, if cooling tower waterfall noise is a major source, noise reduction from waterfall attenuators should be applied in the model. Cooling tower fan noise can be controlled with low speed, low noise fans. Sound from HRSG walls can be controlled with thicker outer steel plate and inlet shrouds. Sound from exhaust stack exits can be reduced with mufflers or silencers. Acoustical consultants and engineers who have design experience in these areas can estimate the effects of such treatments. Alternatively, the consultant can exercise knowledgeable equipment vendors to supply the associated noise reduction of various available treatments. This approach will assure the selected design will likely be attainable.

In cases where the sound level produced is similar in two or more different pieces of equipment (cooling tower and HRSG for instance), yet attenuation of just one would produce the desired sound level, the noise abatement producing the lowest cost should be selected.

When vendor supplied noise treatments have been evaluated and exhausted, additional treatments such as barrier walls, secondary sound enclosures and buildings can be explored.

STARTING WITH POORLY DEFINED OR INCORRECT DATA

Even with today's noise awareness, many vendors will still claim their equipment "doesn't make any noise". For most applications, however, vendors and manufacturers of the major equipment (Gas Turbines, Heat Recovery Steam Generators (HRSG) and Cooling Towers) can estimate A-weighted sound levels at various distances. On the other hand, obtaining good quality octave band sound pressure or power level ***spectra*** is a questionable matter on many noise sources. Without good quality equipment octave band spectrum data, designing effective barrier walls, enclosures or mufflers becomes more luck than science.

Many vendors have stepped up to providing the data necessary to do an adequate noise model. These vendors can provide data on a guaranteed or estimated basis.

Vendors guaranteeing their design may add substantial margin to his best data or calculations. The margin is typically 3 dB or more depending on how the guarantee is written. In cases where the guarantee is "as measured" at a particular distance, say 400 feet, the vendor must also allow for worst case mounting of his component and any associated uncertainty of directivity effects caused by the mounting. For instance, if a vendor assumed his component may be mounted at the intersection of two building walls, he may add a directivity factor correction of 5 dB to his estimated free field data. This coupled with the margin can provide for sound levels given by the vendor 8 dB higher than what he really expects of his actual equipment. An unknowing or overly conservative acoustical designer may use this data, then provide redundant corrections for directivity effects and include his own 3 dB margin. The resulting design can be 11 dB more stringent than what the actual expected sound level of the component may be! This overall "margin" may not be even recognized by acoustic designer if the data's basis was not clearly defined by the vendor. Experience has shown that it is unlikely equipment vendors will disclose "the truth" since the commercial implications of disclosure could involve increased risk and reduced overall profit from additional noise control features.

In cases where the sound levels provided by the vendor are "estimated", it is not always clear that the basis of the data is sound. Some vendors, not all, supply acoustic data based on measurements with conditions less than optimum, or on calculations that do not represent the physics of the noise sources. Data taken of equipment within highly reverberant, noisy manufacturing areas, or from equipment operated or loaded differently than what would be expected in it's actual field installed application is not beneficial for any detailed calculation work. Use of this data can, in fact, erroneously cause the designer to believe he needs additional noise control or worse; falsely get a sense of assurance that the equipment will achieve his requirements because the condition it was measured under was not the case where the equipment generates the most noise.

In many cases, an acoustical designer will use overly conservative or margined data and design acoustical treatments such as noise enclosures, barrier walls or various other silencing devices. These additional treatments unnecessarily add to cost of the overall acoustical package.

SUMMARY

Addressed in this paper were techniques of using a sound propagation model to allocate noise between sources. A fundamental technique of assuring an optimum design includes sorting individual noise sources according to their contribution to the overall sound level and applying appropriate controls to only the necessary sound sources. Care should be given to avoid noise control known to be beyond the state of the art, and caution should be exercised to avoid overly conservative results from modeling vendor "guaranteed" sound levels of sources.

REFERENCES

1.) "Predicting Far Field Sound Levels of Large Industrial Noise Sources Using Point Source Radiation Models", D. Parzych, *Internoise 1999 Proceedings*, **vol 3**, 1113-1118

2.) ISO 9613-2:1996(E), *Acoustics - Attenuation of Sound During Propagation Outdoors*.

3.) "Note on Two Common Problems of Sound Propagation", E. J. Rathe, *J. Sound and Vibration*, **10(3),** 472-476 (1969)

The proceeding paper was authored by **Dave Parzych, Principal Acoustical Consultant and Noise Control Consultant of Power Acoustics, Inc.**

For more information on how Power Acoustics, Inc. can help you, contact us at:

12472 Lake Underhill Rd, #302 • Orlando, Florida • 32828
Phone: (407) 381-1439 • Fax: (407) 381-6080
Email: info@poweracoustics.com

To see more about Power Acoustics, Inc. visit our website http://poweracoustics.com or view more technical papers at: http://poweracoustics.com/publications.html