GE Energy

Power Plant

Near-Field Noise Considerations

Authored by:

Charles Powers
Program Manager
Environmental and Acoustic Engineering
GE Energy

Andrew Dicke
Senior Acoustic Engineer
Environmental and Acoustic Engineering
GE Energy

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Foreword

The following document has been prepared for use during discussions of common questions and issues regarding noise in Power Plant applications. Expected readers include GE Customers, GE Partners and internal GE organizations not involved with the subject of noise on a regular basis.

Our intent is to present brief, easily understood explanations and examples, which may be used for clarification of discussion points which may arise during communication with GE Customers and Partners.

The two sections of this document address common subjects, which are frequently discussed during these communications:

Section I – Power Generation Equipment and Other Factors Concerning the Protection of Power Plant Employees Against Noise

Addresses: Responsibility for compliance to noise-related Health and Safety regulations. The decision by a customer to request a low noise guarantee or a noise guarantee as a maximum value vs. an average value.

Section II – Consideration of Near-Field Noise Contribution in Acoustic Design

Addresses: Questions by Partners and Customers regarding noise contribution issues.

We hope that you find this document informative and helpful during discussions on the subject of Power Plant related noise.

Charles W. Powers
GE Energy

Section I

Power Generation Equipment and Other Factors Concerning the Protection of Power Plant Employees against Noise

Introduction

Noise has become an increasingly important subject in the matter of workers' protection and health. Hearing impairment has been identified as one of the major health issues for Power Plant Employees and Owners. Studies indicate that exposure-related hearing loss is caused by exposure to high noise levels over extended periods of time. Hearing loss is therefore associated with both the level and duration of the noise to which an individual is exposed. Exposure-related hearing loss can also be caused by exposure to extremely loud impulse type noises.

To address this concern, Health and Safety Agencies in many parts of the world have developed noise exposure limits for Power Plant Employees.Typically these Agencies have established lower (trigger) levels and upper average exposure limits, along with peak noise limitations. The lower level typically "triggers" specific actions, which must be taken by the Power Plant Owner. The lower (trigger) and upper exposure limit values are usually the average level of noise a worker is exposed to for an eight (8) hour time period. For the protection of Power Plant Employees, Power Plant Owners must take specific actions when the Employees' exposure to noise has reached these levels. *It should be noted that these regulations do not specify a limit on the noise level of equipment. The regulation is on the level of noise a Power Plant Employee may be exposed to, over a specific period of time.*

In response to these requirements, Power Plant Owners are specifying lower limits for noise levels from the power generation equipment they are purchasing. In many cases, the noise levels that are specified by the Power Plant Owners are at or below the lower threshold for action established by the Health and Safety Agency, and/or are specified as maximum allowable levels.

While ensuring that the respective limits will be met, these noise level requirements are typically more restrictive than required to comply with the specified exposure limits, and impose considerable unnecessary costs to the Power Plant Owners.

The purpose of this paper is to discuss the intent of these requirements and explore the various methods that can be used to ensure the health and safety of the Employee, while controlling the cost impact on the Power Plant Owners.

Before discussion of this topic begins, it must be clearly understood by all parties, that responsibility for compliance with these Health and Safety requirements rests with the Power Plant Owner, and to a lesser extent, with the Power Plant Employee.

Discussion

Noise exposure limits typically include two noise indicators: the daily personal exposure $L_{ex,d}$ and the maximum unweighted instantaneous sound pressure p_{peak} (C weighted).

The following formulas can be used to calculate an Employee's Exposure for an 8-hour period:

$$L_{EX,8h} = L_{Aeq,Te} + 10 \log_{10} \frac{T_e}{T_0}$$

where

$$L_{Aeq,Te} = 10 \log_{10} \left\{ \frac{1}{T_e} \int_0^{T_e} \left[\frac{P_A^{\,2}}{P_0^{\,2}} \right] dt \right\}$$

Te = daily duration of a worker's personal exposure to noise (hr)

T_0 = 8hr

p_0 = 20μPa

P_A = "A"-weighted instantaneous sound pressure in pascals (Pa) to which a person is exposed.

Calculation of a ***daily 8-hour average*** exposure would typically be used for employees who are exposed to a continuous / constant noise level (such as Operators who are in essentially the same location throughout their shift).

However;

In many cases, for employees who are involved in activities where daily noise exposure varies markedly from one working day to the next, Power Plant Owners may, for the purpose of applying the exposure limit values, ***use the weekly noise exposure level in place of the daily noise exposure leve***l to assess the levels of noise to which workers are exposed, on condition that:

a) The weekly noise exposure level, as shown by adequate monitoring, does not exceed an established exposure limit value

- and -

b) Appropriate measures are taken in order to reduce the risk associated with these activities to a minimum

This would typically apply to employees such as Inspectors and Maintenance Personnel, whose responsibilities would normally require them to be in several different areas of the Power Plant in any given time frame.

Local Codes and Regulations vary, and should be reviewed for specific requirements. As an example, the following is a summary of the United States Occupational Safety and Health Administration (OSHA) regulation:

The United States Occupational Safety and Health Administration (OSHA) requires that worker noise exposure not exceed 90 dBA based on an 8 hour time weighted average. If worker noise exposure exceeds this regulatory limit, personal hearing protection is mandatory and exposure must not exceed this level when considering the attenuation provided by the hearing protection. If a worker's exposure exceeds a trigger level of 85 dBA, again based on an 8 hour time weighted average, the employer must implement a hearing conservation program. In addition, exposure to impulsive or impact noise shall not exceed 140 dB peak sound pressure level.

The following Table is copied from the OSHA regulation. As indicated in *Table G-16*, the OSHA regulations do not mandate specific noise limits within a facility. Rather the regulations specify allowable duration of exposure to sound levels.

Table G-16 – Permissible Noise Exposures

Duration per Day, Hours	Sound Level dBA
8	90
6	92
4	95
3	97
2	100
1 1/2	102
1	105
1/2	110
1/4 or less	115

Footnote.[1] When the daily noise exposure is composed of two or more periods of noise exposure of different levels, their combined effect should be considered, rather than the individual effect of each. If the sum of the following fractions: $C_1/T_1 + C_2/T_2 \ldots + C_n/T_n$ exceeds unity, then, the mixed exposure should be considered to exceed the limit value. C_n indicates the total time of exposure at a specified noise level, and T_n indicates the total time of exposure permitted at that level. Exposure to impulsive or impact noise should not exceed 140 dB peak sound pressure level.

Considerations:

The two major factors in limiting exposure are the noise level an individual is exposed to, and the amount of time an individual is exposed to a particular level of noise. Each of these may be controlled in various ways.

Control of the exposure noise level may be achieved by:

1a) Reduction at the source
1b) Use of enclosures, barrier walls, etc.
1c) Use of hearing protection
1d) Designating high noise areas as restricted areas

Control of exposure time may be achieved by:

2a) Monitoring Programs
2b) Varying shifts
2c) Varying job assignments
2d) Avoiding high noise areas

Specification of a maximum allowable level of noise from the source (equipment) takes only two of these control factors into consideration *[1a) Reduction at the source, and 1b) Use of enclosures, barrier walls, etc.]*. These could be the most expensive methods of limiting exposure to noise. The most cost effective approach is a comprehensive noise program, incorporating a combination of the factors listed above.

As indicated earlier, these regulations typically require the implementation of an effective hearing conservation program if exposure levels exceed the lower (trigger) level. Again, to ensure the varying worker exposure levels do not exceed the trigger level, the hearing conservation program is typically initiated if any area in the plant exceeds that level. Within a power facility there will be instances in which a worker is exposed to sound levels in excess of the trigger level. Even if every location in the plant is controlled to a level below the trigger level, there will be times when workers will need to enter the noise control enclosures during facility operation. The workers will be exposed to high noise levels during those periods and hearing protection will need to be worn at those times. The potential for a worker to be exposed to levels above the trigger level will always exist in a power facility. As such, a hearing conservation program will always be necessary and can not be avoided with increased noise mitigation.

Other factors having an impact on average exposure over an 8-hour period include:

a) Power Plant Employee Exposure limits are typically for an average exposure. For example, an individual could be exposed to levels of 82 dBA for 2 hours, 80 dBA for 4 hours and 76 dBA for 2 hours, and still fall under a lower threshold of 80 dBA average for 8 hours.

b) Varying noise levels around complex equipment. Complex equipment designed to meet a specific dBA average noise level will typically have many areas well below that level.

c) Access to areas, which are traditionally “High Noise.” Such access is frequently not permitted during typical Power Plant operation activities for safety reasons.

d) Many areas in a typical plant and on the “turbine island” (including “high noise” areas) require only occasional access, and may be designated as requiring hearing protection for entrance.

e) In most cases, when a maximum exposure limit value has been specified (87dBA, for example), it will take the attenuation provided by individual hearing protection into account when calculating the Employee’s exposure. For example; if the Employee is exposed to a noise level of 90dBA for an eight-hour shift, and is wearing hearing protection that provides 10dBA of attenuation, his/her exposure equals 80dBA for the eight-hour shift, and is well below the exposure limit.

Exposure Thresholds and Required Actions:

The list below shows the relationship between typical exposure thresholds, and the actions that must be taken by the Power Plant Owners at each threshold level.

This comparison of typical required actions at the various Exposure Limits reveals that the differences between actions, which must be taken at the lowest value vs. the highest value, are comparatively small as long as the highest Exposure Limit is not exceeded.

A. When Exposure Action Values are at the lower threshold and above, **Information** and **Training** *are required*.

B. When Exposure Action Values range between the lower and upper thresholds, **Hearing Protection** and **Testing** must be *made available*.

C. When the upper Exposure Action Value is reached, use of **Hearing Protection** is *required*.

Note: It is important to note that in many cases, **Information and Training** is the only *Mandated* action, until the upper Exposure Action Value has been reached.

Average vs. Maximum

When taking the following enumerated factors into consideration, it is logical to conclude that *equipment generating an acceptable average noise level* will enable the Power Plant Owners to ensure that an Employee's exposure does not exceed a permitted *average* 8-hour exposure level:

- In most cases, an employee would not be in one position, within 1 meter of the operating equipment, for an entire 8-hour shift.
- Noise levels around complex equipment vary with location.
- Areas, which are traditionally "High Noise", are frequently access limited.
- Many areas in a typical plant and on the Turbine Island (including "high noise" areas) require only occasional access.

In contrast, a "maximum" noise level specification requires that no noise level, measured in accordance with accepted procedures, may be greater than the level guaranteed. This would include areas that may be inaccessible, and areas that are infrequently occupied.

In view of these facts, there is no significant advantage to be gained from a "maximum" specification.

In addition to the above, a recent internal market study has shown that 80% of the requested equipment guarantees in contracts for Power Plants in European Union countries (where noise regulations are currently most stringent) were average values versus 20% maximum guarantees. This indicates that many Power Plant Owners have reached similar conclusions, and intend to consider all factors when determining the equipment noise levels they will require.

Conclusion

When reviewing Health and Safety requirements regarding noise exposure, there is no specification of the permitted noise levels of power generation equipment. The intent is to limit the exposure of the Employee to noise. As discussed herein, there are two major factors that have a bearing on an individual's average exposure to noise over an 8-hour period (the noise level(s) the Employee is exposed to, and the duration of the exposure). In addition, there are several criteria that influence each of the major factors. The noise level of the power generation equipment is only one of these.

Consideration should also be given to the possibility that mitigation measures required to achieve very low, or maximum, noise levels may have a negative impact on the ability to access certain areas for maintenance purposes, and in some cases may have a negative impact on the performance of the equipment.

Recommendation

An optimum approach to compliance with noise exposure requirements should include a combination of equipment generating an average noise level, and a comprehensive noise exposure management program. This will allow the Power Plant Owner to ensure the health and safety of their employees, while minimizing cost and possible negative impact on maintainability and performance of the equipment.

It is recommended that a thorough analysis be conducted, including all of the factors, variables and considerations presented in this paper, when determining the power generation equipment noise levels that Power Plant Owners will require.

Section II

Considerations of Near-Field Noise Contribution in Acoustic Design

Contribution Considerations

The noise level at any location within a power plant is the combined effect of noise radiated by all sources. Therefore, the noise from each individual source must be less than the overall plant requirement.

In addition, the containment of the sound energy within a building results in a reverberant buildup of noise. The noise reflected from the interior building walls and other surfaces causes an increase in the noise level.

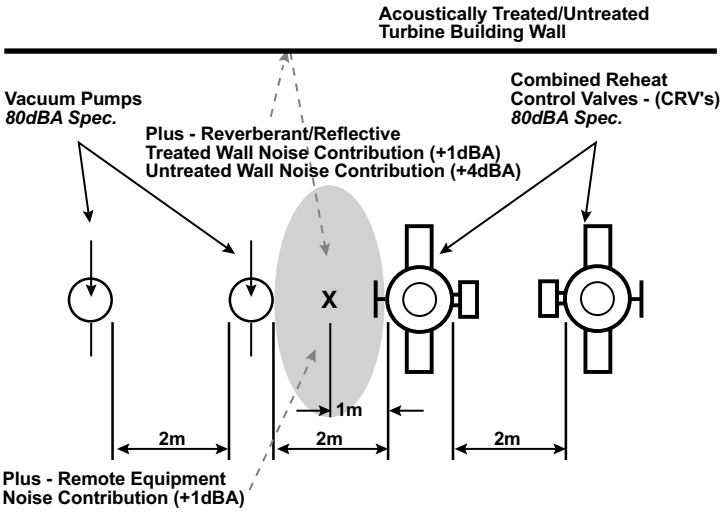
Examples

For example, in order for the entire power plant to satisfy a client-required noise guarantee of 85 dBA, it is necessary for each piece of equipment (including all of GE scope of supply equipment as well as the equipment supplied by others) that may be influenced by one or more of these factors, to radiate less than 85 dBA.

As an example, if the vacuum pump and the combustion turbine are located 2 meters apart, and if the vacuum pump radiates 80 dBA at 1 meter and the combustion turbine radiates 80 dBA at 1 meter, the resulting sound level from the two pieces of equipment is 83 dBA at a location 1 meter from both pieces of equipment (80 dBA + 80 dBA = 83 dBA). In addition, there will be noise from other equipment within the area. A 1 dBA allowance is included to account for the contribution from this other equipment. To account for the reverberant buildup effect of noise within a building with interior walls that are properly treated for acoustics, an additional 1 dBA allowance is also included. Therefore, these two pieces of equipment must be designed to a level of 80 dBA or less for the measured sound levels to meet the client's requirement of 85 dBA.

Note: If the Turbine Building interior walls are untreated, the allowance for reverberant effect should be 4 dBA – 7 dBA, depending on specific conditions.

To minimize the impact of achieving these stringent noise requirements, no design margin is typically included in these design values. The values specified are anticipated to achieve the required sound levels with no additional design margin. The GE-supplied equipment will be designed to the same stringent sound level requirements as the equipment supplied by others. ***See Figure 1 for examples and a representative diagram.***



Shaded Area is 3dBA greater than noise level of 2 equal contributors. If contributor noise level is not equal, use table below. Contribution from Remote Equipment and Reflection/ Reverberation must also be added.

Delta	Add (dBA) to Higher Level
0	3
1	3
2	2
3	2
4	1
5	1
6	1
7	1
8	1
9	1
10+	0

Excerpt from: ISO 11690-2 (1996) Annex B: "Placing 2 equally loud noise sources together increases the total noise level by 3dB."

Figure 1. Near Field Noise Contribution Example

Example A: (Figure 1)

X - Noise Measurement (Designed As Specified to meet 85dBA Guarantee):

Vacuum Pump Noise Emissions	= 80 dBA at 1 meter
CRV Noise Emissions	= 80 dBA at 1 meter
Resulting Sound Level	= 83 dBA at 1 meter
Allowance for Other Equipment	= 1 dBA
Allowance for Reverberation Buildup	= 1 dBA (Treated Building) 4dBA (Untreated)
Measured Sound Level	= 85 dBA (Treated Building) 88dBA (Untreated)

Example B: (Figure 1)

X - Noise Measurement (Designed At Guarantee Level of 85dBA):

Vacuum Pump Noise Emissions	= 85 dBA at 1 meter
CRV Noise Emissions	= 85 dBA at 1 meter
Resulting Sound Level	= 88 dBA at 1 meter
Allowance for Other Equipment	= 1 dBA
Allowance for Reverberation Buildup	= 1 dBA(Treated Building) 4dBA (Untreated)
Measured Sound Level	= 90 dBA(Treated Building) 93dBA (Untreated)

DOES NOT MEET GUARANTEE LEVEL

Example C: (Figure 1)

X - Noise Measurement (With Unequal Contributors, 1 at Spec., 1 at Guarantee):

CRV Noise Emissions	= 80 dBA at 1 meter
Vacuum Pump Noise Emissions	= 85 dBA at 1 meter
Resulting Sound Level	= 86 dBA at 1 meter
Allowance for Other Equipment	= 1 dBA
Allowance for Reverberation Buildup	= 1 dBA(Treated Building) 4dBA (Untreated)
Measured Sound Level	= 88 dBA(Treated Building) 91dBA (Untreated)

DOES NOT MEET GUARANTEE LEVEL