Noise Control Solutions For Standby Power Generators

by David Gries
NVH Applications Engineer
E-A-R
Indianapolis, Indiana

Introduction

Over the past several years, there has been a significant improvement in the range and variety of materials available to meet acoustic, thermal and other gen-set enclosure design requirements. Many of these new material composites provide significantly more integrated, cost-effective solutions to meet or exceed market requirements for acoustic, thermal, water resistance and durability, among other design factors.

In part, this transformation of the toolkit available to the power generation industry for noise and related enclosure design is derived from well-honed engineered solutions to comparable design challenges in other industries. Many innovations in high performance materials for noise control are now available to the power generation industry and in fact have been used in recent years by some of the leading manufacturers of gen-sets.

E-A-R Specialty Composites, which combines a wide variety of solutions for noise, vibration, thermal and comfort with advanced R&D laboratory resources for engineered solutions, has played a leading role in helping power generator manufacturers develop next generation enclosure designs.

In light of recent weather-caused disasters and power instability, power generation units of 25 kW or less are in increasing demand as alternate power sources. The growing popularity of standby generators has coincided with stricter demands for lower environmental impact and physical profiles in ever more powerful units. Community noise ordinances have placed limiting regulations on noise emission from power generators, and the market is asking for more compact units. The end result has been increased demand for smaller quieter units that are nonetheless more powerful, which in turn has created the need for innovative engineered solutions that can outperform traditional, first generation enclosure designs.

E-A-R Specialty Composites has developed a systems approach to engineer noise control solutions that meet the requirements of today's standby power generators. This white paper discusses both the step-by-step approach to develop noise, thermal and other improvements in power gen-set enclosure designs and the materials upon which successful noise control solutions in the power generation industry are based.

Power Generator Noise Sources

The noise spectra for power generators varies widely, but the noise sources are typically the same. Those noise sources are engine noise, engine exhaust, turbulent airflow and blade passage associated with cooling fans, and alternator noise. The noise spectrum of each component is dependent on geometry, output power and load conditions.

Enclosure Design

There are numerous considerations in enclosure design beyond noise levels, such as airflow requirements, exhaust requirements, site requirements and weather protection requirements. This discussion will focus on noise control and other design criteria, such as thermal management, that contribute to the relative success of various noise control solutions.

When developing a new enclosure design, careful consideration should be given to where the noise will radiate from the enclosure. Typically, it is best to minimize enclosure openings and to incorporate torturous paths where openings cannot be avoided.

However, eliminating enclosure openings can be typically detrimental to cooling the generator. This difficulty is exacerbated by recent trends toward smaller profile gen-sets that have resulted in noise control materials being exposed to higher generator temperatures. The resulting heat issues can make thermal management one of the dominant design considerations in the ultimate solution package.

Thus, the typical enclosure design is an optimization of noise control and thermal management. Ideally, it is best to design additional space for noise control materials to be incorporated into the enclosure to preclude any interference with functionality of the power generator. This assists in optimizing the openings in the enclosure to maximize airflow for thermal management while at the same time minimizing openings for better noise control.

Building computer models of generators and making assessments of the unit's noise sources while it is in virtual operation is a good first step in the design process. At this point, well before tooling or component purchasing has begun, noise control engineers can suggest design changes to help sidestep noise and thermal issues or to accommodate whatever treatments may be ultimately required.

While designing an enclosure with noise and thermal management is the ideal situation, it is also common that E-A-R's noise control engineers are asked to engineer noise and thermal solutions after enclosure designs have been established in great detail.

Identify and Quantify Noise

The first step in developing an effective noise control solution for existing enclosure designs is to identify the dominant noise sources and quantify noise levels and noise spectra by collecting baseline data for the particular power generator. From this information, the noise control solution can be tailored to treat the dominant noise sources and address the significant noise transmission paths.

Typical tests involve sound pressure measurements at eight locations, seven meters from the power generator under full load. Test data is critical for identifying which of the components contribute most to the overall sound level. An overall noise level can be calculated based on the eight position average of the sound pressure levels measured. By investigating the unit's noise spectra, problem frequencies can also be identified. Differences in noise measurements gathered at the eight test positions are also examined to identify and rank problem noise sources.

A well-developed test plan and iterative testing is used to quantify the noise attenuation gained by current treatments, if they exist, or to optimize noise solutions. By recognizing the problem noise sources and corresponding spectra, design changes and noise control materials are selected to further optimize the noise control solution.

Noise Control Theory and Materials

Typically there are two main methods for controlling the airborne noise in a power generator: blocking airborne noise via a weighted barrier or absorbing airborne noise via acoustical absorbing insulation.

Weighted Barrier – Power generator equipment manufacturers can achieve significant noise control by lining the generator's sheet metal enclosure with a weighted barrier or a decoupled weighted barrier (composite of barrier over decoupling foam). Ideally, at least 90 percent of the enclosure should be lined. For optimal effect the enclosure openings must be minimized. The limit to barrier effectiveness for enclosures with openings can be seen in Figure 1.

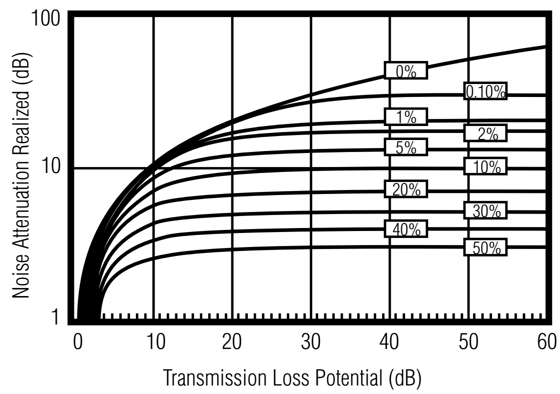

Figure 1: Relationship between transmission loss and realized noise attenuation for barriers as a percent of open area.

The performance of a barrier is quantified by transmission loss or the level of sound blocked. For weighted barriers, it is governed by the Mass Law, which is represented by the equation

$$TL = 20\ Log_{10}\ (SM \times F) - 33.5\ dB$$

Where

- *TL* is transmission loss
- *SM* is total surface mass in pounds per square foot
- *F* is frequency.

Hence, by doubling either the mass of the barrier or the frequency of the sound, a theoretical 6 dB improvement in transmission loss may be realized, essentially doubling the attenuation of sound pressure.

Further improvements in transmission loss can be achieved by adding a decoupler between the weighted barrier and substrate, i.e. enclosure wall. Decoupled barriers typically comprise acoustical foam sandwiched between the inner surface of a power generator enclosure and weighted barrier. The substrate-foam-barrier (double-wall) construction acts like a spring-mass system, in which the composite has increased transmission loss above the resonant frequency or double wall frequency of the composite, as seen in Figure 2.

The thickness of the decoupler layer needed depends on the problem noise frequency. Essentially, a thicker decoupler will result in a lower stiffness. Lower stiffness results in a lower double wall frequency and higher transmission loss in lower frequencies. Decoupler thickness can be adjusted for maximum transmission loss at the unit's problem noise frequencies.

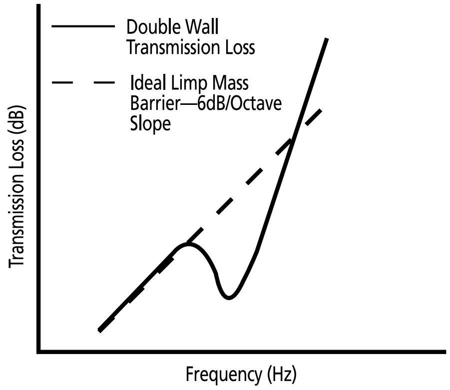

Figure 2: Comparison of sound transmission loss of single- and double-wall barriers

Sound Absorbers – Absorption reduces airborne noise due to mechanical sound energy by converting it into low grade heat energy. As air is pushed into the absorbing material by the sound pressure wave, viscous forces dissipate the mechanical sound energy as heat.

Sound absorbing materials are often characterized by sound absorption coefficient, α, which is a ratio of the sound pressure dissipated by the material to the sound pressure incident on the surface of the absorber.

Most power generation equipment requires several openings in the metal enclosure – for air intake, exhaust and heat release. These openings are generally detrimental to the performance of barriers and decoupled barriers as they can allow noise to escape unhindered. By incorporating acoustical absorbers as a lining for louvers or by creating a torturous path for airflow, noise can be absorbed before it escapes the enclosure.

Typically, sound absorption varies with frequency depending on the geometry and physical make up of the absorber. For instance, increasing the thickness of an absorber increases the absorption at the lower frequencies that are most difficult to control.

Multi-function absorbing foams are available with a variety of protective facings, which help protect the foams from grease and fluids, and enhance the noise control performance at low frequencies. In many gen-set enclosures, aluminized polyester facings can be highly beneficial because they reflect radiant heat, offering excellent solutions for thermal management issues.

Multi-Layer Composites – Multi-layer composites can often provide cost-effective noise control for power generation equipment. Barrier-foam or foam-barrier-foam constructions can both block and absorb the airborne sound. By incorporating multi-layer composites in the noise control solution, one can realize dramatic reductions in a large span of frequencies and do so within relatively limiting space constraints. Often, these are the most cost-effective solutions, as the combination of materials with different properties can result in significant improvements in noise control, while at the same time decreasing the amounts of materials used and reducing installation time.

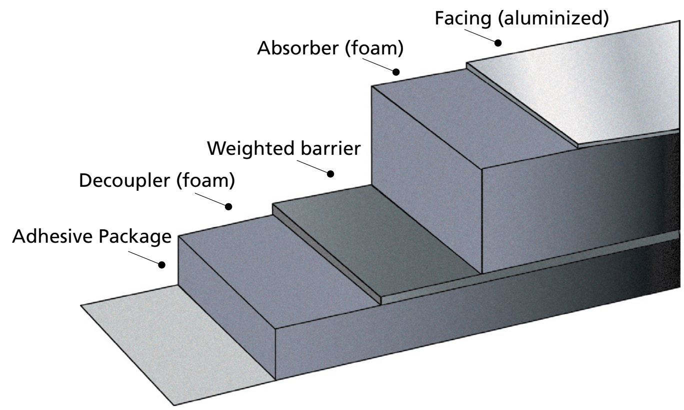

Figure 3: Diagram of a typical composite decoupled barrier and faced absorber

Additional Considerations

Flammability

Flame resistance properties of noise control materials can be important considerations, especially with respect to meeting the UL 2200 requirements for stationary gen sets. To assure compliance, composites of foam and facing should be listed HF-1 to the UL 94 flammability standard. Alternately, on a case-by-case basis, composites should pass the 3/4” flame test per UL 746C standard.

Thermal Management

Reflective facings such as aluminized polyester, allow acoustical foams to help manage radiant heat and potentially function as significant tools in thermal management. Foams with black facings, which are still common in many enclosure designs, can absorb radiant heat, often making thermal management more difficult.

Environmental Considerations

In most gen-set enclosure designs, faced acoustical foams can be used as added protection against rain and moisture, as well as other contaminants. Impervious foam facings can be an improvement over more traditional solutions, and some newer formulations of acoustic foams are also useful for direct water impingement.

Material Durability Considerations

Added durability can be achieved by using facings with reinforcing grid designs that resist puncture propagation during operation or maintenance.

Aluminized facings have the added advantage of providing reflective surfaces that can enhance visibility during gen-set maintenance.

Noise Control Design Examples

Described in the following section are two noise control solutions based on two different power generators. The data presented is typical of power generators with outputs less than 25 kW.

__Example Enclosure 1__

Baseline noise measurements are assumed for a power generator without any acoustical insulation and a metal enclosure of less than 10% of the total surface area open under full load conditions. The spectrum presented in Figure 4 is the eight position average sound pressure levels (SPL) having an overall SPL of 73.5 dBA.

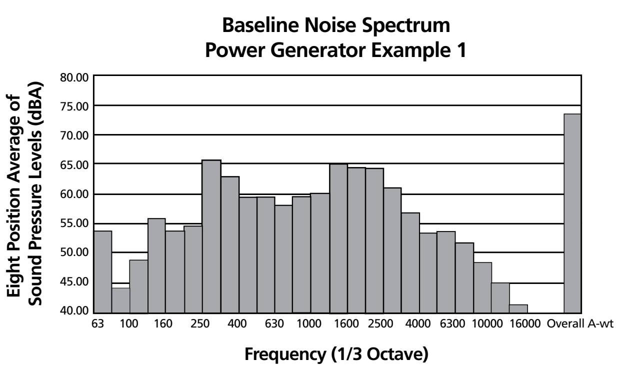

Figure 4: 8 position SPL average for power generator 1 without any acoustical insulation

Driven by market demand, there is a desire to be at or below 68 dBA. At the time of the noise control solution design, the enclosure footprint for the power generator had been established. Fortunately there were few openings in the enclosure (<10%). Unfortunately, limited room had been allotted for acoustical insulation.

From the noise spectrum of the baseline, dominant frequencies were found to be present at 250-315 Hz third Octaves and 1250-2000 Hz third Octaves. By investigating the sources of the noise it was found that the engine and exhaust were the cause of the lower frequency noise. Airflow, fan and alternator noise were the dominant sources of the higher frequency noise.

Due to the limited space inside the generator enclosure and due to the low frequency noise problems, a multi-layer composite decoupled barrier and faced absorbing foam were used. By having a > 1/2″ thick decoupler foam attached to a barrier, attenuation in the lower frequencies was realized given the limited space. Further, by adding a 1/2″ faced acoustical foam on top of the decoupled barrier, additional noise was dissipated. This prevented a buildup of noise inside the enclosure, which would have resulted in increased radiation from the openings. Further, by using aluminized polyester facing on the acoustical foam, the acoustical properties were tuned for lower frequency absorption. Additionally, thermal management and protection of the acoustical insulation at elevated temperatures in close proximity to the engine and muffler were achieved.

To attenuate the higher frequency noise, 1″ faced acoustical foam was used near the fan and air inlets of the enclosure.

By incorporating specific noise control treatments that address the appropriate frequencies, a significant noise reduction was achieved. A reduction from 73.5 dBA to 67.0 dBA was observed, as seen in Figure 5. From the figure, reductions in dominant frequencies were achieved throughout with an added emphasis at high frequencies.

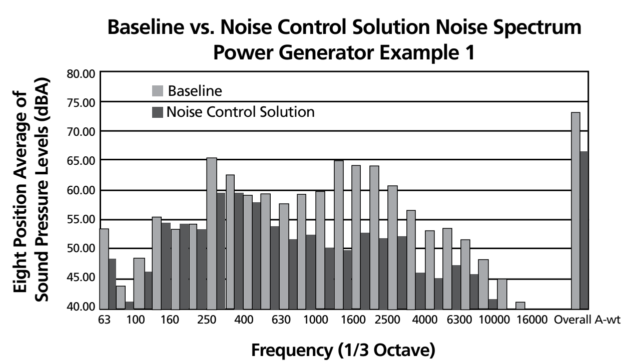

Figure 5: 8 position SPL average for power generator 1 with and without noise control solution

__Example Enclosure 2__

Baseline noise measurements are assumed for a power generator with a metal enclosure of greater than 20% opening under full load conditions without any acoustical insulation. The spectrum presented in Figure 6 is the eight position average sound pressure levels having an overall SPL of 78.1 dBA.

Driven by noise regulations, there is a desire for the overall SPL average to be 75 dBA or below. As in Example Enclosure 1, the enclosure for the power generator had been established prior to the noise control solution design.

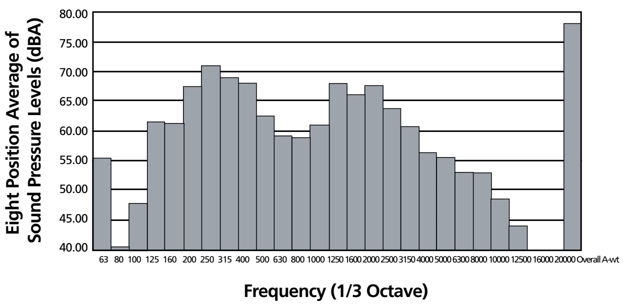

Figure 6: 8 position SPL average for power generator 2 without any acoustical insulation

Due to the large percentage of open area in the enclosure, it was found that using a weighted barrier alone did not reduce the overall SPL of the unit. Consequently, faced acoustical absorbing foams were selected in 1" and 2" thicknesses. In this example, the low problem frequencies were addressed by using increased thicknesses of acoustical foams, as well as selecting faced constructions tuned for low frequency absorption. As in Example Enclosure 1, concerns of heat were addressed by implementing faced foam with aluminized polyester facing to act as a heat shield in select locations of the enclosure. In addition, two inches of rigid large, closed cell polyethylene acoustical foam material was applied to line end-cap baffles.

By incorporating the noise control solution based on spectrum and enclosure geometry, a noise reduction from 78.1 dBA to 73.9 dBA was achieved, as seen in Figure 7.

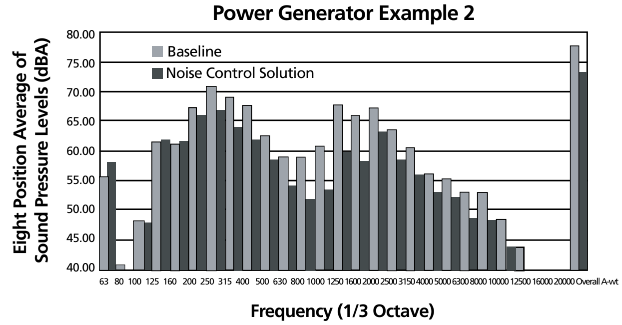

Figure 7: 8 position SPL average for power generator 2 with and without noise control solution

Conclusion

Proper engineering and design of gen-set enclosures and proper application of a variety of well-selected materials is critical to optimizing sound attenuation properties in power generation equipment. New materials can often achieve superior results yet be more cost-effective by decreasing the number of components needed to comply with industry standards and meet market demands for more powerful units with smaller profiles.

Materials Selection

In recent years, a wide range of elastomer innovations has been created that can be utilized in designing next generation gen-set enclosures. These materials must meet multiple design objectives including noise frequencies, operating temperature range and operating environment including thermal management, contaminant resistance and maintenance considerations.

Most standby generator enclosures can incorporate the following types of materials for best results and often with cost and performance improvements as compared to more traditional solutions:

- Faced acoustical foams in thicknesses ranging from 1/4″ to 2″ and with numerous facings, including reflective and reinforced facings

- Flexible non-lead barriers in weights ranging from 1/4″ lb/ft^2 to 2 lb/ft^2

- Decoupled barrier composites and barrier/absorber composites in a range of barrier weights, decoupler thicknesses and absorption layer thicknesses faced with numerous films

- Damping composites comprising a damping layer to manage structureborne vibration combined with acoustical foam layers to absorb airborne noise

E·A·R™

Aearo Technologies • a 3M company

7911 Zionsville Road
Indianapolis, IN 46268
Phone (651) 575-0151

Toll-Free Solutions Hotline
(877) EAR-IDEA
(327-4332)

www.earglobal.com
E-mail: solutions@earglobal.com