

SOUND SCIENCE: UNDERSTANDING AND IMPLEMENTING GENERATOR SET NOISE CONTROL

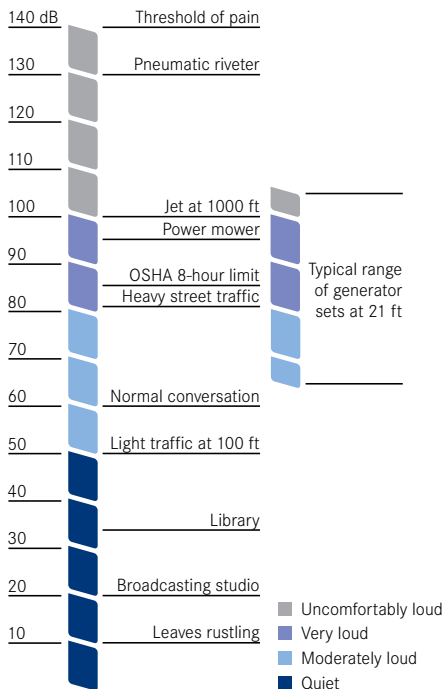
The principles of generator set noise control are well understood, leaving economics as the primary limiting factor in implementing noise reduction strategies for specific applications.



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With the expanding use of diesel generator sets for emergency standby power, peak shaving and demand response, there has come an increased focus on controlling the noise these generators create. Whether generator sets are located in enclosures outside a facility, inside or on the roof, design engineers are making more efforts to control generator set noise and vibration in order to reduce the effects on neighbors and building occupants alike. And whether generator sets run continuously in prime-power applications, intermittently in demand response applications, or occasionally in emergency standby situations or testing, their operating sound levels may require remediation.

DECIBEL LEVELS OF TYPICAL SOUNDS



While local codes and zoning laws often require nominal noise reduction strategies, it is end users who are currently driving the demand for quieter generator set installations within available budgets. The cost to make modest reductions in noise is generally quite low, and generator set manufacturers have made the job easier by making engines that run quieter and with less vibration. In addition, a large aftermarket exists in advanced noise control solutions. However, the cost of noise control is not linear. The first 10 decibels (dBA) of reduction may be relatively inexpensive, but the last 10 dBA may be prohibitively expensive. That is why the current strategy in generator set noise control is to control as much noise as possible without losing control of the budget. This paper will examine the science behind generator set noise control and discuss a variety of solutions that will help consultants and design engineers achieve optimum noise control solutions.

WHAT IS NOISE?

Vibrating objects induce pressure waves that travel through the air and reach our ears as sound. Noise, by definition, is merely unwanted sound. When the amplitude of the pressure waves becomes too high, the amount of sound becomes uncomfortable. In addition to being annoying, excessive sound can cause permanent hearing damage. This is why the Occupational Safety and Health Administration (OSHA) established safety standards for workers exposed to loud noises. Local ordinances and zoning laws also establish rules regarding the amplitude of unwanted sound, but the standards are geared toward reducing public annoyance rather than promoting safety.

The human ear has such a wide dynamic range that the logarithmic decibel scale (dB) was devised to express sound levels in a convenient way. The ratio between the softest sound the ear can hear and the loudest sound it can experience without damage is approximately a million to one or $1:1 \times 10^6$. By using a base-10 logarithmic scale, the whole range of human hearing can be described by a more convenient number that ranges from 0 dB (threshold of normal hearing) to 140 dB (the threshold of pain).

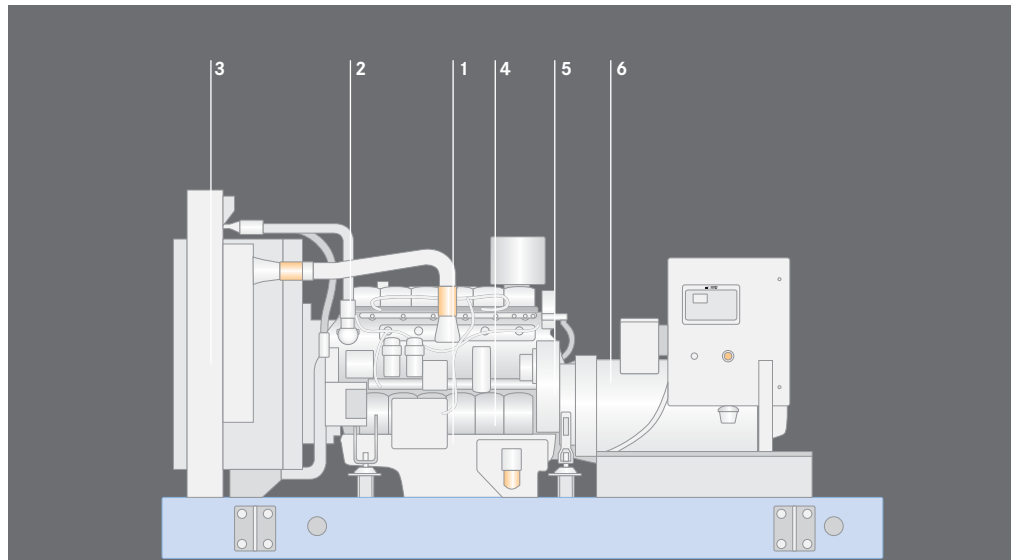
There are two dB scales used to describe sound: A and L.

// The dB(L) scale is linear and treats all audible frequencies as having equal value. However, the human ear does not experience all frequencies the same way. Our ears are particularly sensitive to frequencies in the range of 1,000 to 4,000 Hz, and they are less sensitive to sounds in lower or higher frequencies.

// To adjust the sound pressure levels to more accurately reflect what the human ear perceives, engineers use an “A-weighting filter.” This results in the frequency-weighted dB(A) scale, which was adopted by OSHA in 1972 as the official regulated sound level unit.

SOURCES OF GENERATOR SET NOISE

There are two major frequency bands that not only emanate from different moving components on the generator set but also require different methods to control. Frequencies below 300 Hz are generally considered low frequency; frequencies above 300 Hz are considered high frequency. Furthermore, there are no universal standards for the amount of permissible generator set noise. Rather, each application is different, and each locale sets its own standards for noise emanating from a property.



Sound produced by generator sets:

1 Engine mechanical noise

// With the advent of high-pressure common rail fuel injection, advanced turbocharging and better combustion control, manufacturers have significantly reduced overall mechanical noise from diesel engines. The amount of sound varies with the size of the engine and its load, and can be as high as 110 dB(A) measured at one meter. High-horsepower engines are actually quiet for their size because the V-configuration of the cylinders makes them self-balancing. Engines with more cylinders have more power strokes per revolution and therefore deliver a smoother flow of power with less vibration. Smaller engines tend to be harsher in operation and produce more noise and vibration for their size.

2 Exhaust noise

// Engine exhaust is a major contributor to overall sound levels and, when measured without an exhaust silencer, can be 120 dB(A) or more, depending on the size of the engine. The sound level can be reduced by up to 24 dB(A) and up to 40 dB(A) depending on the silencer.

3 Cooling fan noise

// Sound emanates from turbulent air as the cooling fan moves it across the engine and through the radiator. The amount of sound varies with the speed and volume of air being moved as well as with the design and distortion of the fan blades. The amount of sound can be as high as 95 dB(A) at one meter.

4 Alternator noise

// The alternator has an internal cooling fan, and the combination of cooling air movement and brush friction produces a sound level that is always small compared to the driving engine.

5 Induction noise

// Current fluctuations in the alternator windings create mechanical noises that add to total noise when load demand changes.

6 Structural/mechanical noise

// This is caused by mechanical vibration of various structural parts and components that is radiated as sound. Elastomeric isolators between the engine, alternator, controls and other components help to reduce the amount of vibration that gets converted to noise.

MEASURING NOISE

During design and manufacture, generator sets are tested at the factory, and sound levels are recorded using a process defined in ISO 3744. Sound measurements are sometimes done in the field but usually only to verify compliance to a specific local code or noise-reduction objective related to the installation. In the factory, the manufacturer develops sound measurement profiles for each model of generator set rather than testing every individual unit. Test results are recorded and kept on file for each model in case there is a need to revisit the information for a specific installation.

To get accurate sound data, measurements must be taken in a “free-field environment.” As distinguished from a “reverberant field environment,” a free-field environment is a location in which there are negligible effects from sound reflected off obstacles or boundaries. In practical terms, this means being about four to six feet (one to two meters) away from a wall. Closer surfaces reflect sound and cause higher, erroneous readings.

In a typical factory test, technicians take sound measurements at 12 to 19 locations (depending on the size of the generator set) on the outside of an imaginary box, one meter (39 inches) larger than the generator set profile. This procedure standardizes the measurements so that end users can rely on the data for installation and site planning. Usually this is done with a handheld calibrated microphone one point at a time, but more sophisticated arrangements with multiple simultaneous measurements are also used. Measurements are recorded as sound pressure readings and are later converted into sound power levels from each of the positions.

While factory sound measurements are taken at one meter from the unit for the sake of convenience, the standard distance quoted in specification sheets and used by the industry is seven meters (23 feet). Unless otherwise stated, all published generator set sound data is calibrated to what one would measure at seven meters. Manufacturers simply use an algorithm to convert the one-meter readings to seven-meter readings.

To establish sound pressure levels, calibrated microphones are placed at regular intervals around the perimeter of an imaginary box, one meter larger than the envelope of the generator set. These measurements are later converted into standard sound power levels at seven meters (23 feet).



NOISE-REDUCTION STRATEGIES

Noise-reduction strategies vary depending on whether the generator set is located in a building or outdoors in an enclosure. In any case, it is vitally important to not let noise-control solutions interfere with the flow of cooling air to the generator set. Low-frequency noise is the most difficult to attenuate and is best controlled by the use of rigid barriers that have substantial mass. High-frequency noise can be controlled by the use of acoustic foam and other types of sound-absorbing insulation.

Generator set manufacturers generally offer sound-attenuating enclosures for units up to about 2,000 kW. Typically, these factory drop-over enclosures are offered in three grades of sound control – from a basic sheet metal enclosure (Level 1) to units with substantial sound-attenuating capability (Level 3). A basic Level-1 enclosure will typically reduce noise by approximately 3 dB(A), while a Level-3 enclosure can achieve reductions of 14 dB(A). For generator sets larger than 2,000 kW, many custom sound-attenuated enclosure solutions are available in the aftermarket.

Overall, there are six basic strategies for controlling noise.

1. Acoustic barriers

Rigid barriers that have substantial mass and stiffness reduce the transmission of sound energy. Examples include sheet steel typically used in enclosures and sand-filled block walls or poured concrete walls used in indoor locations. As there has been a trend to lighter-weight sheet steel for enclosures as a cost-saving measure, it is sometimes necessary to install reinforcing ribs when steel enclosure walls lack sufficient stiffness. Steel panels can also be covered with a barium-filled rubber mat that adds mass and is very effective at preventing the transmission of low-frequency sound. It is also important to eliminate sound paths by sealing seams around doors, panels, exhaust ports and conduit channels.

2. Acoustic insulation

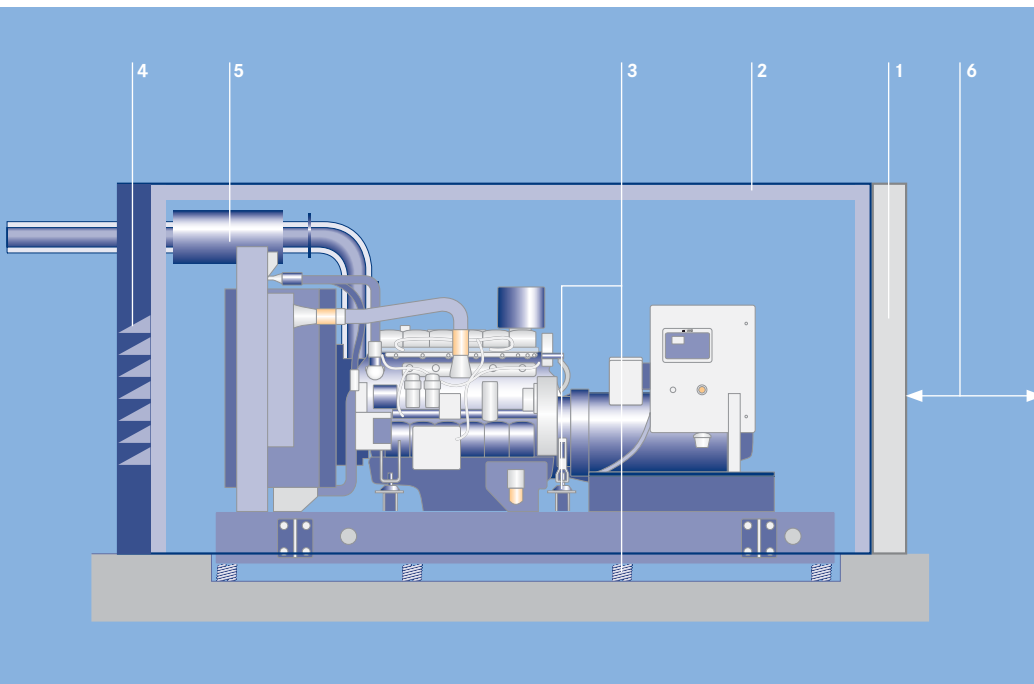
Sound-absorbing acoustic foam is effective for controlling high-frequency noise and is used extensively in outdoor enclosures. In indoor installations, it can be very effective at reducing noise when used to line air ducts or when used as a wall or ceiling covering. Fire-retardant urethane foam is the most common material used in enclosures; however, fiberglass is also effective.

3. Vibration isolation

Vibrating generator components induce pressure waves as sound into the environment. Also, anything that is attached to the generator set can cause vibrations to be transmitted into the building structure or foundation. These attachment points include skid anchors, radiator discharge air ducts, exhaust piping, coolant piping, fuel lines and electrical conduit. Mounting the generator set on isolation springs or on a base fuel tank helps reduce the transmission of vibration into the foundation. Pouring a separate mounting slab also helps isolate vibrations from the building. Flexible connectors on fuel lines and exhaust and electrical conduits effectively eliminate the transmission of vibration.

4. Attenuation of cooling air noise

The movement of cooling air is a significant source of high-frequency noise, but restricting its flow is detrimental to generator set cooling efficiency. More than 20 cubic meters per second of air is required for cooling a 50-liter diesel engine. In indoor installations, high-frequency noise can be reduced by making the air flow turn two 90-degree angles as it enters and leaves the power room. In Level-3 outdoor enclosures, cooling air is drawn in from the roof near the rear of the enclosure and turned 90 degrees in order to flow over the engine and through the radiator. It is then turned 90 degrees again and ejected upward out the roof of the enclosure. In this way, much of the air flow sound at ground level is reduced and is directed upwards, away from people and other structures.



Various barrier and absorption sound-reduction strategies are effective in indoor installations and outdoor installations in enclosures.

5. Exhaust silencers

Silencers are available in several different sound-attenuation grades, commonly referred to as industrial, residential or critical/hospital. The standard industrial-grade silencer reduces exhaust noise from 12 to 18 dB(A). Residential silencers provide an 18 to 25 dB(A) reduction, and critical/hospital silencers cut noise up to 40 dB(A). In indoor installations with long exhaust piping, the length of exhaust pipe alone provides some additional level of sound attenuation.

6. Maximize the distance from the source

Noise zoning ordinances typically set noise limits based on what can be measured at the property line. Since sound diminishes as the square of the distance from the source, simply increasing the distance from the property line may be enough to meet local regulations.

CONCLUSION

Today, the science of noise control is well understood, and generator set noise can be controlled to a significant degree in both indoor and outdoor installations. The trend toward greater noise reduction of generator sets is driven by a combination of local ordinances and the desire of end users to have a more quiet work environment. Generator set noise control is mostly limited by economics. The first 10 dB(A) of sound reduction is relatively inexpensive, while the last 10 dB(A) may strain the budget.

When controlling noise, it is important to not compromise generator set cooling or overall performance and reliability. Barriers that contain noise also tend to contain heat, and any restrictions in cooling air flow over a generator set can reduce its performance or threaten its longevity. By working with generator set manufacturers or aftermarket enclosure suppliers, end users will be able to achieve the maximum sound reduction for the available budget. In addition, end users should involve local zoning and regulatory agencies to make sure that the installation meets all applicable noise regulations.

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