Acoustical testing of the QSK95 Series generator set and acoustical noise data interpretation

White Paper

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Apples to Apples: Comparing Acoustical Data

A growing number of businesses find that large, heavy-duty generator sets are critically important to their operations, whether for continuous, prime or standby power. Not surprisingly, large generator sets produce high levels of noise that often must be mitigated to meet local, state and federal regulations or directives. This usually involves key decisions about the optimal generator set location and installation, how to design noise control systems, and other factors. That’s why it’s important to have an accurate assessment of noise levels early on, before investments are made and facility and enclosure designs are locked in. However, it can be difficult to obtain precise, consistent data that’s easily compared.

The problem? Not all manufacturers measure generator noise the same way, and some use less precise standards for their data. As generator set acoustic performance grows in importance, it’s important to understand how to compare the data in a way that’s “apples to apples”.

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Why precision acoustical testing matters

Noise levels at workspaces are regulated by federal governments to protect workers’ safety. In addition, communities are increasingly enacting ordinances aimed at reducing sounds that are disruptive to nearby residents.

For example, in North America, typically permitted noise levels at the property line at daytime and nighttime are around 60 dB(A) and 50 dB(A), respectively. However, in certain special zones, local authorities have set even lower noise limits. That's why it is very important to measure noise levels using appropriate and applicable national and international standards in order to establish an accurate platform for comparison.

These precisely measured noise levels are also useful for understanding the noise characteristics of generator sets so that noise control strategies, such as acoustic enclosures and acoustic walls, can be successfully implemented.

In order to bring a generator’s noise levels into compliance with local ordinances and federal regulations, facility design engineers must carefully evaluate where to locate the generator and what noise reduction strategies will be most effective. These strategies may include the construction of sound-attenuating enclosures or the addition of acoustic insulation or barriers, exhaust silencers or isolation mounts. By equipping power system designers with precise acoustic data, they’re better able to design a noise reduction system that reliably meets local noise restrictions.

Understanding acoustical data measurements

When comparing generator noise and sound data, it helps to understand some of the most common units of measurement used for industrial products.

Sound levels are often expressed in terms of Sound Pressure Level and Sound Power Level (see Glossary, p. 05). Both are important measurements, but they’re quite different.

**A-weighted Sound Pressure Level (SPLA or L<sub>A</sub>)** is specific to the distance of the receiver from the sound source. Sound Pressure Level decreases as distance from the sound source increases, and vice versa. Without the context of distance from the source, Sound Pressure Level data is meaningless.

**A-weighted Sound Power Level (SPWLA or L<sub>WA</sub>)** is a measure of acoustical energy produced by a sound source, with no regard to its distance from the point of observation. Sound Power Level is calculated based on Sound Pressure Level measured by using Parallelepiped or Hemispherical Array method per ISO or ANSI standards.

For electric power generator sets, noise levels are also dependent on two major operating parameters: engine speed and load. Since noise levels increase as speed and load increase, it’s important to know at what speeds and loads the noise levels were measured.

Cummins Power Generation conducts noise testing at its world-class Acoustical Testing Center (ATC) in Fridley, Minnesota, USA. This carefully engineered and environmentally controlled facility provides exceptionally reliable acoustic data through the use of precision-grade acoustical equipment and rigorous measurement techniques.
A look at the Cummins Acoustical Testing Center

The Cummins Power Generation Acoustical Testing Center is among the largest in the diesel and power generation industries, featuring a hemi-anechoic chamber certified as “Precision Grade,” the maximum accuracy level per ISO 3745:2009. Its vast size is needed to accommodate large generator sets and the many microphone positions required for precision-grade testing, including those at 7 meters from the face of the largest generator set Cummins manufactures.

By using the microphone setup according to ISO and ANSI standards, measurements are conducted all around the generator set so that all unique noise characteristics of its components are captured and also the directionality of the noise sources studied. This precision-grade noise data increases the operator’s confidence level and eventually helps in devising noise control strategies quickly and economically.

Figure 1 — The Cummins Power Generation Acoustical Testing Center features an exceptionally large hemi-anechoic chamber that is 105 feet (32 meters) long, 80 feet (24.5 meters) wide and 36.5 feet (11 meters) high.

The Cummins Acoustical Testing Center adheres to the most stringent national and international standards for acoustic noise measurements:

- ISO 3744:2010
- ISO 3745:2012
- ISO 8528-10:1998
- ISO 6798:1995
- ISO 9614-1:1993
- ISO 9614-2:1996
- ISO 9614-3:2002
- ISO 6798:1995
- ANSI S1.13:2005
- ANSI S12.18:1994
- SAE J1074:2014

Details concerning the construction and acoustical features of the Acoustical Testing Center are published in the technical paper, Design and Performance of Acoustical Testing Center of Cummins Power Generation, authored by Shashikant More, Martin Myers and Victor Clemente, as included in the Proceedings of Inter-Noise 2012, New York, USA, August 2012.
Testing the Cummins QSK95 Series generator set

The QSK95 Series generator set is equipped with a 16-cylinder diesel engine capable of producing approximately 3.5 MW of power. It was tested at a variety of operating conditions and a range of acoustic parameters to determine how different aspects of normal operation would contribute to overall noise levels. Testing focused on sounds that are most impactful to the human ear and structures surrounding the generator sets, and frequencies that have a higher potential to perturb people in surrounding communities.

Cummins strived to achieve high precision and reliability in its numbers, calculating average readings from an array of 71 microphones. This covered the entire human audible frequency range, from 20 to 20,000 Hz. Cummins conducted 58 different test configurations over a total of 321 hours in the testing facility and acquired almost 360 GB of noise data.

By using advanced noise measurement techniques developed at the Acoustical Testing Center, Cummins was able to determine the noise contributions from individual components of the generator set to overall noise levels. This included the noise characteristics of the engine, cooling system, exhaust system, air intake system, fuel injection system and alternator. Acquiring noise data in this manner helps ensure precise information is incorporated in product specification sheets. It is also helpful for quickly devising noise control strategies without the need for extensive engineering resources, whether it's to meet regulation- or directive-based noise limits or customer-specific requirements.

Some highlights of the QSK95 Series generator set testing:

- Baseline noise data was acquired at 1 meter using the parallelepiped method per ISO 3744:2010 with 59 microphone locations around the generator set (engine and alternator ends, sides and top of the generator set).
- Baseline noise data was also acquired at 7 meters using eight microphones (eight locations spanning 360 degrees around the generator set, each microphone placed at 45-degree increments) based on Cummins' internal noise measurement standard derived from the U.S. Department of Defense power generator set noise measurement requirements.

Noise data collection at 7 meters from the surface of the generator set is important because sound levels are generally stable at that distance, which enables reliable extrapolation and prediction of noise levels beyond 7 meters. Very few hemi-anechoic chambers in the world are large enough to conduct testing at that distance.

- Cummins used 71 microphone locations to measure noise levels at 1 and 7 meters from the generator set, 1 meter from the line of exhaust and fuel pump, and at operator location to achieve a very high degree of reliability.
- The average A-weighted Sound Pressure Levels at 1 and 7 meters reported in the data sheets is an average of 59 and eight microphone locations at a distance of 1 and 7 meters from the generator set, respectively.
- The A-weighted Sound Power Level reported in the data sheets was calculated using the average A-weighted Sound Pressure Level measured by using 59 microphones placed at 1 meter from the generator set, per the Parallelepiped Method of ISO 3744:2010.

Testing of the QSK95 Series generator set resulted in roughly 360 GB of data. Seventy-one microphones were used to capture sound data from many possible locations emanating from the generator, providing very high degrees of accuracy and reliability in the data. In addition, Cummins found that the QSK95 Series generator set's noise frequency content is very balanced and does not exhibit annoying noise characteristics (e.g., harsh, unexpected or distinct frequency components) in the human audible frequency range.

These extensive testing configurations resulted in highly detailed, three-dimensional (sound field) sound data. This provides a valuable resource to customers who seek to design effective and cost-efficient generator enclosures and noise attenuation systems.
A glossary of acoustical terms

**A-weighted Sound Power Level (SPWLA or LWA)**
is a measure of the acoustical energy produced by
a sound source, no matter what its distance from the
point of observation.

**A-weighted Sound Pressure Level (SPLA or L_A)**
is a relative measure of the impact of a sound wave
at a specific distance from the source.

*Example:* A generator set producing an
average Sound Pressure Level of “X” dBA
will be much quieter when heard from
50 feet away than from 5 feet away. There-
fore, the average Sound Pressure Level will
be lower at 50 feet than at 5 feet, although
the Sound Power Level has not changed.

Note: Both A-weighted Sound Power Level (SPWLA)
and A-weighted Sound Pressure Level (SPLA) are
represented by the same unit of measure — dBA —
but they are two different metrics.

**Cycle** The complete oscillation of pressure above
and below the atmospheric static pressure.

**dBA** A-weighted variation of the standard decibels
measurement. Since the human ear has different
sensitivity to different frequencies, noise levels are
often measured with an “A-weighted” filter that has a
frequency response similar to that of the human ear,
stated as dBA(A) or dBA.

**Free field** A sound field in which there are no or
negligible sound reflections.

**Hertz** (Hz) Frequency of sound expressed by cycles
per second (see “Cycle”).

**Noise** Unwanted sound that is annoying or
uncomfortable.

**Parallelepiped array** A three-dimensional
arrangement of microphones at a certain distance
(most commonly at 1 meter) from an imaginary
parallelepiped that encloses the testing object.

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**Recommendations for evaluating acoustical data**

With the growing focus on generator set noise and
its impact on workers and nearby communities, noise
mitigation is an essential component of generator
set installation. Obtaining precise acoustical data
allows for the design of effective and cost-effective
noise control solutions that bring generator sets in
compliance with community and federal noise limits.

However, comparing generator set acoustical data
isn’t as simple as it would seem. Not all testing
facilities meet the latest ISO, ANSI and SAE
standards. In addition, various manufacturers
may offer different types of data, which can make
comparing “like to like” numbers difficult.

**Here are some questions to consider when comparing generator set acoustical data from different manufacturers:**

- Were the generators tested at the same
  engine load/power node?
- Were the generators tested at the same
  engine speed?
- Was the data collected with or without a
  set-mounted radiator?
- Are the units of measurement the same?
  (A-weighted Sound Pressure Level [SPLA] or
  A-weighted Sound Power Level [SPWLA])
- Were Sound Pressure Level measurements taken
  at the same distance?
- Was the same standard or measurement method
  used for the noise measurements?
- How reliable is the data?
- Were the measurements conducted at Precision-
or Engineering-Grade test facilities? Precision
  Grade is more precise than Engineering Grade.

For additional information about the QSK95 Series
generator set, visit cumminspowerofmore.com.
For technical support, please contact your local
Cummins Power Generation distributor, or visit
power.cummins.com.
About the author

Dr. Shashikant More is a technical specialist in the Department of Applied Technology at Cummins Power Generation and leads the Applied Mechanics Functional Excellence (AMFE) Acoustic Area sub-team. He received his Ph.D. in mechanical engineering with a specialization in acoustics from Purdue University. Before joining Cummins, Dr. More conducted doctoral research on aircraft noise which was sponsored by the Federal Aviation Administration (FAA), National Aeronautics and Space Administration (NASA), and Transport Canada. He is an active contributor to the field of power generator noise research, including programs with the National Academy of Engineering (NAE), National Institute for Occupational Safety and Health (NIOSH) and the U.S. National Park Service (NPS). He is a member of Institute of Noise Control Engineering (INCE) and a reviewer of journal papers published in prestigious journals such as International Journal of Environmental Research and Public Health (IJERPH), Basel, Switzerland; Journal of the Acoustical Society of America (JASA), USA; and Noise Control Engineering Journal (NCEJ), USA.