

Sound Attenuation and Test Strategies for Generator Set Installations

PowerHour webinar series for consulting engineers
Experts you trust. Excellence you count on.

April 10, 2018 11:00 PDT / 13:00 CDT
(1PDH issued by Cummins)

Welcome!

PowerHour is designed to help our engineer partners to...

- Keep up to date on products, technology, and codes and standards development
- Interact with Cummins experts and gain access to ongoing technical support
- Participate at your convenience, live or on-demand
- Earn Professional Development Hours (PDH)

Technical tips:

- Audio is available through teleconference, or your computer (don't forget to unmute)
- You are in **"listen only"** mode throughout the event
- Use the **WebEx Q&A Panel** to submit questions, comments, and feedback throughout the event. We will provide sufficient Q&A time after presentation
- If you lose audio, get disconnected, or experience a poor connection, please disconnect and reconnect
- Report technical issues using the **WebEx Q&A Panel**, or email powergenchannel@cummins.com



Meet your panelists

Cummins presenter:



Michael Sanford
Sales Application Engineering Leader – North America
Cummins Inc.

Cummins facilitator:



Tom Bakritz,
Global Sales Training Manager
Cummins Inc.

Your local Cummins contacts:

- AZ, ID, NM, NV: Carl Knapp (carl.knapp@cummins.com), Rocky Mountain Region
- CO, MT, ND, UT, WY: Joe Pekarek (joe.a.pekarek@cummins.com), Rocky Mountain Region
- Northern IL, IA: John Kilinskis (john.a.kilinskis@cummins.com), Central Region
- UP of MI, MN, East ND, WI: Michael Munson (michael.s.munson@cummins.com), Central Region
- NB, SD, West MO, KS: Earnest Glaser (earnest.a.glaser@cummins.com), Central Region
- South IL, East MO: Jeff Yates (Jeffery.yates@cummins.com), Central Region
- TX: Scott Thomas (m.scott.thomas@cummins.com), Gulf Region
- FL, GA, SC, NC and Eastern TN: Robert Kelly (robert.kelly@cummins.com), South Region
- NY, NJ, CT, PA, MD: Charles Attisani (charles.attisani@cummins.com), East Region
- CA, HI: Brian E Pumphrey (brian.Pumphrey@cummins.com), Pacific Region
- WA, OR, AK: Tom Tomlinson (tom.tomlinson@cummins.com), Pacific Region
- For other states and territories, email powergenchannel@cummins.com or visit <http://power.cummins.com/sales-service-locator>

Disclaimer

The views and opinions expressed in this course shall not be considered the official position of any regulatory organization and shall not be considered to be, nor be relied upon as, a Formal Interpretation.

Participants are encouraged to refer to the entire text of all referenced documents. In addition, when in doubt, reach out to the Authority Having Jurisdiction.



Course Objectives

Sound Attenuation and Test Strategies for Generator Set Installations

This course will provide a brief overview of acoustics including methods of specification and on-site testing. The instructor will review common sound attenuation strategies for generator set installations and will include recommendations for methods employed to meet stringent noise requirements. The course will also review data commonly provided by manufacturers, how it is interpreted and how it can be best applied.

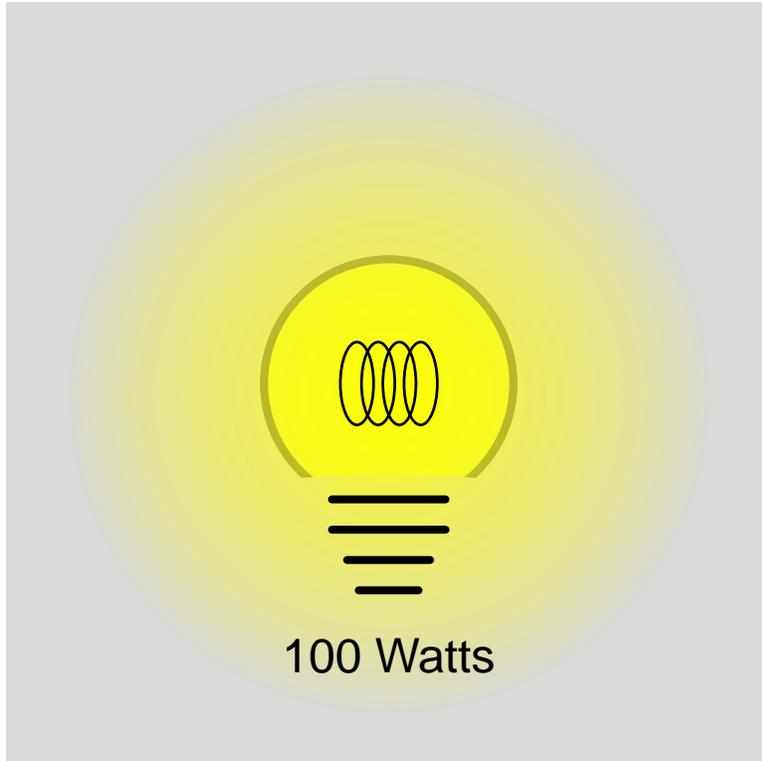
After completing this course, participants will be able to:

- Describe the fundamentals of acoustics relative to generator set installations.
- Identify appropriate strategies for specifying sound requirements and test methods.
- Recognize data provided by manufacturers that is most relevant to site noise limits.

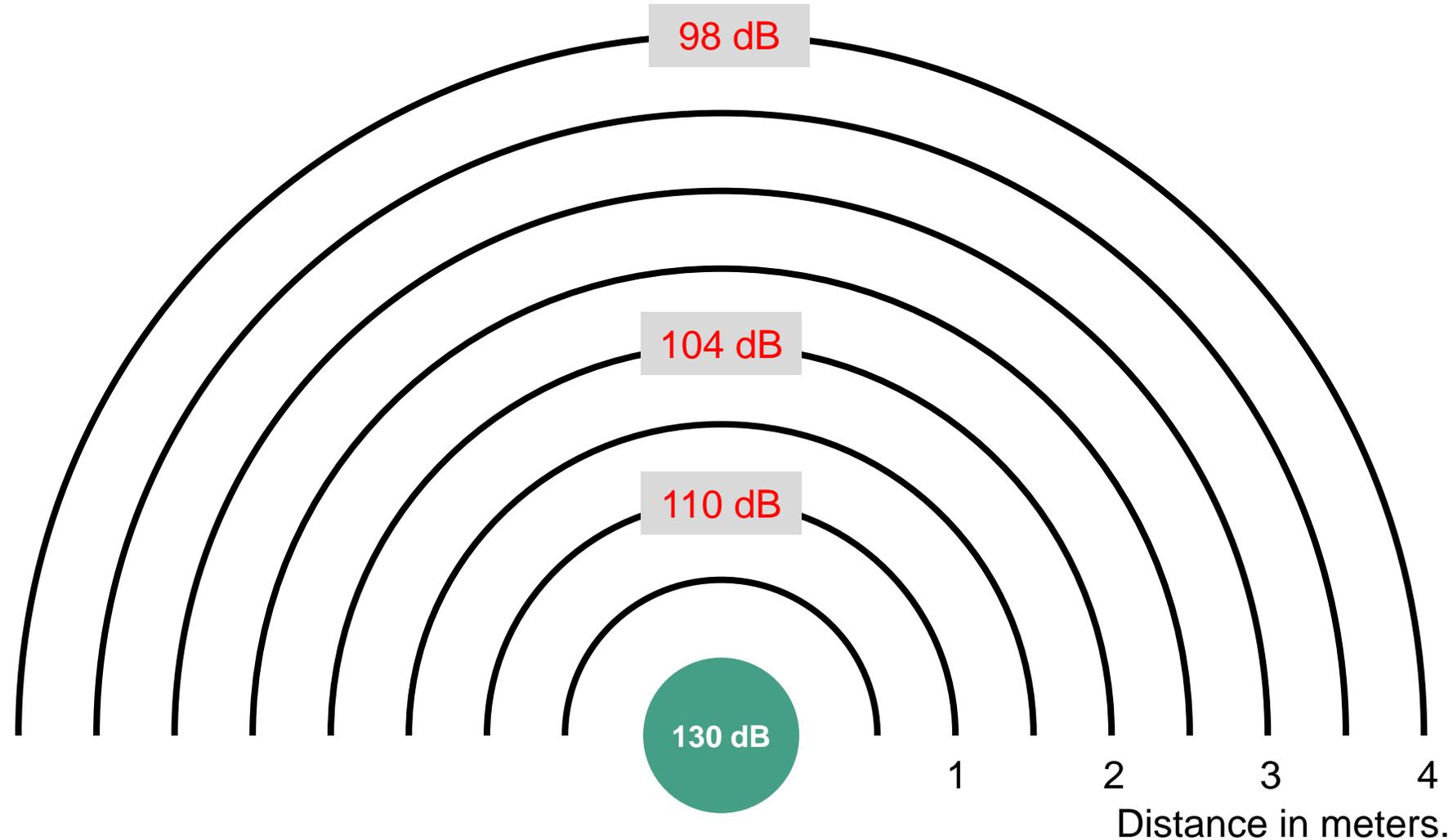
What do you know about sound?



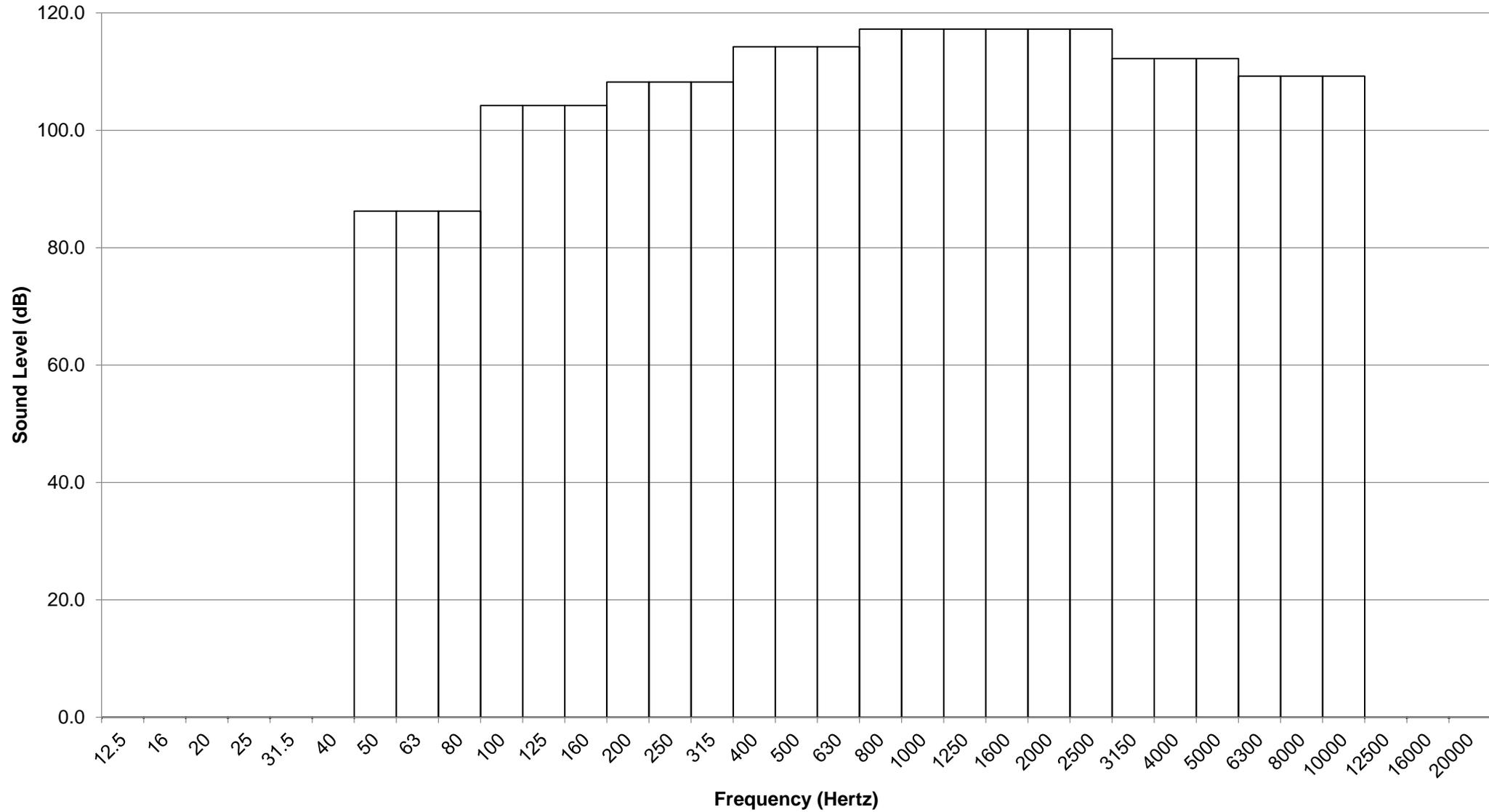
Sound Power vs. Sound Pressure



Sound Power vs. Sound Pressure



Measured Sound Level



dB

(Decibels)

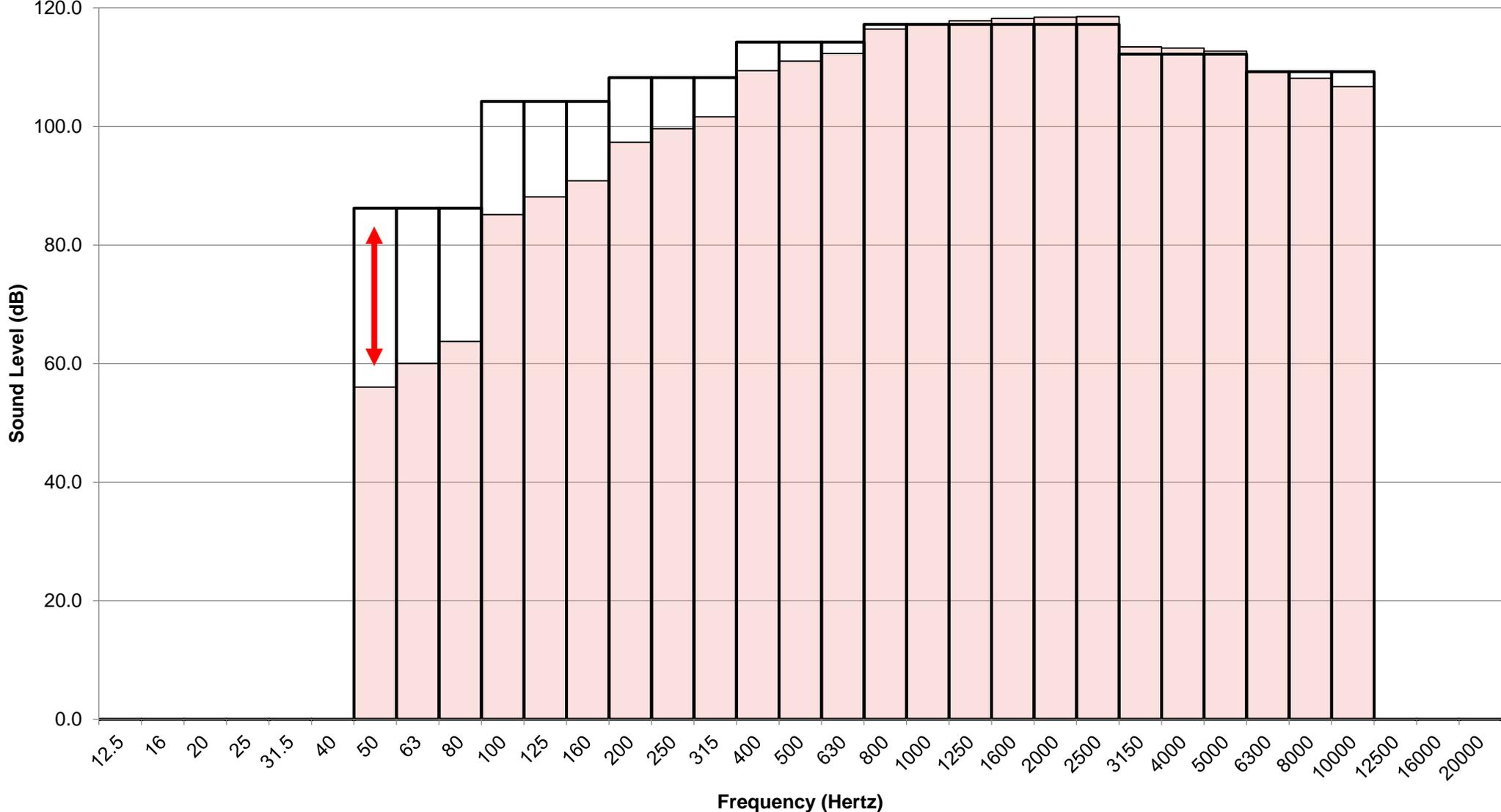
dB

(Decibels)

(A)

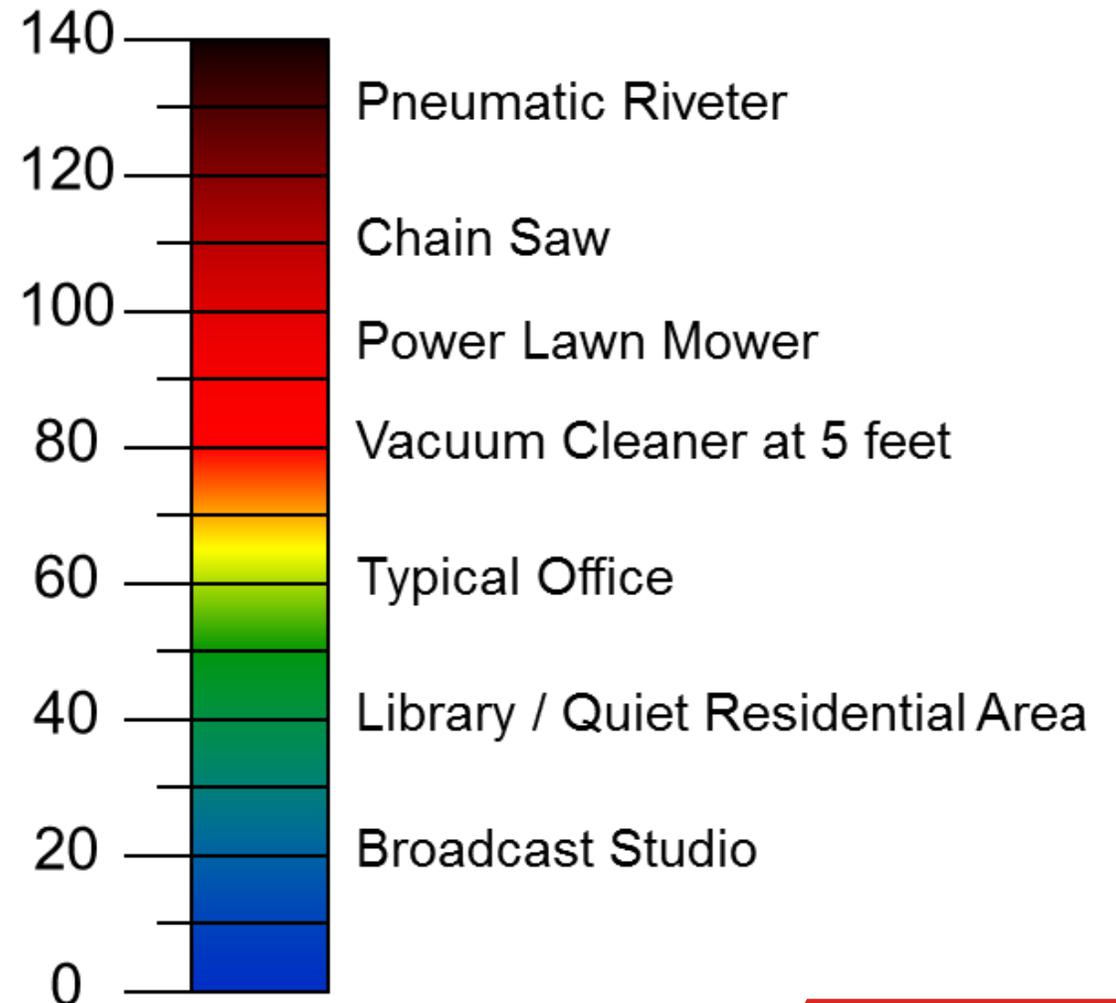
(A-Weighted)

Perceived Sound Level (A-Weighting)

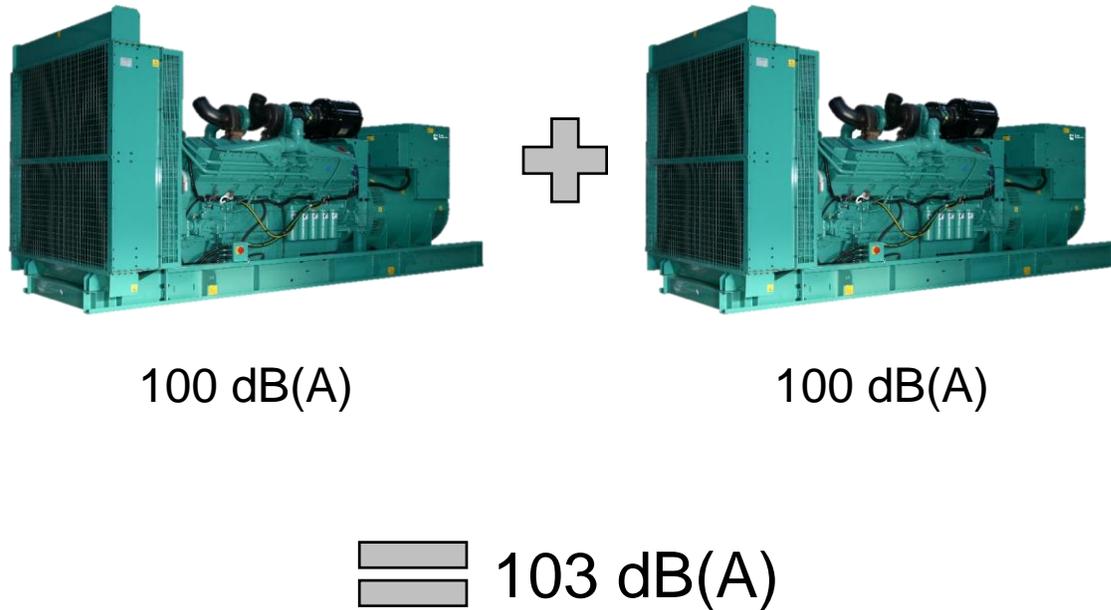


Generator Set Sound Contributors

- Un-silenced engine exhaust
 - 120-130 dB(A) @ 1m
- Radiator cooling fan
 - 100-110 dB(A) @ 1m
- Engine
 - 100 -105 dB(A) @ 1m
- Alternator
 - 80 – 90 dB(A) @ 1m



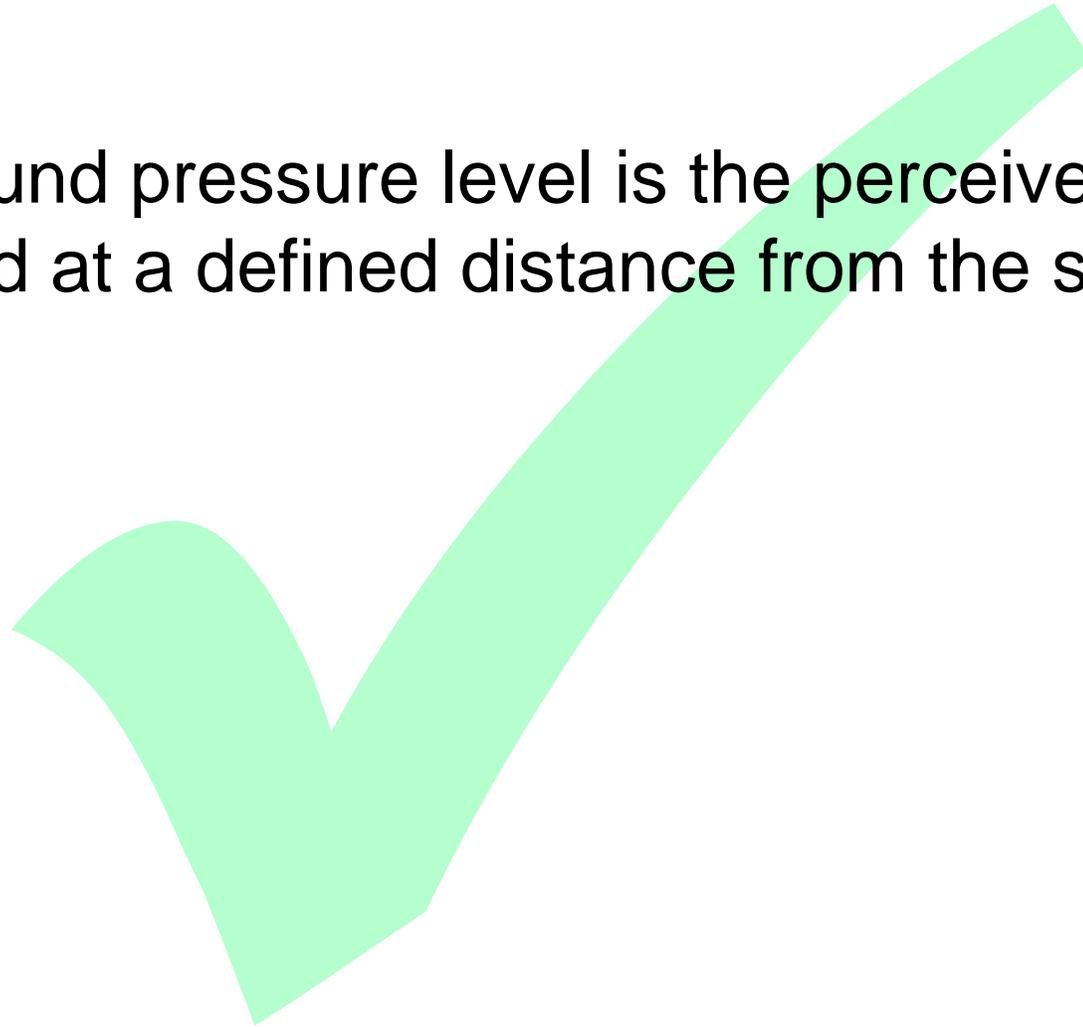
The Sum of Sound Sources



Adding decibels	
When the numerical difference in dB(A) between two noise levels is:	Add this dB(A) to the higher of the two noise levels for a total:
0	3.0
0.1 – 0.9	2.5
1.0 – 2.4	2.0
2.4 – 4.0	1.5
4.1 – 6.0	1.0
6.1 – 10	0.5
>10	0

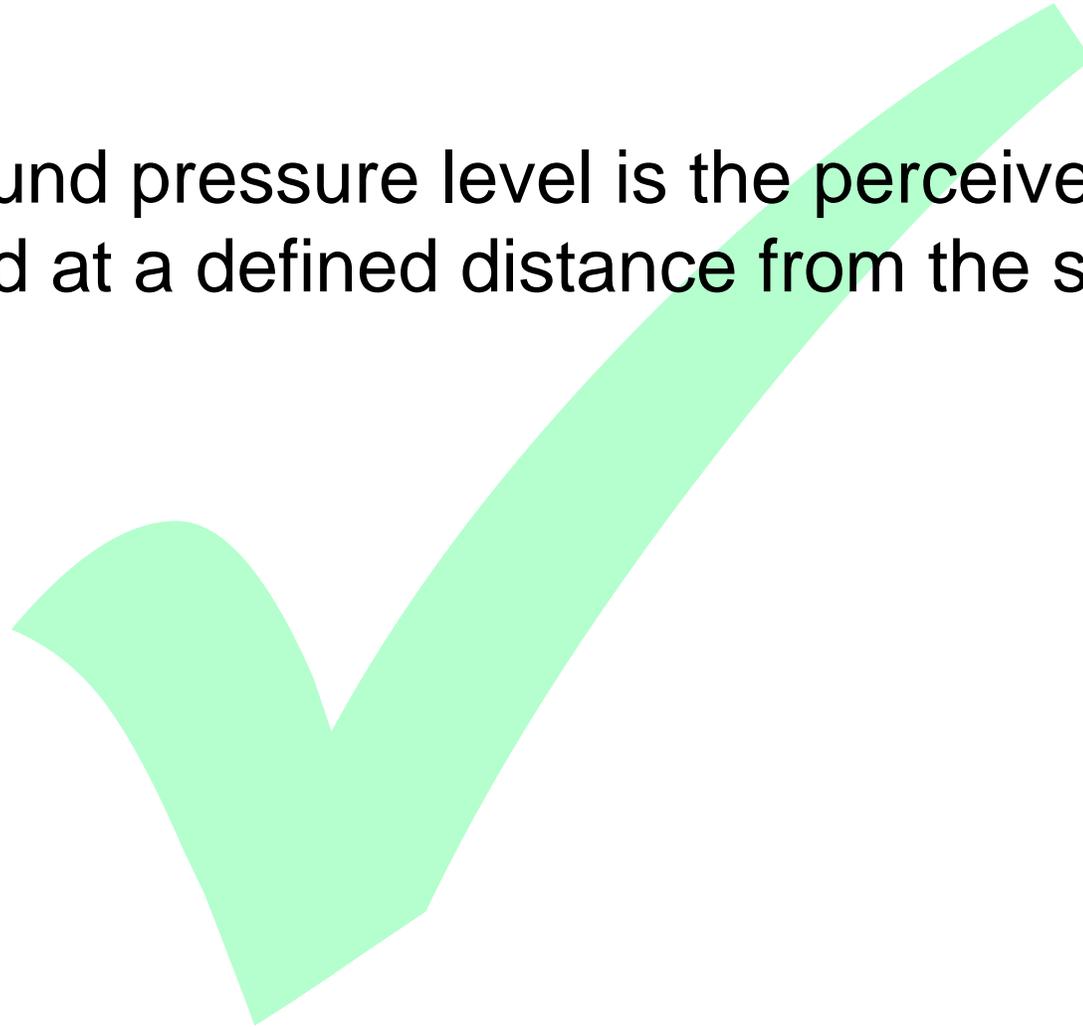
Concept Check – Sound Basics

True or False. Sound pressure level is the perceived sound level of a source measured at a defined distance from the source.



Concept Check – Sound Basics

True or False. Sound pressure level is the perceived sound level of a source measured at a defined distance from the source.



How do you see owner sound level requirements defined?



How do you specify sound level requirements for manufacturers?

Installation Considerations

- Limits are almost always based on sound pressure at the property line.
- Location is the single greatest ally or enemy
- Increase distance from source to receiver
 - Sound pressure drops ~6 dB(A) at 2x distance
- High mass, absorptive barriers
- Avoid reflective surfaces
 - Perceived sound pressure increases:
 - 3dBA due to a reflective surface
 - 5dBA for two reflective surfaces
- Direct noise away from sensitive locations
 - Radiator discharge turning vanes
 - Exhaust discharge elbows



Common Specification Pitfalls

Generator set shall include critical grade muffler.

- Grades are not standardized.
- Advertised sound attenuation is dependent on application.

Generator set shall include [critical grade / level X] housing.

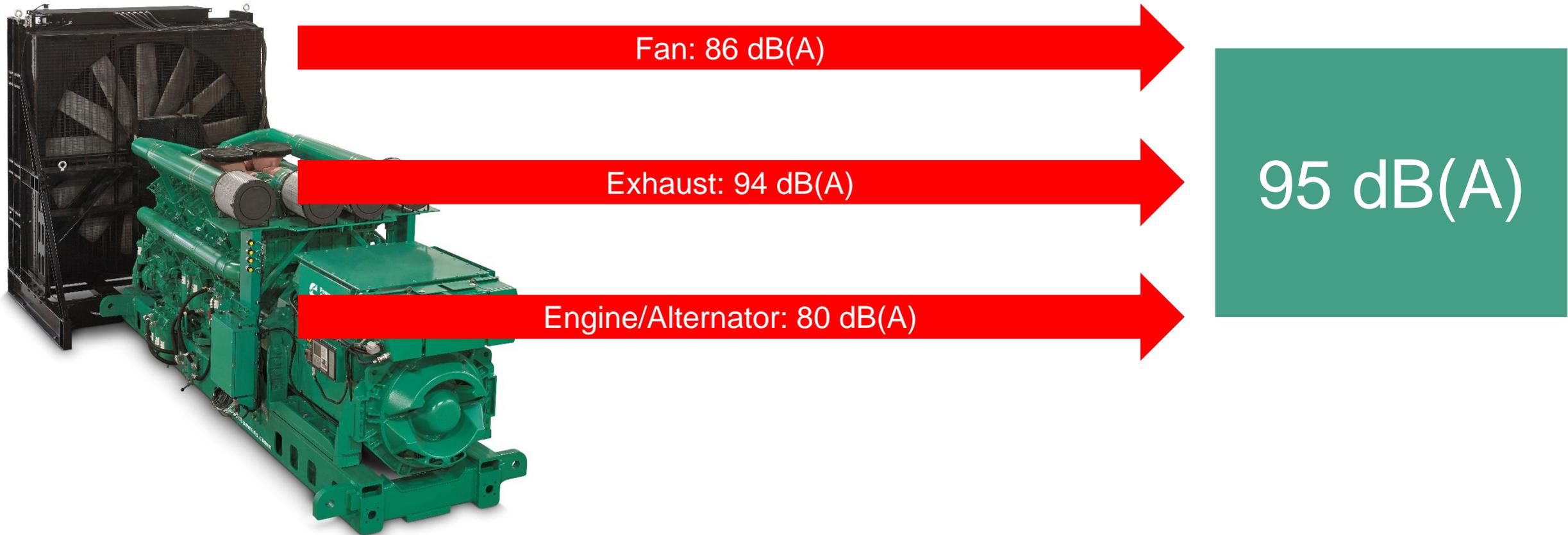
- Does not mandate compliance with the limit imposed on the owner.
- Enclosure/housing grades are not standardized.

Generator set shall include housing/muffler with X dB(A) reduction.

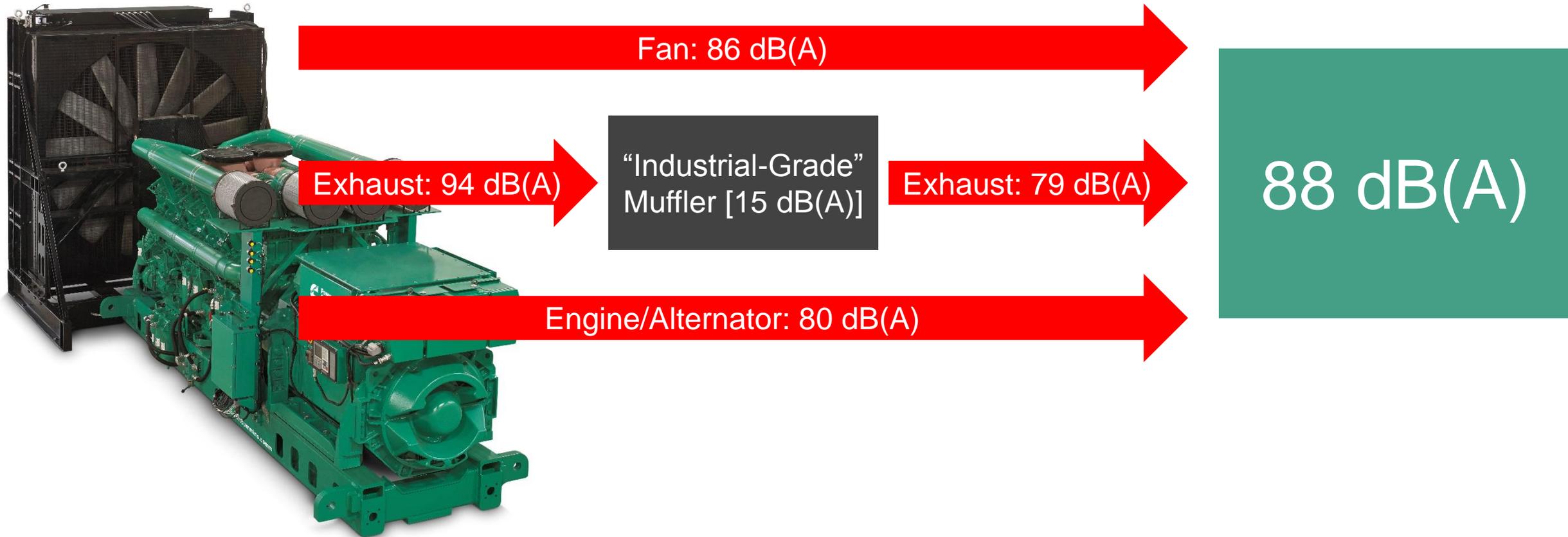
- Does not mandate compliance with the limit imposed on the owner.
- Magnitude of reduction is not relative to the raw or resulting sound levels.



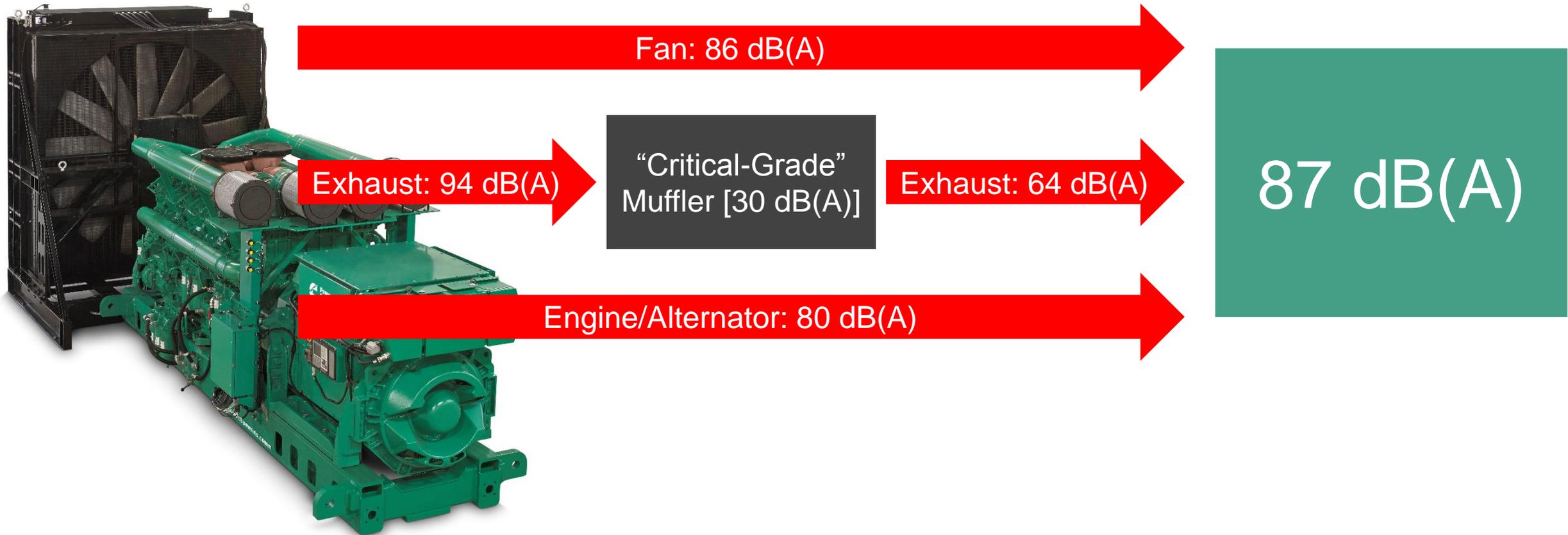
Specification Pitfalls: Mufflers Grades



Specification Pitfalls: Mufflers Grades



Specification Pitfalls: Mufflers Grades



Enclosure “Grades”



Frequency Cut-Off Requirements

- Be cognizant of sound level AND frequency
 - Higher frequencies dissipate quickly
 - Lower frequencies carry significant distances
- Local noise limits may include maximum sound pressure levels at a given frequency.



Submit sound power level data for the packaged unit operating at 100 percent load in a free field environment. The data should demonstrate compliance with the sound limitation requirements of this specification. Submit certification from the manufacturer stating that the sound emissions meet the specification. The noise generated by the diesel generator set operating at 100 percent load shall not exceed the following sound pressure levels in any of the indicated frequencies when measured in a free field at a radial distance of 22.9 feet 7 meters at 45 degrees apart in all directions.

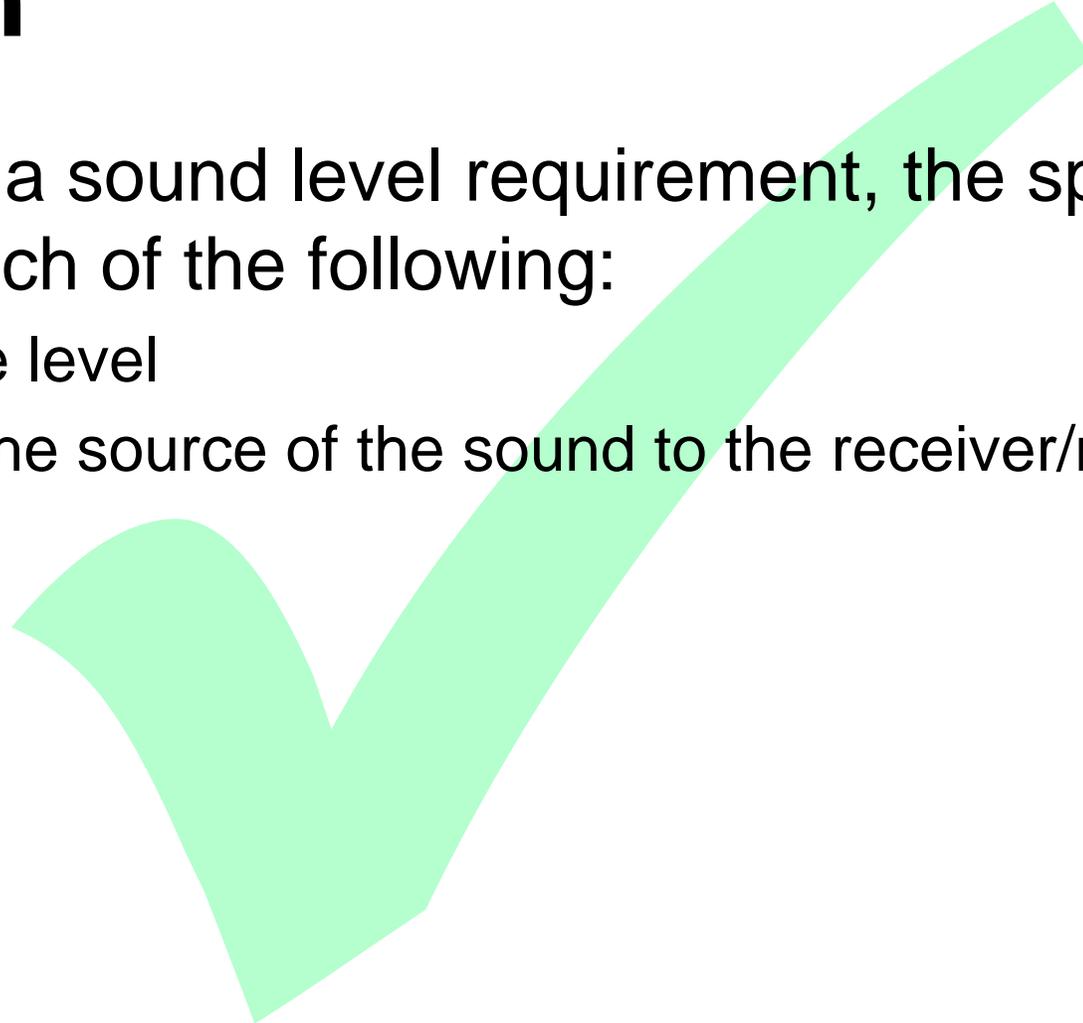
Frequency Band (Hz)	Maximum Acceptable Sound Level (Decibels)
31	81
63	81
125	72
250	64
500	58
1,000	55
2,000	54
4,000	54
8,000	56

Concept Check – Installation and Application



In order to specify a sound level requirement, the specification should include which of the following:

- a) Sound pressure level
- b) Distance from the source of the sound to the receiver/measurement point
- c) Muffler grade
- d) Enclosure type

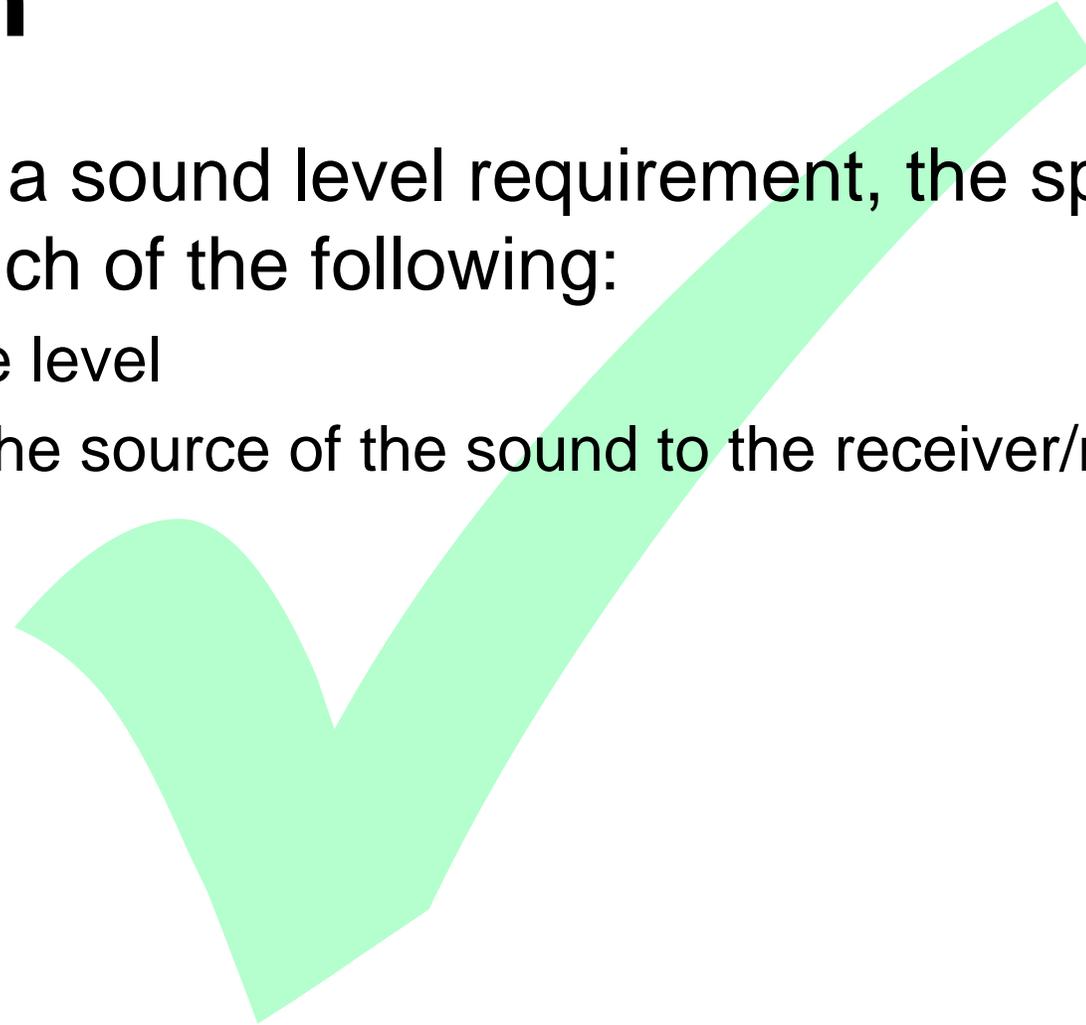


Concept Check – Installation and Application



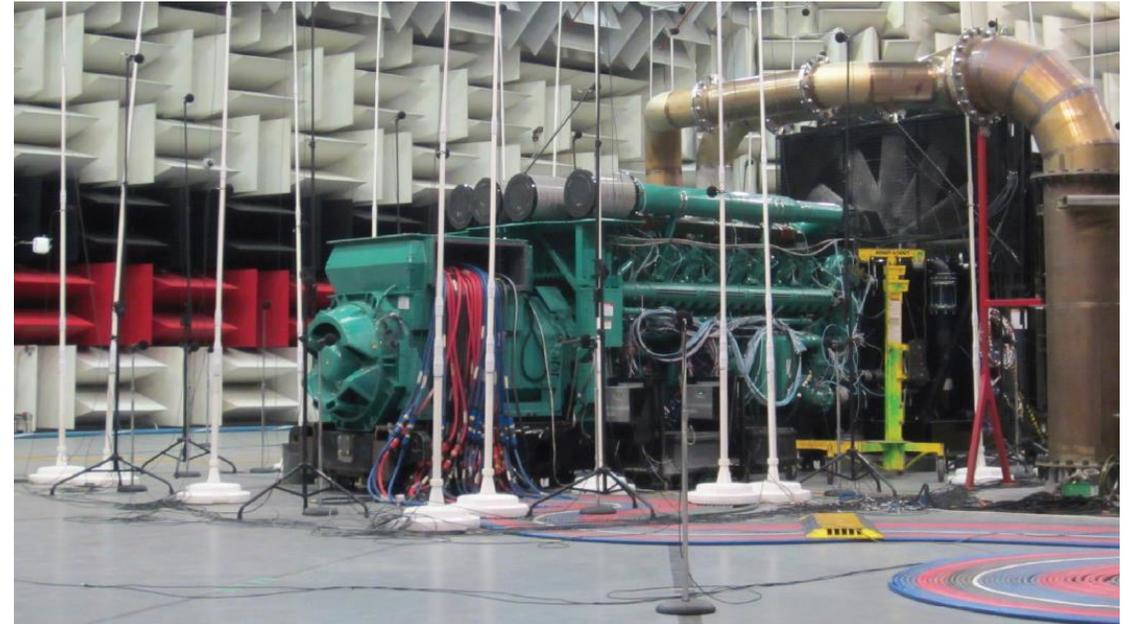
In order to specify a sound level requirement, the specification should include which of the following:

- a) Sound pressure level
- b) Distance from the source of the sound to the receiver/measurement point



Data Considerations

- At what load was the data measured?
- In which configuration of the product was the data measured?
- Which units of measure are used to represent the results of the measurements?
 - Under what conditions are the given units of measure?
- Which standard or measurement methods were used to collect the data?



Sound pressure level @ 7 meters, dB(A)

See notes 1-6 listed below

1

Configuration	Exhaust	Measurement location number (note 1)								8 Position average
		1	2	3	4	5	6	7	8	
Unhoused - remote cooled	Infinite	94.5	100.2	98.2	98.9	95.3	100.5	100.5	99.2	98.9
Unhoused - high ambient cooling system	Infinite	94.6	101.0	101.0	100.6	96.4	101.2	100.0	102.5	100.2
Unhoused - enhanced high ambient cooling system	Infinite	96.4	101.9	101.1	101.4	99.7	101.8	103.1	100.9	101.1

Sound power level, dB(A)

See notes 2-4, 7 and 8 listed below

2

Configuration	Exhaust	Octave band center frequency (Hz)										Overall sound power level
		31.5	63	125	250	500	1000	2000	4000	8000	16000	
Unhoused - remote cooled	Infinite	67.2	86.9	106.9	110.7	118.1	119.7	120.6	118.9	124.4	100.7	128.1
Unhoused - high ambient cooling system	Infinite	72.5	89.9	113.5	118.4	121.2	122.0	121.8	118.7	124.0	99.3	129.4
Unhoused - enhanced high ambient cooling system	Infinite	72.4	90.0	116.4	120.0	123.3	122.9	122.1	119.7	124.3	101.2	130.3

Exhaust sound power level, dB(A)

See note 2 and 9 listed below

3

Open exhaust (no muffler) @ rated load	Octave band center frequency (Hz)										Overall power level
	31.5	63	125	250	500	1000	2000	4000	8000	16000	
	71.0	101.1	110.2	123.0	124.9	124.6	124.6	125.2	123.7	104.1	132.2

Note:

- Position 1 faces the generator front per ISO 8528-10. The positions proceed around the generator set in a counter-clockwise direction in 45° increments. All positions are at 7 m (23 ft) from the surface of the generator set and 1.2 m (48 in) from floor level.
- Sound levels are subject to instrumentation, measurement, installation and manufacturing variability.
- Data based on full rated load. Sound data with remote-cooled generator sets are based on rated loads without cooling fan noise.
- Sound data for generator set with infinite exhaust do not include exhaust noise.
- Sound pressure levels are measured per ANSI S1.13 and ANSI S12.18, as applicable.
- Reference sound pressure is 20 μ Pa.
- Sound power levels per ISO 3744 and ISO 8528-10, as applicable.
- Reference power = 1 μ w (10^{-12} W).
- Exhaust sound power levels are per ISO 6798, as applicable.

4

Sound pressure level @ 7 meters, dB(A)

See notes 1-6 listed below

Configuration	Exhaust	Measurement location number (note 1)								8 Position average
		1	2	3	4	5	6	7	8	
Unhoused - remote cooled	Infinite	94.5	100.2	98.2	98.9	95.3	100.5	100.5	99.2	98.9
Unhoused - high ambient cooling system	Infinite	94.6	101.0	101.0	100.6	96.4	101.2	100.0	102.5	100.2
Unhoused - enhanced high ambient cooling system	Infinite	96.4	101.9	101.1	101.4	99.7	101.8	103.1	100.9	101.1

Generator Set Configuration

Engine Exhaust Configuration

Position of one sound pressure level measurement.

Note:

1. Position 1 faces the generator front per ISO 8528-10. The positions proceed around the generator set in a counter-clockwise direction in 45° increments. All positions are at 7 m (23 ft) from the surface of the generator set and 1.2 m (48 in) from floor level.

Sound pressure level in dB(A) at given distance (7 meters) from source at noted position.

Average of 8 position measurements at given distance (7 meters).

Sound power level, dB(A)

See notes 2-4, 7 and 8 listed below

Configuration	Exhaust	Octave band center frequency (Hz)										Overall sound power level
		31.5	63	125	250	500	1000	2000	4000	8000	16000	
Unhoused - remote cooled	Infinite	67.2	86.9	106.9	110.7	118.1	119.7	120.6	118.9	124.4	100.7	128.1
Unhoused - high ambient cooling system	Infinite	72.5	89.9	113.5	118.4	121.2	122.0	121.8	118.7	124.0	99.3	129.4
Unhoused - enhanced high ambient cooling system	Infinite	72.4	90.0	116.4	120.0	123.3	122.9	122.1	119.7	124.3	101.2	130.3

Sound power level in dB(A) at noted frequency.

Overall sound power level – weighted sum of sound power level across measured frequencies.

Exhaust sound power level, dB(A)

See note 2 and 9 listed below

Open exhaust (no muffler) @ rated load	Octave band center frequency (Hz)										Overall power level
	31.5	63	125	250	500	1000	2000	4000	8000	16000	
	71.0	101.1	110.2	123.0	124.9	124.6	124.6	125.2	123.7	104.1	132.2

Sound power level in dB(A) at noted frequency.

Overall sound power level – weighted sum of sound power level across measured frequencies.

Note:

1. Position 1 faces the generator front per ISO 8528-10. The positions proceed around the generator set in a counter-clockwise direction in 45° increments. All positions are at 7 m (23 ft) from the surface of the generator set and 1.2 m (48 in) from floor level.
2. Sound levels are subject to instrumentation, measurement, installation and manufacturing variability.
3. Data based on full rated load. Sound data with remote-cooled generator sets are based on rated loads without cooling fan noise.
4. Sound data for generator set with infinite exhaust do not include exhaust noise.
5. Sound pressure levels are measured per ANSI S1.13 and ANSI S12.18, as applicable.
6. Reference sound pressure is 20 μPa .
7. Sound power levels per ISO 3744 and ISO 8528-10, as applicable.
8. Reference power = 1 pw (10^{-12}W).
9. Exhaust sound power levels are per ISO 6798, as applicable.

Concept Check – Interpreting Data

When reviewing sound data provided by a manufacturer, it is key to note which of the following:

- a) Generator Set Load
- b) Distance from Source to Point of Measurement
- c) Test Method
- d) Units of Measure (Power vs. Pressure)
- e) All of the Above

Sound pressure level @ 7 meters, dB(A)

See notes 1-6 listed below

Configuration	Exhaust	Measurement location number (note 1)								8 Position average
		1	2	3	4	5	6	7	8	
Unhoused - remote cooled	Infinite	94.5	100.2	98.2	98.9	95.3	100.5	100.5	99.2	98.9
Unhoused - high ambient cooling system	Infinite	94.6	101.0	101.0	100.6	96.4	101.2	100.0	102.5	100.2
Unhoused - enhanced high ambient cooling system	Infinite	96.4	101.9	101.1	101.4	99.7	101.8	103.1	100.9	101.1

Sound power level, dB(A)

See notes 2-4, 7 and 8 listed below

Configuration	Exhaust	Octave band center frequency (Hz)										Overall sound power level
		31.5	63	125	250	500	1000	2000	4000	8000	16000	
Unhoused - remote cooled	Infinite	67.2	86.9	106.9	110.7	118.1	119.7	120.6	118.9	124.4	100.7	128.1
Unhoused - high ambient cooling system	Infinite	72.5	89.9	113.5	118.4	121.2	122.0	121.8	118.7	124.0	99.3	129.4
Unhoused - enhanced high ambient cooling system	Infinite	72.4	90.0	116.4	120.0	123.3	122.9	122.1	119.7	124.3	101.2	130.3

Exhaust sound power level, dB(A)

See note 2 and 9 listed below

Open exhaust (no muffler) @ rated load	Octave band center frequency (Hz)										Overall power level
	31.5	63	125	250	500	1000	2000	4000	8000	16000	
	71.0	101.1	110.2	123.0	124.9	124.6	124.6	125.2	123.7	104.1	132.2

Note:

1. Position 1 faces the generator front per ISO 8528-10. The positions proceed around the generator set in a counter-clockwise direction in 45° increments. All positions are at 7 m (23 ft) from the surface of the generator set and 1.2 m (48 in) from floor level.
2. Sound levels are subject to instrumentation, measurement, installation and manufacturing variability.
3. Data based on full rated load. Sound data with remote-cooled generator sets are based on rated loads without cooling fan noise.
4. Sound data for generator set with infinite exhaust do not include exhaust noise.
5. Sound pressure levels are measured per ANSI S1.13 and ANSI S12.18, as applicable.
6. Reference sound pressure is 20 µPa.
7. Sound power levels per ISO 3744 and ISO 8528-10, as applicable.
8. Reference power = 1 pw (10⁻¹²W).
9. Exhaust sound power levels are per ISO 6798, as applicable.

Concept Check – Interpreting Data

When reviewing sound data provided by a manufacturer, it is key to note which of the following:

- a) Generator Set Load
- b) Distance from Source to Point of Measurement
- c) Test Method
- d) Units of Measure (Power vs. Pressure)
- e) All of the Above

Sound pressure level @ 7 meters, dB(A)

See notes 1-6 listed below

Configuration	Exhaust	Measurement location number (note 1)								8 Position average
		1	2	3	4	5	6	7	8	
Unhoused - remote cooled	Infinite	94.5	100.2	98.2	98.9	95.3	100.5	100.5	99.2	98.9
Unhoused - high ambient cooling system	Infinite	94.6	101.0	101.0	100.6	96.4	101.2	100.0	102.5	100.2
Unhoused - enhanced high ambient cooling system	Infinite	96.4	101.9	101.1	101.4	99.7	101.8	103.1	100.9	101.1

Sound power level, dB(A)

See notes 2-4, 7 and 8 listed below

Configuration	Exhaust	Octave band center frequency (Hz)										Overall sound power level
		31.5	63	125	250	500	1000	2000	4000	8000	16000	
Unhoused - remote cooled	Infinite	67.2	86.9	106.9	110.7	118.1	119.7	120.6	118.9	124.4	100.7	128.1
Unhoused - high ambient cooling system	Infinite	72.5	89.9	113.5	118.4	121.2	122.0	121.8	118.7	124.0	99.3	129.4
Unhoused - enhanced high ambient cooling system	Infinite	72.4	90.0	116.4	120.0	123.3	122.9	122.1	119.7	124.3	101.2	130.3

Exhaust sound power level, dB(A)

See note 2 and 9 listed below

Open exhaust (no muffler) @ rated load	Octave band center frequency (Hz)										Overall power level
	31.5	63	125	250	500	1000	2000	4000	8000	16000	
	71.0	101.1	110.2	123.0	124.9	124.6	124.6	125.2	123.7	104.1	132.2

Note:

1. Position 1 faces the generator front per ISO 8528-10. The positions proceed around the generator set in a counter-clockwise direction in 45° increments. All positions are at 7 m (23 ft) from the surface of the generator set and 1.2 m (48 in) from floor level.
2. Sound levels are subject to instrumentation, measurement, installation and manufacturing variability.
3. Data based on full rated load. Sound data with remote-cooled generator sets are based on rated loads without cooling fan noise.
4. Sound data for generator set with infinite exhaust do not include exhaust noise.
5. Sound pressure levels are measured per ANSI S1.13 and ANSI S12.18, as applicable.
6. Reference sound pressure is 20 µPa.
7. Sound power levels per ISO 3744 and ISO 8528-10, as applicable.
8. Reference power = 1 pw (10⁻¹²W).
9. Exhaust sound power levels are per ISO 6798, as applicable.

Testing Considerations

- At what load can the generator set be tested?
- Are there any other contributors to sound at the site? (load bank, ambient noise)
- Who is performing the measurements?
- When are the measurements being performed?
- What type of measurement equipment will be used to perform the validation testing?



Testing with Ambient Noise



If the ambient noise at the site is more than 10 dB(A) greater than the generator set, validating sound performance on site will present a challenge.

Adding decibels	
When the numerical difference in dB(A) between two noise levels is:	Add this dB(A) to the higher of the two noise levels for a total:
0	3.0
0.1 – 0.9	2.5
1.0 – 2.4	2.0
2.4 – 4.0	1.5
4.1 – 6.0	1.0
6.1 – 10	0.5
>10	0

Exhaust System Considerations

- Insulate:
 - Muffler(s)
 - Exhaust Piping
 - Flexible Bellows*
- Do Not Insulate:
 - Turbocharger(s)
 - Exhaust Manifold(s)



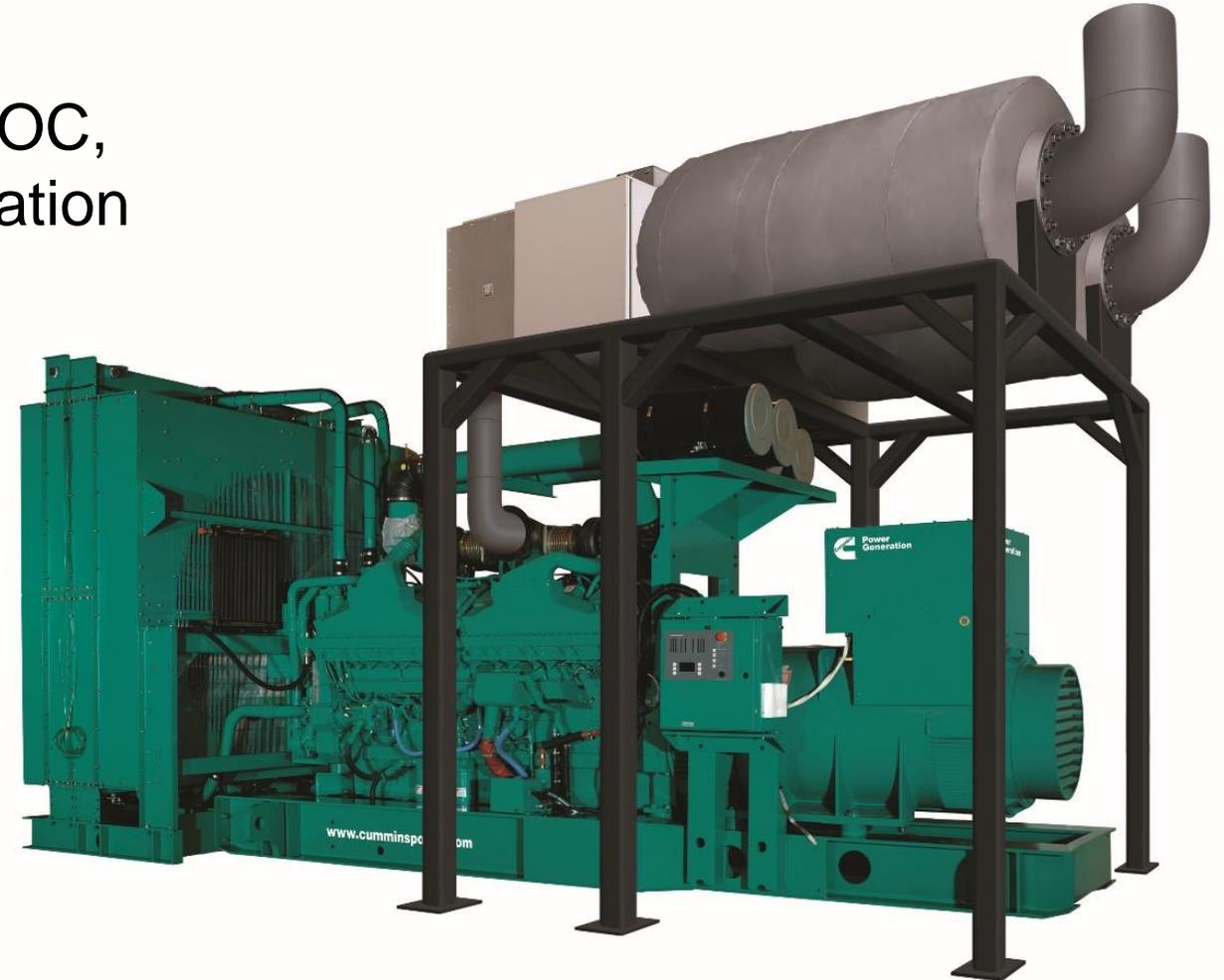
Silencer Application Impact

- Specifying an oversized silencer may lead to:
 - Additional (excessive) exhaust system restriction
 - Additional space claim for generator set(s)
 - Additional project cost
 - **Limited change in overall sound**



Impact of Exhaust Aftertreatment

- Exhaust aftertreatment (SCR, DPF, DOC, etc.) may have inherent sound attenuation properties.
- Exhaust aftertreatment may reduce available engine exhaust restriction.
- Additional engine exhaust sound attenuation may not be necessary – consult generator set manufacturer to verify product performance.



When looking at sound data, make sure to ask yourself...

- Were the generators tested at the same load/power node?
- Was the data collected in a comparable configuration? (e.g. 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?

Course Summary

Sound Attenuation and Test Strategies for Generator Set Installations

- Describe the fundamentals of acoustics relative to generator set installations.
- Identify appropriate strategies for specifying sound requirements and test methods.
- Recognize data provided by manufacturers that is most relevant to site noise limits.

Specify:

- Overall sound pressure level limits in dB(A) at a given distance (typically based on the property line).
- Test method and conditions used to validate performance on site (if applicable).

Avoid specifying:

- Sound reduction levels. (reduction from what?)
- Muffler and enclosure grades. (not consistent from one manufacturer to another)

Q&A

Type your questions, comments, feedback in the **WebEx Q&A box**. We will get to as many questions as we can
We will publish consolidated FAQ along with presentation and webinar recording on powersuite.cummins.com

Your local Cummins contacts:

- AZ, ID, NM, NV: Carl Knapp (carl.knapp@cummins.com), Rocky Mountain Region
- CO, MT, ND, UT, WY: Joe Pekarek (joe.a.pekarek@cummins.com), Rocky Mountain Region
- Northern IL, IA: John Kilinskis (john.a.kilinskis@cummins.com), Central Region
- UP of MI, MN, East ND, WI: Michael Munson (michael.s.munson@cummins.com), Central Region
- NB, SD, West MO, KS: Earnest Glaser (earnest.a.glaser@cummins.com), Central Region
- South IL, East MO: Jeff Yates (Jeffery.yates@cummins.com), Central Region
- TX: Scott Thomas (m.scott.thomas@cummins.com), Gulf Region
- FL, GA, SC, NC and Eastern TN: Robert Kelly (robert.kelly@cummins.com), South Region
- NY, NJ, CT, PA, MD: Charles Attisani (charles.attisani@cummins.com): East Region
- CA, HI: Brian E Pumphrey (brian.Pumphrey@cummins.com)
- WA, OR, AK: Tom Tomlinson (tom.tomlinson@cummins.com)
- For other states and territories, email powergenchannel@cummins.com or visit <http://power.cummins.com/sales-service-locator>

Closing

Visit powersuite.cummins.com for

PowerHour webinar recording, presentation and FAQ archive

Other Cummins Continuing Education programs

Sizing and spec development tool

Please contact Mohammed Gulam to request the PDH certificate the PowerHour webinar completed (mohammed.gulam@cummins.com)

