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POWER

SESSION HANDOUTS

Session 109034

Friday, October 23

2:00pm-3:15pm

Noise and Vibration Control for Building Electrical Systems

Chad N. Himmel

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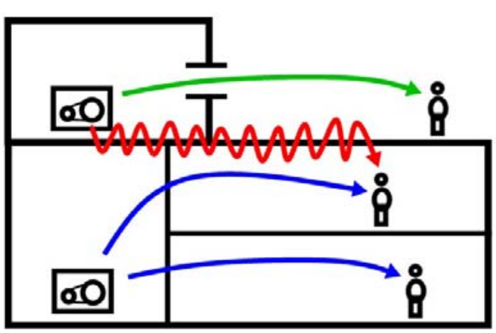
Chad N. Himmel, PE
JEAcoustics
1705 W Koenig Ln, Austin, TX 78756
himmel@jeacoustics.com

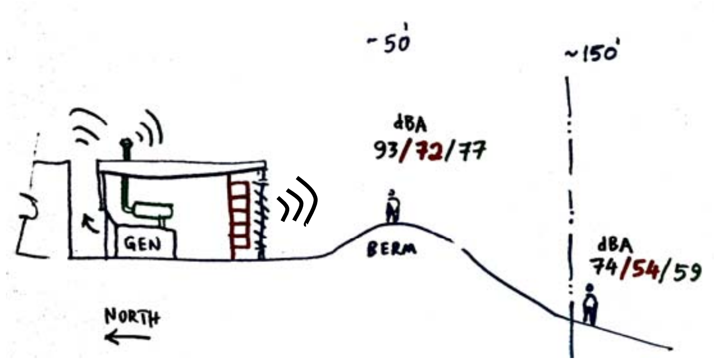
Power and electrical systems can be a source of unwanted noise and vibration for building occupants. This presentation discusses common problems, objective criteria, and solutions.

Noise and vibration paths and types in electrical systems:

- Airborne noise
- Structure borne / ground borne vibration
- Airborne noise that induces structure borne vibration
- Structure borne vibration that radiates as noise from building surfaces
- Electromagnetic (EM) and radio frequency (RF) interference
- Broadband noise and tonal noise
- Continuous noise and temporal/transient/changing noise



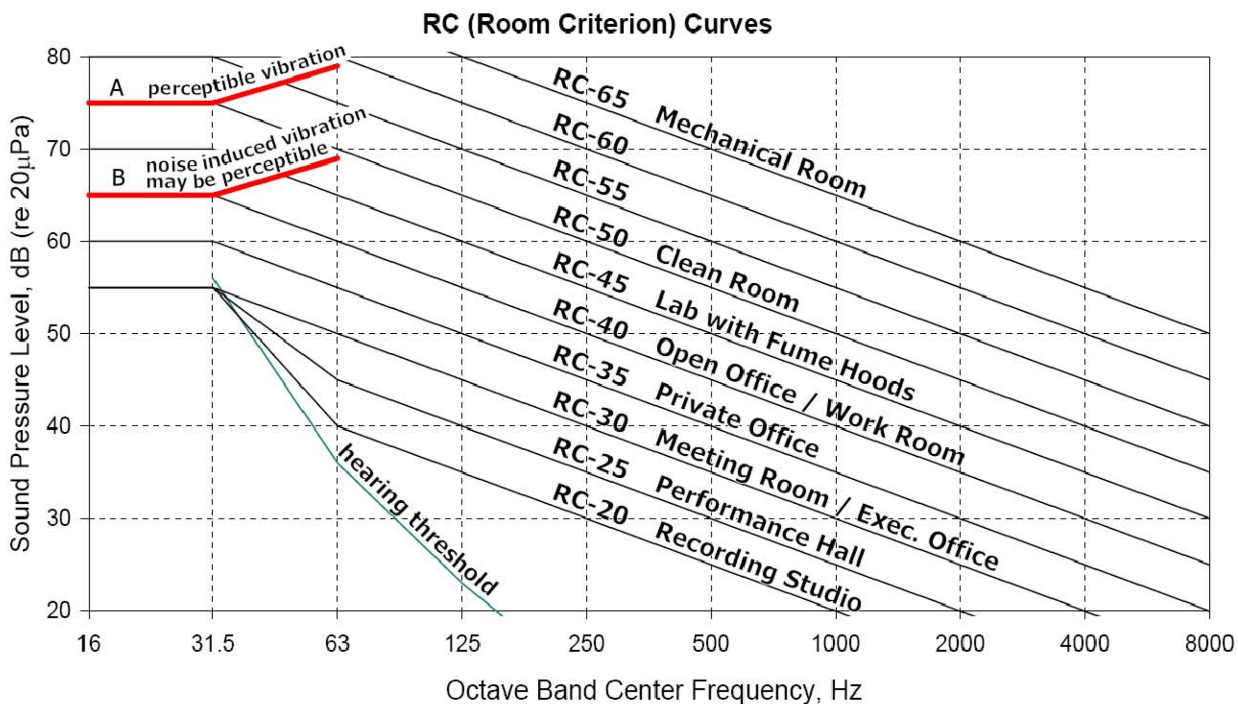
Source – Path – Receiver
INDOORS



Source – Path – Receiver
OUTDOORS

Standards and publications

The basis of many standards is to limit A-weighted (dBA) equipment noise levels. Effective noise control is difficult when based only on a manufacturer's dBA data. It is much better to evaluate the noise spectrum (16 Hz - 8000 Hz). ASHRAE provides guidelines for allowable spectral noise generated by building mechanical, electrical, and plumbing systems in terms of Room Criterion (RC) curves, below.



ASHRAE. 2007. American Soc. for Heating Refrigeration and Air Conditioning Engineers, HVAC Applications Handbook, Ch 47.

ANSI/ISO. 1986. 1680 Test Code for the Measurement of Airborne Noise Emitted by Rotating Electrical Machinery, Part 1 and Part 2.

NEMA, National Electrical Manufacturers Association

CMHC, Canada Mortgage and Housing Corporation

NEIS, National Electrical Installation Standards

NEC, National Electrical Code

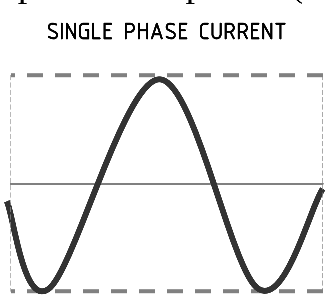
Electric motors

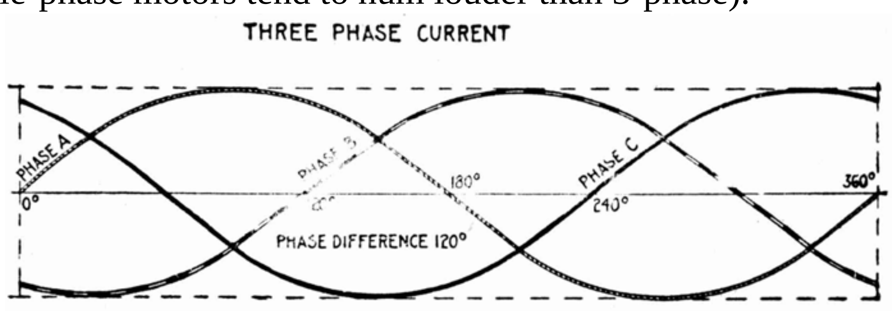
Most motors are quieter than the equipment they drive, but some can pose a noise and vibration concern separate from the driven equipment.

Motor noise levels depend mostly on the horsepower (hp) and rotating speed (rpm). Most motors that rotate at speeds greater than 1750 rpm will generate broadband noise. Motors rotating less than 1750 rpm can generate high-frequency tonal noise.

ODP (open drip proof) motors radiate noise from fan inlet/discharge openings located at both shaft ends.
TEFC (totally enclosed fan-cooled) motors may be "low noise" but still radiate noise from casing and fan noise from fan inlet/discharge openings.
Motors and motor enclosures must be ventilated, making a path for noise.
Motor silencers can be attached to enclosures or TEFC housings.

1-phase vs 3-phase: (single-phase motors tend to hum louder than 3-phase).





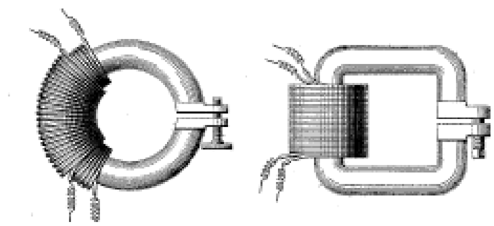
VFD (variable frequency drive) or VSD (variable speed drive):
The VFD system itself can generate a high-frequency whine, or it may also cause motors to whine, but this is rarely a problem compared to low-frequency noise generated by other equipment located in the same mechanical room.

Operations impact: VFD systems allow designers to oversize mechanical equipment, knowing they can always ramp down to a normal volume using a lower VFD setting. This can encourage designers to settle for a less efficient "normal" operating point, which tends to generate more equipment noise.

Transformers

Noise sources:

- Rattling and deformation of internal coils and laminated core generates a strong 120 Hz tone (airborne and structure borne noise).
- Internal vibration is radiated as tonal noise from sheet metal casing, or
- Noise and vibration is transmitted to building by rigid contact or close proximity of transformer and wall surfaces.



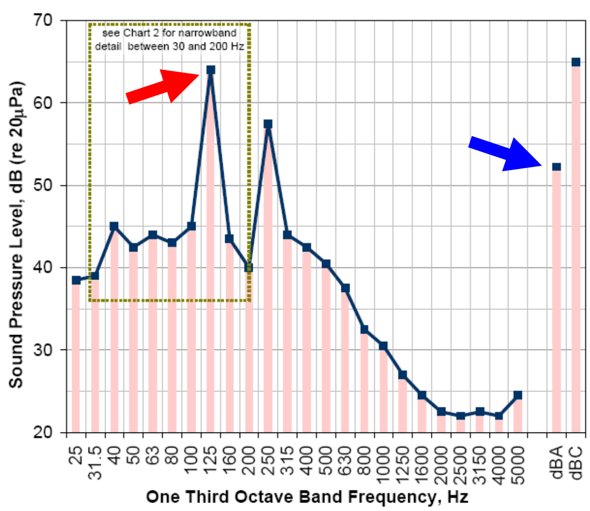


Chart 1. 1/3-octave band noise

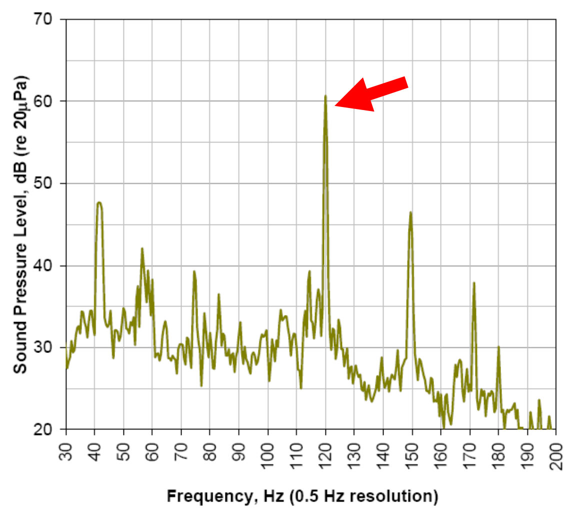


Chart 2. Narrowband noise levels

The NEMA standard for transformer noise levels in terms of A-weighted (dBA) values does not quantify low-frequency tonal noise content.

Note, in Chart 1 the tonal “spike” noise level at 125 Hz is well above 60 dB (red pointers), while the overall dBA value is only around 52 dBA (blue pointer).

Also similar to transformers: UPS (uninterruptible power supply) systems.

Wind turbines

Noise sources:

- Aerodynamic and blade noise (mid and low frequency; some infrasound)
- Mechanical sounds: airborne and structure borne noise from gearbox, generator, yaw drives, vent fans, and ancillary equipment

Noise variability with changing wind conditions and directions, and occurrence at nighttime, can be aggravating factors.

Regulations: a sample of wind turbine noise limits.

Place	**Noise Limit**
Benecia CA	55 dBA 300 feet from the tower
Lake County CA	55 dBA CNEL[1] at any property line
Monterey County CA	45 dBA at the property line
St Paul MN	50 dBA at the property line
Monterey County CA	45 dBA at the property line
Springettsbury PA	60 dBA at 75 ft from unit
Solano County CA	50 dBA CNEL at the property line in a residential zone or 60 dBA CNEL at any other property line
Guilford CT	55.4 to 65.4 dBA at the property line depending on background levels
Schaumburg IL	70 dBA to 31 dBA for 20 to 10000 Hz corrected for nighttime operation and periodic character
Topsfield MA	10 dBA above background
Santa Fe NM	Background level
Webster NY	Nighttime background level
Santa Clara CA	Sufficient to protect adjacent properties from physical damage and noise
Shawano County, WI	One-third octave band spectral limits within one mile

[1] The CNEL is the "Community Noise Equivalent Level," which is calculated as the 24-hour Leq weighted by adding 5 dB to sound levels between 7:00 PM and 10:00 PM and 10 dB to sound levels occurring between 10:00 PM and 7:00 AM.

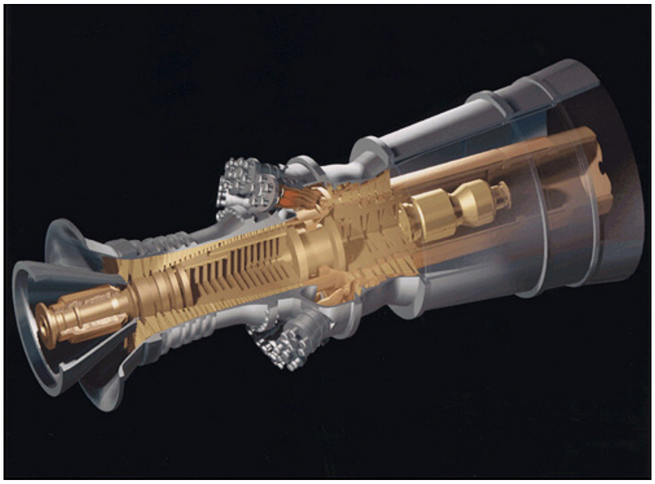
[2] Code of Federal Regulations 23 Part 772.

Gas turbines

Industrial turbines for electrical generation in central power plants or cogeneration.

Usually enclosed within a separate industrial building or within a sound attenuated enclosure (i.e., when installed outdoors or in an open yard).

Noise sources:
- Turbine casing noise and vibration (airborne and structure/ground borne)
- Vent openings and combustion exhaust stack discharge (airborne noise)


Turbine diagram


Inlet vent and exhaust stack




Turbine sections




Gearbox, generator, and alternator sections

Standby generators

Types:

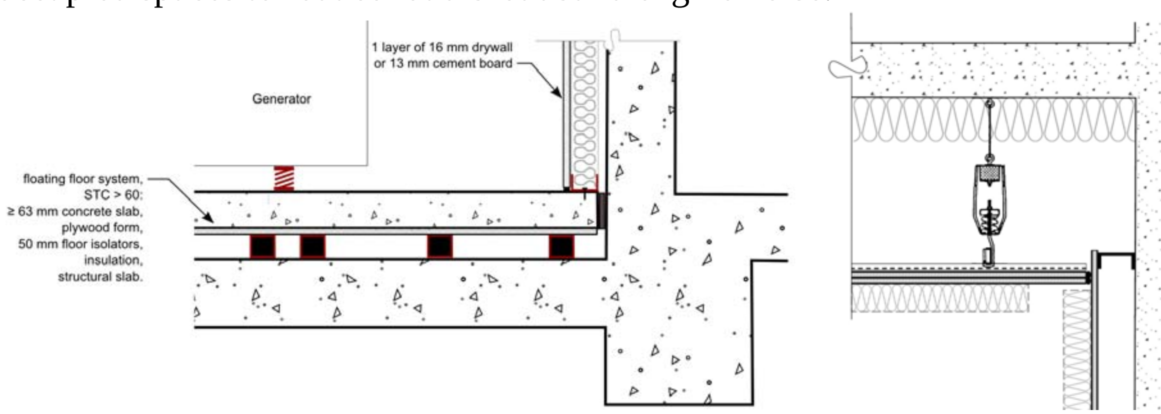
- Diesel fuel stored in tank or natural gas (or propane) supplied by utility.
- Un-housed or housed in an enclosure for weather resistance or noise control.
- Air-cooled with radiator, or fluid cooled with no radiator.
- Air-cooled engine with radiator fan attached.
- Air-cooled engine with “remote” radiator and fan.

The most common genset type architects will likely encounter is the air-cooled diesel power engine with radiator and fan, installed either indoors or outdoors.

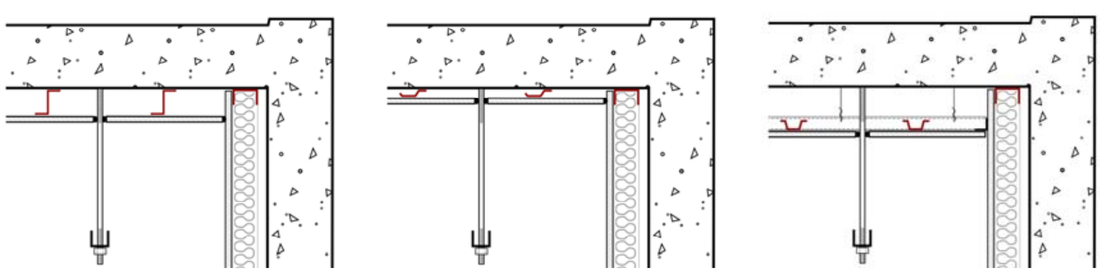
Noise sources:

- Engine casing: airborne and structure borne noise
- Radiator fan: airborne noise (and some structure borne)
- Exhaust stack: airborne noise (and some structure borne at pipe supports)

Massive, decoupled demising assemblies are a must for indoor installations near occupied spaces to reduce loud broadband engine noise.



Generator Room Floating Floor Slab and Floating Barrier Ceiling with Decoupled Wall Furring



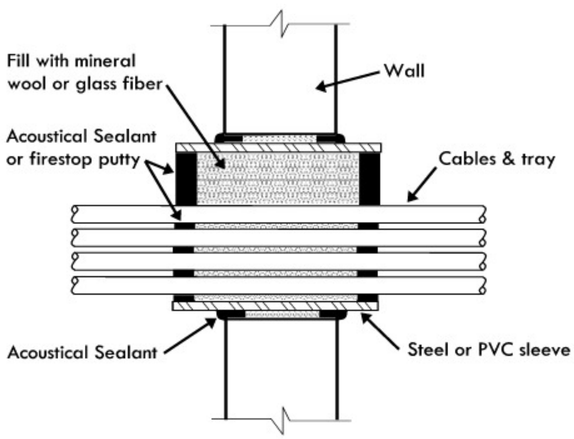
Furred Ceilings and Walls to Reduce Vibration Induced by Airborne Generator Noise

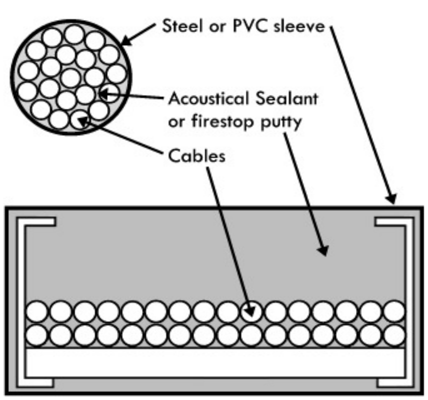
Lighting

Fluorescent lighting ballast noise (in very quiet spaces)
Dimmer rooms (and noise from ventilation/exhaust fans)
Small transformers within light fixture casings (low-level 120 Hz tone)

Wires, cables, conduit, and distribution layout

Large current transmissions can cause cables to wiggle or rattle against conduit or building structure, with audible impact noise.





Conduit and cable tray penetrations through walls create paths for unwanted sound transmission.

Electrical outlets back-to-back also allow sound transmission through walls.

Care is needed to identify and eliminate or seal these paths.

Conduit, even flexible conduit, can bridge gaps needed in acoustical walls and acoustical floor-ceiling assemblies or structural isolation joints.

Conduit can also bridge across equipment vibration isolation mounts.

Care is needed to identify bridging and coordinate new or alternative isolation measures.

Electromagnetic interference

Wires might travel near or through sensitive areas like electron microscopy that would be affected by electromagnetic interference (EMI). Shielding, in the form of copper sheet or foil enclosure, or active wire cage (Helmholtz or Faraday), needs to be designed into assemblies built around the sensitive installation.

Further reading

BASIC ACOUSTICS TEXTS
Kinsler, L., Frey, A., Coppens, A., & Sanders, J., Fundamentals of Acoustics, Wiley, New York, 1999. About $90. Probably the most widely used book to introduce engineering graduate students or advanced undergraduates to acoustics.

GENERAL ARCHITECTURAL ACOUSTICS
Irvine, L., & Richards, R., Acoustics and Noise Control Handbook for Architects and Builders, Krieger Publishing Co., Malabar, FL, 1998. About $45. By two acoustical consultants, concisely presents much useful information, including some discussion of community noise and industrial noise control.

Harris, C., Noise Control In Buildings - A Guide for Architects and Engineers, McGraw- Hill, Inc. 1994, republished by Institute of Noise Control Engineering, Poughkeepsie, NY, 199X. Edited by a pioneer in architectural acoustics, includes discussions of building materials, structures, and mechanical systems noise control.

HVAC NOISE AND VIBRATION CONTROL
Ebbing, C. & Blazier, W., Application of Manufacturers' Sound Data, ASHRAE, Atlanta, GA, 1998. About $45. Essential discussions of the source, use, and reliability of available data.

ASHRAE, HVAC Applications Handbook, Chapter 47 - Sound and Vibration Control, 2007. About $150. Most of the methodology needed to analyze and develop controls for HVAC systems.

NOISE CONTROL
Lord, H., Gatley, W., & Evensen, H., Noise Control for Engineers, Krieger Publishing Company, Melbourne, FL, 1980, reprinted 1987. About $55. Good text and reference on noise control.

Bell, L., & Bell, D., Industrial Noise Control - Fundamentals and Applications, 2nd Edition, Marcel Dekker, Inc.,

Bies, D., & Hansen, C., Engineering Noise Control Theory and Practice, Second Edition, E & FN Spon, London, 1996. About $75 in paperback. Theory and practical noise control including many special calculation techniques and methods of estimating noise. Metric system units. A comprehensive discussion of the theory of principles and concept of noise control. The authors provide a range of practical applications of current noise-control technology. The book provides a sound base to understanding and solving real-life problems.

Beranek, L., & Ver, I., (Editors), Noise and Vibration Control Engineering Principles and Applications, Wiley Interscience, New York, 1992. About $190. Latest in a series of classic references edited by Beranek. A cross between a textbook and a handbook.

Pelton, H., Noise Control Management, Van Nostrand Reinhold, New York, 1993. About $90. Includes discussions of the management and prioritization of noise control in industry as well as noise control methodology and case histories.

ENVIRONMENTAL NOISE
George E. Winzer, "Noise Assessment of Building Sites", Chapter 49 of *Handbook of Acoustical Measurements and Noise Control*, 3rd. ed., C.M. Harris (ed.), McGraw-Hill, Inc., New York, NY, 1991.

Dwight E. Bishop and Paul D. Schomer, "Community Noise Measurements", Chapter 50 of *Handbook of Acoustical Measurements and Noise Control*, 3rd. ed., C.M. Harris (ed.), McGraw-Hill, Inc., New York, NY, 1991.

http://en.wikipedia.org/wiki/Transformer
http://www.jeacoustics.com/library/pdf/SFA_1610-JBE.pdf
http://www.jeacoustics.com/library/pdf/Evans-n05_212P.pdf
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