Sound Advice
Presented by

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What You Will Learn

- Sound power vs sound pressure
- Sound quality
- AHRI 880/885
- NC vs RC
- Liner effects
- Installation effects
Sound Power vs Sound Pressure

- Sound power is the total sound energy produced.
- Sound pressure is the sound level that results after some sound energy is lost to the environment.
- If 80 dB is produced but only 70 dB is measured, the difference is a 10 dB room effect or attenuation.
The decibel (dB) is measured against a frequency and averaged into octave bands.

<table>
<thead>
<tr>
<th>Center Frequency</th>
<th>63</th>
<th>125</th>
<th>250</th>
<th>500</th>
<th>1000</th>
<th>2000</th>
<th>4000</th>
<th>8000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Band Designation</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
</tr>
</tbody>
</table>
Octave Bands

- Sound room size & design can affect octave band
  1 & 8 readings

- Speech interference bands

- Typically report octave bands 2-7 only
Decibel Addition

To add two decibel values:

\[
80 \text{ dB} + 74 \text{ dB} = 154 \text{ dB}
\]
Decibel Addition

To add two decibel values:

\[ 80 \text{ dB} + 74 \text{ dB} = 154 \text{ dB} \] (Incorrect)
To add two decibel values:

\[
\begin{align*}
80 \text{ dB} \\
-74 \text{ dB} \\
= 6 \text{ dB}
\end{align*}
\]

Difference in Values: 6 dB

From Chart: Add 1.0 dB to higher Value

\[
\begin{align*}
80 \text{ dB} \\
+ 1 \text{ dB} \\
\hline
81 \text{ dB} \quad \text{(Correct)}
\end{align*}
\]
Good to Know

- Any sound source 10 dB lower than background level will not be heard.
- Add 3 dB (or 3 NC) to double a sound source.
  - Two NC40 terminal units over an office would likely create an NC43 sound level.
  - Two NC20 diffusers in a room would create at most a sound level of NC23 (if they are close together).
  - Don’t try to add-up dissimilar products in this manner.
### Equation for sound power changes = $10 \log_{10} n$

<table>
<thead>
<tr>
<th>Fan Configuration</th>
<th>vs. Fan Configuration</th>
<th>$n$</th>
<th>Additional dB</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Fan on</td>
<td>vs. 2 Fans on</td>
<td>2</td>
<td>Add 3 dB</td>
</tr>
<tr>
<td>1 Fan on</td>
<td>vs. 4 Fans on</td>
<td>4</td>
<td>Add 6 dB</td>
</tr>
<tr>
<td>1 Fan on</td>
<td>vs. 10 Fans on</td>
<td>10</td>
<td>Add 10 dB</td>
</tr>
<tr>
<td>1 Fan on</td>
<td>vs. 100 Fans on</td>
<td>100</td>
<td>Add 20 dB</td>
</tr>
<tr>
<td>50 Fans on</td>
<td>vs. 100 Fans on</td>
<td>2</td>
<td>Add 3 dB</td>
</tr>
</tbody>
</table>
Proximity To Sound Sources

- Would you really expect to hear 100 fans running at the same time?
- Properly selected diffusers shouldn’t be heard from more than 10 feet away.
- Although there may be multiple diffusers in a space, it’s unlikely that more than one or two are within 10 feet of an occupant.
- We would only expect to be able to hear a 10 foot section of continuous linear diffuser from any single location.
For High Frequencies

- 1 dB  not noticeable
- 3 dB  just perceptible
- 5 dB  noticeable
- 10 dB twice as loud
- 20 dB four times as loud
For Low Frequencies

- 3 dB noticeable
- 5 dB twice as loud
- 10 dB four times as loud
Both tones are equally loud

65 dB @ 63 Hz

40 dB @ 1000 Hz
## Acoustic Quality

<table>
<thead>
<tr>
<th>Not too quiet</th>
<th>Don’t destroy acoustic privacy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not too loud</td>
<td>Avoid hearing damage</td>
</tr>
<tr>
<td></td>
<td>Don’t interfere with speech</td>
</tr>
<tr>
<td>Not too annoying</td>
<td>No rumble, no hiss</td>
</tr>
<tr>
<td></td>
<td>No identifiable machinery sounds</td>
</tr>
<tr>
<td></td>
<td>No time modulation</td>
</tr>
<tr>
<td>Not to be felt</td>
<td>No noticeable wall vibration</td>
</tr>
</tbody>
</table>
Diffusers tested per ASHRAE Standard 70
Sound Tests

- Diffusers and grilles
  - Supply sound
  - Return/exhaust sound

ASHRAE
Terminal units tested per ASHRAE Standard 130
Sound Tests

- VAV terminals
  - Radiated sound
  - Discharge sound
Terminal unit performance rated per AHRI Standard 880

- Now includes new end reflection loss (ERL) correction that must be applied to discharge sound levels
What is end reflection?

- Occurs when sound source is ducted to room
- Noise reflected back to source
- Not captured in reverb room testing
- Deducted when estimating NC (??????)
- Can be calculated based on duct dimensions
AHRI Standard 885 provides sound path and attenuation values for

- Lined duct
- Ceiling materials
- Elbows
- Flex duct
- Etc
Sound Path Estimation

C = Casing Radiated and Induction Inlet
D = Discharge Sound
O = Outlet Generated Sound

SOUND POWER $L_w$
NC Chart

Approximate threshold of human hearing

OCTAVE BAND LEVEL – dB RE 0.0002 MICROBAR

MID - FREQUENCY, HZ

63   125  250  500  1K  2K  4K  8K

NC-70  NC-60  NC-50  NC-40  NC-30  NC-20
Typical NC Levels

- Conference Rooms $\leq$ NC30
- Private offices $\leq$ NC35
- Open offices = NC40
- Hallways, utility rooms, rest rooms $\leq$ NC45
- NC should match purpose of room
- Difficult to achieve less than NC30
- Select diffusers for NC20-25 (or less)
Terminal unit radiated NC values based on standard assumptions from AHRI 885 Appendix E

- 3 ft deep ceiling plenum with unbounded sides
- 5/8” thick, 20 lb/ft³, mineral fiber lay-in ceiling
Terminal unit discharge NC values are based on standard assumptions from Appendix E:
- 5 ft of 8x8” lined ductwork
- End reflection losses based on an 8” round diffuser neck
- 5 ft of 8” vinyl core flex duct
- 2500 ft³ room with listener 5 ft from diffuser
- Additional deductions based on division of flow as airflow
Diffuser NC values are based on a 10 dB room effect deduction in each octave band

- Typical medium office with 8-10 ft high lay-in ceiling, commercial carpet, sheetrock walls, and some office furniture
- 10 dB is a reasonable room effect deduction for the critical octave bands
- Critical octave bands are 4th (500 Hz), 5th (1000 Hz), and 6th (2000 Hz)
NC Plot

Octave Band Level dB RE 0.0002 Microbar

Approximate threshold of human hearing

NC rating given is NC-45 since this is highest point tangent to an NC curve
Specifying and unqualified NC value is an ‘open’ specification

Specifying an NC with specific path attenuation elements could result in acceptable sound quality

It is far preferable to set maximum allowable sound power levels than to specify NC
NC Plots

Approximate threshold of human hearing

Octave Band Level (dB RE 0.0002 Microbar)

NC-70
NC-60
NC-50
NC-40
NC-30
NC-20
What does NC35 sound like?
Region A
High probability that noise induced vibration levels in light wall and ceiling structures will be noticeable. Rattling of lightweight light fixtures, doors and windows should be anticipated.

Region B
Moderate probability that noise-induced vibration will be noticeable in lightweight light fixtures, doors and windows.
NC vs RC

Noise criteria

- Rates speech interference and puts limits on loudness
- Gives no protection for low frequency fan noise problems
- Stops at 63 Hz octave band
NC vs RC

- Room criteria
  - Includes the 31.5 Hz and 16 Hz octave bands
  - Indicates acoustical quality
Two Parts of RC

- Example – RC 40 N
- The number is the speech interference level
- The letter tells you speech quality
  - (N) = neutral spectrum
  - (R) = too much rumble
  - (H) = too much hiss
  - (V) = possible wall vibration
Who Uses RC?

- NC is preferred for equipment selection
- RC is preferred as an analysis tool
- Acoustical consultants will typically report whether or not equipment meets NC spec but will describe the resulting sound spectrum in terms of RC
- You should continue to see catalog application data in terms of NC
Attenuators

- Single duct
  - Equivalent to lined ductwork

- Dual duct
  - Provides temperature mixing, but little sound attenuation

- Fan powered
  - Lined elbow or “boot” may provide 2dB attenuation by removing line of sight to motor
  - Carefully engineered attenuators can provide additional sound reductions
Silencers

- Must be tested with terminal unit
  - Don’t assume that silencer will provide published sound reduction
  - A silencer could actually increase noise!

- Silencers are tested to a different standard
  - Silencers work when applied as intended
  - They perform differently when close coupled
Liners

- Softer and thicker liners tend to absorb sound
  - Lower discharge sound
- Harder or more dense liners tend to block or reflect sound
  - Lower radiated sound
  - Higher discharge sound
- Lining effects on fan-powered products can be hard to predict
Ideal Terminal Unit Installation

- 3 duct diameters of straight duct
- 4 ft before diffusers
- Lined flex duct to diffusers
- <2000 fpm
- Maximize height above ceiling
- Lined ductwork
- Flexible connectors at inlet & discharge of fan boxes
Diffuser Installation

- Locate balancing dampers at branch takeoff
- Keep flexible duct bends as gentle as possible
  - Flex duct is a great attenuator of upstream noise sources
- Keep duct velocities as low as possible
  - But over-sizing can result in higher thermal loss
NC remains the preferred sound specification
RC is often used after-the-fact
Specified max sound power levels are safest
Lining materials affect sound levels
Careful selection, design and installation are required to avoid problems.

AHRI Standard 885 can be used to estimate sound path effects.

Multiple sound paths must be considered.

Open ceilings require adjustments to catalog data.