Basics of Fan Noise

AMCA *insite* ™ Webinar Series | AMCA International | www.amca.org

Scott Arnold

Content Manager, AMCA International

Webinar Moderator

- Joined AMCA in 2017
- Leads development and publication of technical articles, white papers and educational materials.
- Editor-in-chief of the award-winning *AMCA inmotion* magazine.

Introductions & Guidelines

- Participation Guidelines:
  - Audience will be muted during the webinar.
  - Questions can be submitted anytime via the GoToWebinar platform and will be addressed at the end of the presentation.
  - Reminder: This webinar is being recorded!
  - To earn PDH credit for today, please stay clicked onto the webinar **for the entire hour**.
  - A post-webinar evaluation will be emailed to everyone within one day, and it <u>must</u> be completed to qualify for today's PDH credit.
  - Every person that wants to receive PDH credit must be individually registered. If people are watching in a group and want credit, please contact Lisa Cherney (*lcherney@amca.org*) for a group sign-in sheet.

Q & A

To submit questions:

- From the attendee panel on the side of the screen, select the "Questions" drop down option.
- Type your question in the box and click "Send".

- Questions will be answered at the end of the program.

AMCA International has met the standards and requirements of the Registered Continuing Education Program. Credit earned on completion of this program will be reported to RCEP at RCEP.net. A certificate of completion will be issued to each participant. As such, it does not include content that may be deemed or construed to be an approval or endorsement by the RCEP.

Attendance for the entire presentation AND a completed evaluation are required for PDH credit to be issued.

COPYRIGHT MATERIALS

Rad Ganesh

Director, Product Applications,
AMCA Member Company

- Over 32 years of experience in the Movement (HVAC and Fan) industries.
- Currently has 6 patents and 5 pending patent applications.
- Very actively involved with AMCA and ASHRAE, on committees, contributing to publications and giving presentations.
- Earned Ph.D. in Mechanical Engineering and is a registered P.E. in Wisconsin.

Basics of Fan Noise

Purpose and Learning Objectives

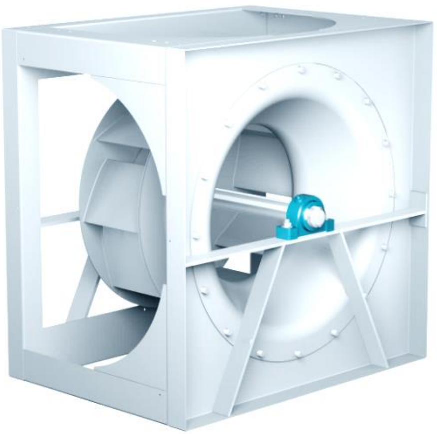
The purpose of this presentation is to educate industry professionals about the Basics of Fan Noise and the ratings published by various fan manufacturers. This session complements the previous AMCA webinar on ‘Environmental Noise due to Fans and Equipment’.

At the end of this presentation you will be able to:

1. Explain the basic definitions related to fan noise.
2. Identify the AMCA standards used for testing and rating fan noise.
3. Outline the difference between Sound Power Level (Lw), Sound Pressure Levels (Lp), and ‘A’ Weighting (dBA).
4. Describe the noise characteristics of various fan types.

Elements of Sound or Noise

- When air is moved, small, repetitive pressure disturbances are imparted to the air.
- When these pressure disturbances are sensed by a hearing mechanism (your ear), sound is created.



SOURCE

PATH

RECEIVER

Sound vs. Noise – Expectations

- In general, undesirable sound is called noise.
- Perception of sound ranges from ‘voodoo’ or ‘black magic’ to a perfect science by acousticians.
- Only definitions and basics of sound will be covered here.
  - *AMCA Sound Seminar, by Dr. Ralph T. Muehleisen*

Sound vs. Vibration

- The phenomena of sound and vibration are closely related.
- Sound is caused by pressure disturbances in an air or gas.
- Vibration is caused by disturbance of motion in a solid.
- Sound impacting a solid can impart a vibration
  - Ex: Rocket Launch vibrating windows and structures.
- The vibration of a solid can also result in sound.
  - Ex: Low Frequency Fan rumble

Sound Hearing Limits and Levels, dB(decibel)

Lower hearing Limit =

- 0.0000000002 bar =
- 0.0002 µbar =
- 0.00002 Pa =
- 0.0000000029 psi =
- 0.00000008 inches w.g.

Upper hearing Limit =

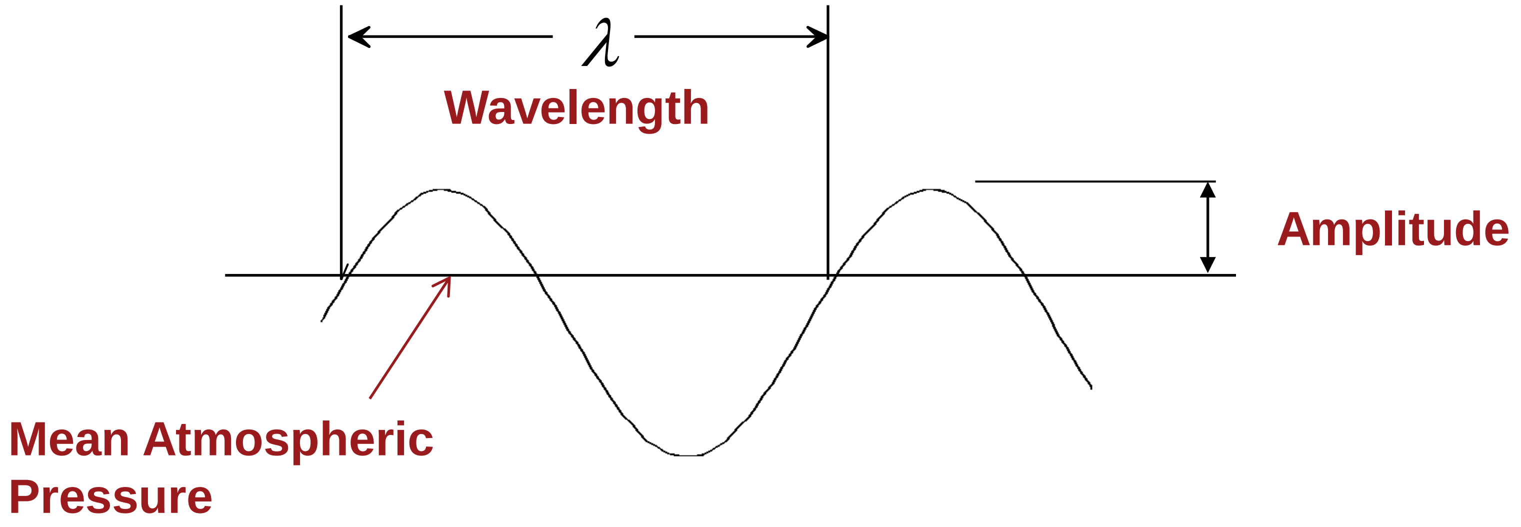
- 1.0 bar =
- 1,000,000 µbar =
- 100,000 Pa =
- 14.5 psi =
- 401 inches w.g.

Decibel, dB = 10 * log (dimensionless ratio of power or 'power like' quantities)

- $dB = 10 \log_{10} (W / Wref)$

Sound Amplitude

- **Amplitude** – Amount pressure oscillations deviate about the mean.
- **Wavelength** – Distance from peak-to-peak (or trough-to-trough)
  - Mean atmospheric pressure at standard conditions at sea level is 29.92 inches of Hg (~407 inches w.c. or 1,013,250 microbar)



Sound Frequency

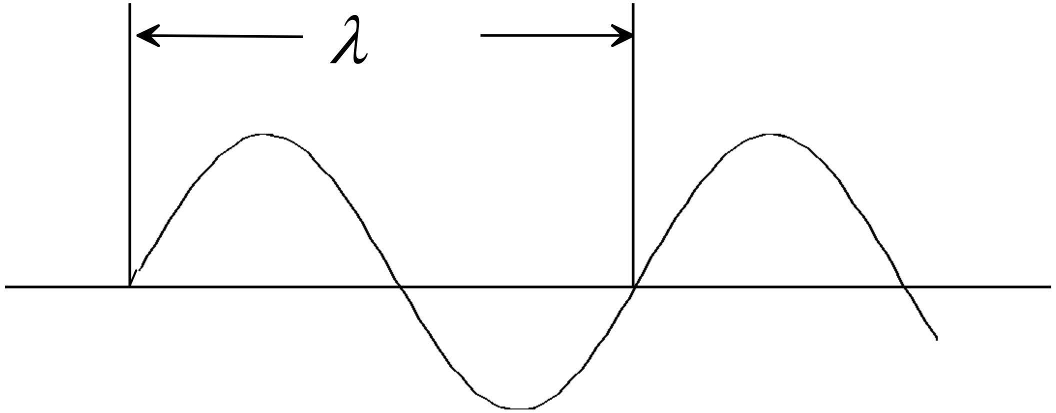
Frequency, f

- Number of pressure peaks per second t
- Measured in Hertz (Hz)

Speed of Sound,
c ~ 1100 ft/sec

Wavelength, λ

$$\lambda = c/f$$



FREQUENCY (f)	λ
100 Hz	3.5 m, ~10 ft.
1000 Hz	0.35 m, ~1 ft.
10,000 Hz	0.035 m, ~0.1 ft.

Sound Frequency

- Sound spectrum: The human ear is sensitive to frequencies between 20 and 20,000 Hz.
- For fans, frequencies between 45 and 11,000 Hz are of interest.
- Reasons the frequency characteristic of sound ratings is used:
  - Sound at different frequencies behaves differently
  - Human ear responds differently to different frequencies of sound

Octave Band Frequencies

- Audible sound is divided into 8 octave bands.
- Starting at 63 Hz, each succeeding octave band has a center frequency twice the previous band.
- Sound Level is defined for every fan operating point by a spectrum of frequencies as below:

Octave Bands	1	2	3	4	5	6	7	8
Frequency Range (Hz)	45 to 90	90 to 180	180 to 355	355 to 700	710 to 1400	1400 to 2800	2800 to 4600	5600 to 11200
Center Frequency (Hz)	63	125	250	500	1000	2000	4000	8000

Separating Octave Band Frequencies

- How do we analyze sound at different frequencies?
  - Electrical filters are used that allow only the frequencies within the desired octave band to pass through, while others are blocked.
  - When combined with a microphone and metering circuitry, you have a sound octave band analyzer.
- This method is incorporated into AMCA laboratory test standards.

Sound Power Level, Lw dB

Sound Power Level

- The acoustic power radiating from a source (often compared to the wattage of a light bulb).
- This value is NOT dependent on:
  - Location
  - Distance
  - Environment
- Sound power cannot be measured directly.
- Sound power is expressed in decibels with a reference level to 10^{-12} watts (or 1 Picowatt). It is the logarithmic ratio of 2 'power like' quantities:

Lw (dB) = $10\log_{10}$ (W / Wref)

Where, Wref = 1 pW = 10^{-12} Watts

Sound Power

Source	Typical Sound Power Level, Lw (dB re 1 pW)	Power (W)
Saturn Rocket	180	1,000,000
Turbojet engine with afterburner	170	100,000
Turbojet engine, 7000 lb thrust	160	10,000
4 Engine Propeller aircraft	140	100
75 piece orchestra	130	10
Large chipping hammer	120	1
Auto horn	110	.1
Radio	100	.01
Shouting voice	90	.001
Open Office	80	.0001
Conversational voice	70	.00001
Bedroom	60	.000001
Whisper	50	.0000001

Note that maximum wattage difference is 12 orders of magnitude!

Sound Pressure Level, Lp dB

Sound Pressure Level

- The amplitude of pressure oscillations at some location.
- Describes the loudness level of the sound
  (often compared to the brightness of a light bulb)
- This value IS dependent on:
  - Location
  - Distance
  - Environment
- Sound pressure CAN be measured directly using a handheld meter.
- Sound pressure is expressed in decibels with a reference level of 20 µPa:

$$Lp\ (dB) = 10\log_{10} (P^{2} / Pref^{2}) = 20\log_{10} (P / Pref)$$

Where, Pref = 20 m Pa

Sound Pressure

Typical sound pressure levels

PRESSURE (MICROBAR)	PRESSURE Level (db)	SOURCE (LONG TIME AVERAGE)
200,000	180	ROCKET LAUNCH AT PAD (3 PSI)
2,000*	140	JET PLANE *APPROX. 1* H2O
	130	THRESHOLD OF PAIN
200	120	THRESHOLD OF DISCOMFORT, LOUD BAND, RIVETING
	110	BLARING RADIO, AUTOMOBILE HORN
20	100	STEEL SAW
	90	PUNCH PRESS, AUTOMOBILE AT 40 MPH IN HEAVY CITY TRAFFIC
2	80	RELATIVELY QUIET FACTORY
	70	QUIET AUTOMOBILE, CONVERSATIONAL SPEECH
0.2	60	NOISY RESIDENCE (INSIDE)
	50	QUIET RESIDENCE (INSIDE)
0.02	30	QUIET WHISPER AT 5 FEET
0.002	20	ELECTRIC CLOCK
0.0002	0	THRESHOLD OF HEARING

A-Weighting

- A human’s ability to perceive sound varies with its frequency.
- ‘A’ weighting adjusts the sound power level for the response of the human ear – LwA.
- ‘A’ weighting is also used in the calculation of sound pressure levels – LpA.

A-Weighting Corrections

Band Center Frequency (Hz)	One-Third-Octave-Band Weightings (dB)	Octave-Band Weightings (dB)
50	−30.2	—
63	−26.2	−26.2
80	−22.5	—
100	−19.1	—
125	−16.1	−16.1
160	−13.4	—
200	−10.9	—
250	−8.6	−8.6
315	−6.6	—
400	−4.8	—
500	−3.2	−3.2
630	−1.9	—
800	−0.8	—
1,000	0.	0.
1,250	0.6	—
1,600	1.0	—
2,000	1.2	1.2
2,500	1.3	—
3,150	1.2	—
4,000	1.0	1.0
5,000	0.5	—
6,300	−0.1	—
8,000	−1.1	−1.1
10,000	−2.5	—

What is dB(A) or dBA?

- **A-weighted dB:**
  - A single value of the estimated sound level in a space (most commonly sound pressure)
  - Logarithmically combines all octave bands
  - At a given distance
  - Using a given directivity factor (Q=1, 2, 4, 8, etc.)

What is LwA?

- The 8-octave band sound power levels can be reduced to one number (LwA).
- The LwA value represents the logarithmic summation of all 8 octave band values, 'A weighted' to account for the response of the human ear.
  – Log summation: $L_w = 10 \log (10^{Lw1/10} + .. 10^{Lw8/10})$

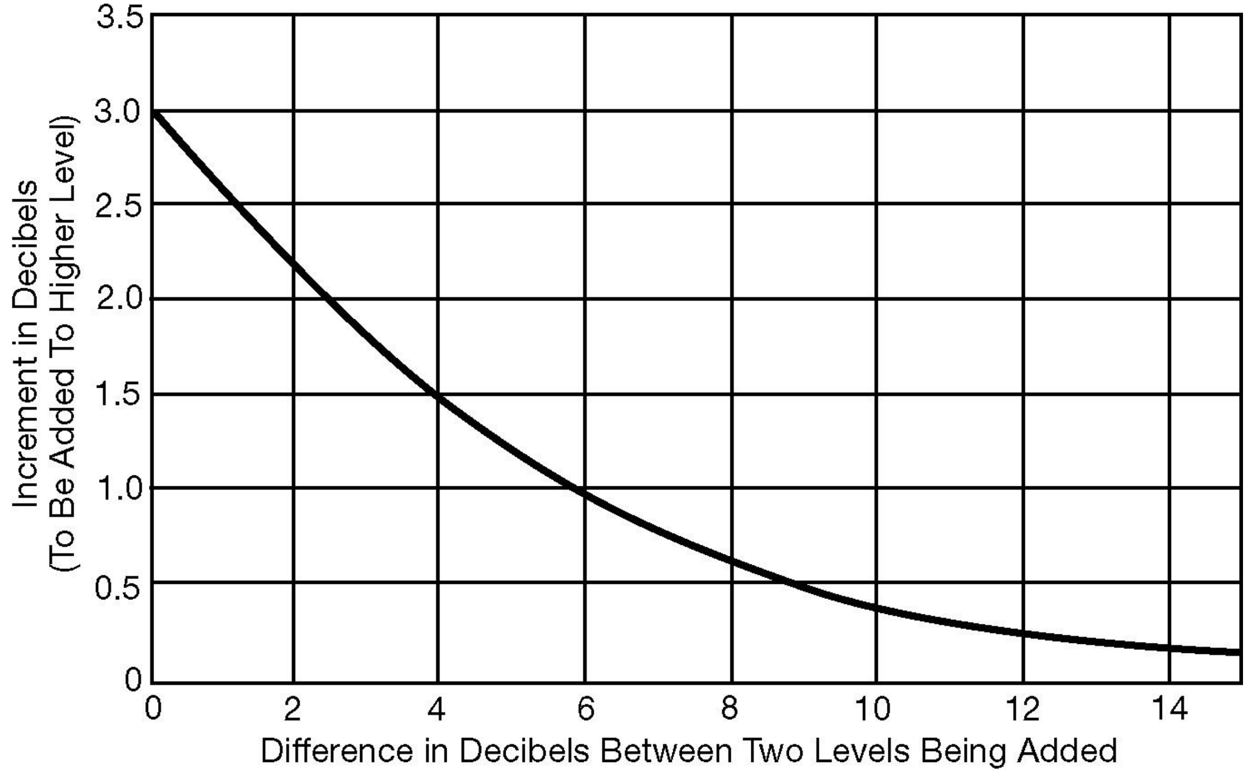
Row	Octave Band	1	2	3	4	5	6	7	8	LwA
1	Lw at Inlet	99	98	94	91	88	84	79	73	
2	A weighting	-26.2	-16.1	-8.6	-3.2	0	1.2	1	-1.1	
3	Lw A weighted	72.8	81.9	85.4	87.8	88	85.2	80	71.9	93

***Note**: Although Lw (row 1) in bands 1-3 are significantly higher than Lw A weighted (row 3) the human ear will always perceive the sound as LwA = 93. Thus it does not make too much sense in saying band 1 is 26 dB 'lower' or 'quieter' when 2 fans are compared.*

Chart for Combining Decibels

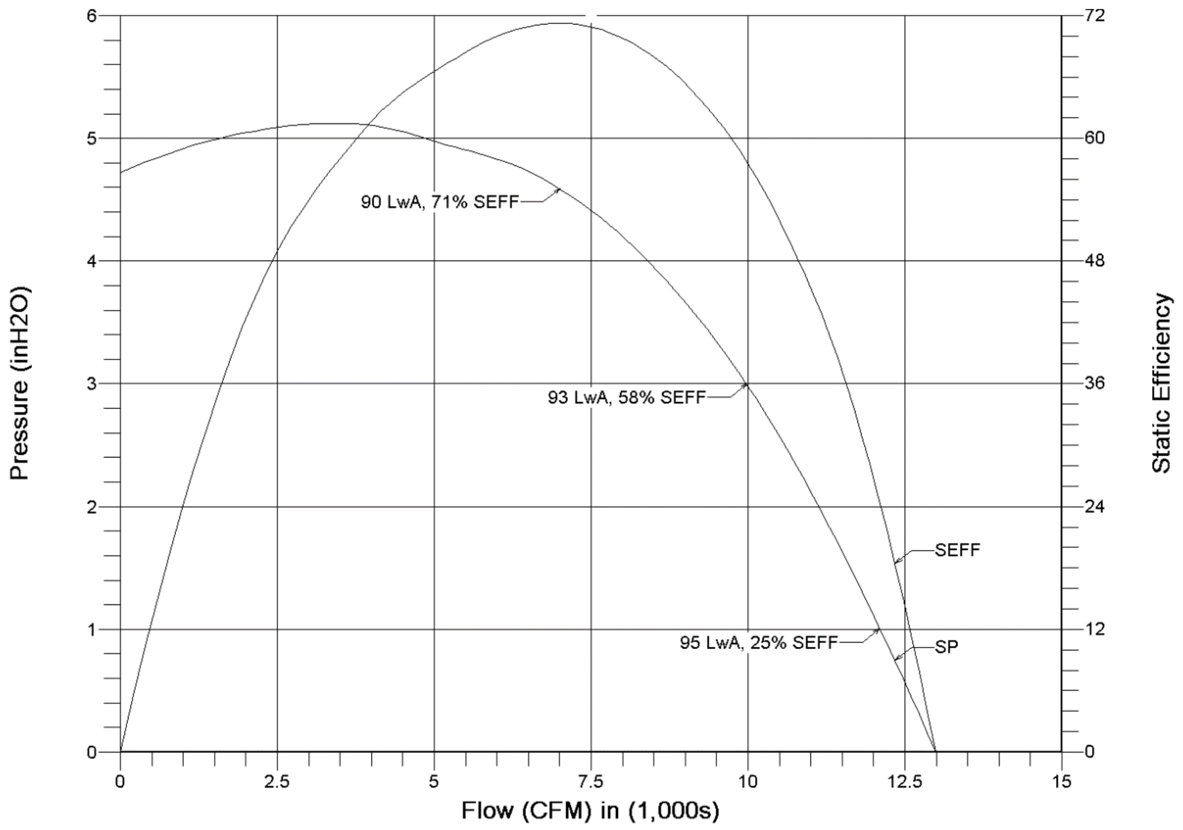
Sound Levels (dB) are combined by logarithmic addition

50 + 50 = 53 50 + 56 = 57 50 + 70 = 70



Point of Operation – LwA

LwA is commonly lowest at the most efficient operation point.



Size 24” dia, backward inclined centrifugal, 1500 RPM

What is a Sone?

- A sone is a unit of loudness and refers to Sound Pressure (Lp)
  - 1 sone is the loudness of Lp = 40 dB re 20μPa at 1KHz
- A value in sones doubles when the sound is perceived as twice as loud.
- An increase in sound pressure of 9-10 dB doubles the sone rating.
- Useful for comparing relative sound output of two fans
- Converts sound to a linear scale

Calculating Sones – Loudness Index

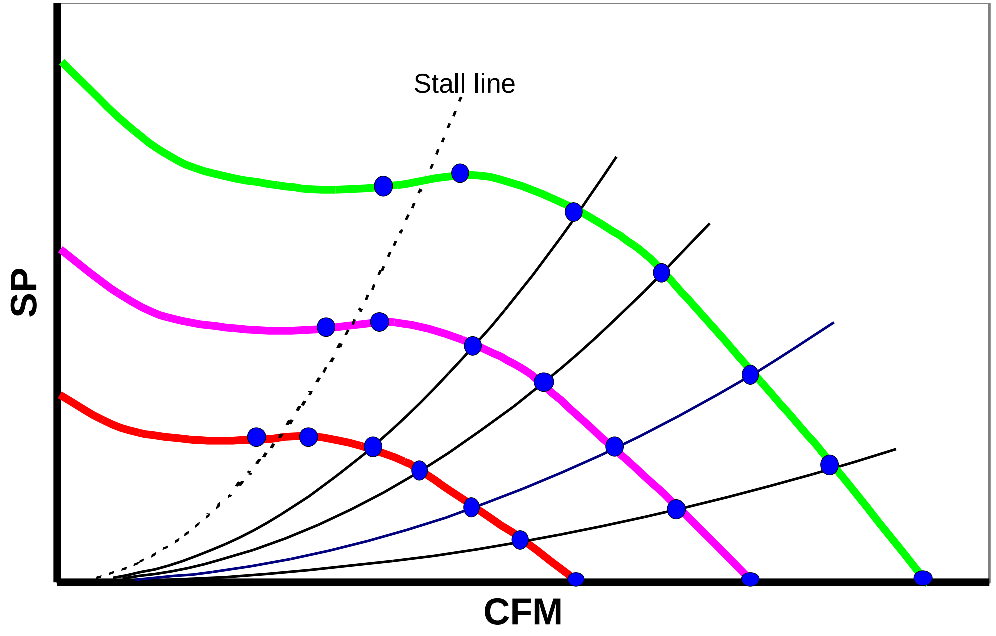
- From Lw determine Lp at 5 ft in a hemispherical free field using Lp=Lw-11.5
- For this Lp determine loudness indices from table for each octave band (s1-8)
- Overall Sone Level = $0.3*(s_1+s_2+s_3+s_4+s_5+s_6+s_7+s_8)+0.7*s_m$
- Where sm = max. level from s_1 to s_8

Lp	OCTAVE BAND							
	63	125	250	500	1000	2000	4000	8000
11								0.18
12							0.1	0.22
13							0.14	0.26
14							0.18	0.3
15						0.1	0.22	0.35
16						0.14	0.26	0.4
17						0.18	0.3	0.45
18					0.1	0.22	0.35	0.5
19					0.14	0.26	0.4	0.55
20					0.18	0.3	0.45	0.61
21					0.22	0.35	0.5	0.67
22					0.26	0.4	0.55	0.73
23				0.12	0.3	0.45	0.61	0.8
24				0.16	0.35	0.5	0.67	0.87
25				0.21	0.4	0.55	0.73	0.94
26				0.26	0.45	0.61	0.8	1.02
27				0.31	0.5	0.67	0.87	1.1
28				0.37	0.55	0.73	0.94	1.18
29			0.12	0.43	0.61	0.8	1.02	1.27
30			0.16	0.49	0.67	0.87	1.1	1.35
31			0.21	0.55	0.73	0.94	1.18	1.44
32			0.26	0.61	0.8	1.02	1.27	1.54
33			0.31	0.67	0.87	1.1	1.35	1.64
34			0.37	0.73	0.94	1.18	1.44	1.75
35		0.12	0.43	0.8	1.02	1.27	1.54	1.87
36		0.16	0.49	0.87	1.1	1.35	1.64	1.99
37		0.21	0.55	0.94	1.18	1.44	1.75	2.11
38		0.26	0.62	1.02	1.27	1.54	1.87	2.24
39		0.31	0.69	1.1	1.35	1.64	1.99	2.38
40		0.37	0.77	1.18	1.44	1.75	2.11	2.53
41	0.12	0.43	0.85	1.27	1.54	1.87	2.24	2.68
42	0.16	0.49	0.94	1.35	1.64	1.99	2.38	2.84
43	0.21	0.55	1.04	1.44	1.75	2.11	2.53	3
44	0.26	0.62	1.13	1.54	1.87	2.24	2.68	3.2
45	0.31	0.69	1.23	1.64	1.99	2.38	2.84	3.4
46	0.37	0.77	1.33	1.75	2.11	2.53	3	3.6
47	0.43	0.85	1.44	1.87	2.24	2.68	3.2	3.8
48	0.49	0.94	1.56	1.99	2.38	2.84	3.4	4.1
49	0.55	1.04	1.68	2.11	2.53	3	3.6	4.3
50	0.62	1.13	1.82	2.24	2.68	3.2	3.8	4.6
51	0.69	1.23	1.96	2.38	2.84	3.4	4.1	4.9
52	0.77	1.33	2.11	2.53	3	3.6	4.3	5.2
53	0.85	1.44	2.24	2.68	3.2	3.8	4.6	5.5
54	0.94	1.56	2.38	2.84	3.4	4.1	4.9	5.8
55	1.04	1.68	2.53	3	3.6	4.3	5.2	6.2
56	1.13	1.82	2.68	3.2	3.8	4.6	5.5	6.6
57	1.23	1.96	2.84	3.4	4.1	4.9	5.8	7
58	1.33	2.11	3	3.6	4.3	5.2	6.2	7.4
59	1.44	2.27	3.2	3.8	4.6	5.5	6.6	7.8
60	1.56	2.44	3.4	4.1	4.9	5.8	7	8.3
61	1.68	2.61	3.6	4.3	5.2	6.2	7.4	8.8
62	1.82	2.81	3.8	4.6	5.5	6.6	7.8	9.3
63	1.96	3	4.1	4.9	5.8	7	8.3	9.9
64	2.11	3.2	4.3	5.2	6.2	7.4	8.8	10.5
65	2.27	3.5	4.6	5.5	6.6	7.8	9.3	11.1

Lp	OCTAVE BAND							
	63	125	250	500	1000	2000	4000	8000
66	2.44	3.7	4.9	5.8	7	8.3	9.9	11.8
67	2.61	4	5.2	6.2	7.4	8.8	10.5	12.6
68	2.81	4.3	5.5	6.6	7.8	9.3	11.1	23.5
69	3	4.7	5.8	7	8.3	9.9	11.8	14.4
70	3.2	5	6.2	7.4	8.8	10.5	12.6	15.3
71	3.5	5.4	6.6	7.8	9.3	11.1	13.5	16.4
72	3.7	5.8	7	8.3	9.9	11.8	14.4	17.5
73	4	6.2	7.4	8.8	10.5	12.6	15.3	18.7
74	4.3	6.6	7.8	9.3	11.1	13.5	16.4	20
75	4.7	7	8.3	9.9	11.8	14.4	17.5	21.4
76	5	7.4	8.8	10.5	12.6	15.3	18.7	23
77	5.4	7.8	9.3	11.1	13.5	16.4	20	24.7
78	5.8	8.3	9.9	11.8	14.4	17.5	21.4	26.5
79	6.2	8.8	10.5	12.6	15.3	18.7	23	28.5
80	6.7	9.3	11.1	13.5	16.4	20	24.7	30.5
81	7.2	9.9	11.8	14.4	17.5	21.4	26.5	33
82	7.7	10.5	12.6	15.3	18.7	23	28.5	35.3
83	8.2	11.1	13.5	16.4	20	24.7	30.5	38
84	8.8	11.8	14.4	17.5	21.4	26.5	33	41
85	9.4	12.6	15.3	18.7	23	28.5	35.3	44
86	10	13.5	16.4	20	24.7	30.5	38	48
87	10.8	14.4	17.5	21.4	26.5	33	41	52
88	11.7	15.3	18.7	23	28.5	35.3	44	56
89	12.6	16.4	20	24.7	30.5	38	48	61
90	13.6	17.5	21.4	26.5	33	41	52	66
91	14.7	18.7	23	28.5	35.3	44	56	71
92	16	20	24.7	30.5	38	48	61	77
93	17.3	21.4	26.5	33	41	52	66	83
94	18.7	23	28.5	35.3	44	56	71	90
95	20	24.7	30.5	38	48	61	77	97
96	21.4	26.5	33	41	52	66	83	105
97	23	28.5	35.3	44	56	71	90	113
98	24.7	30.5	38	48	61	77	97	121
99	26.5	33	41	52	66	83	105	130
100	28.5	35.3	44	56	71	90	113	139
101	30.5	38	48	61	77	97	121	149
102	33	41	52	66	83	105	130	160
103	35.3	44	56	71	90	113	139	171
104	38	48	61	77	97	121	149	184
105	41	52	66	83	105	130	160	197
106	44	56	71	90	113	139	171	211
107	48	61	77	97	121	149	184	226
108	52	66	83	105	130	160	197	242
109	56	71	90	113	139	171	211	260
110	61	77	97	121	149	184	226	278
111	66	83	105	130	160	197	242	298
112	71	90	113	139	171	211	260	320
113	77	97	121	149	184	226	278	
114	83	105	130	160	197	242	298	
115	90	113	139	171	211	260	320	
116	97	121	149	184	226	278		
117	105	130	160	197	242	298		
118	113	139	171	211	260	320		
119	121	149	184	226	278			
120	130	160	197	242	298			

Fan Sound Ratings

- Fan sound ratings are normally based on sound power levels.
  - These ratings are independent of the environment.
  - ANSI/AMCA test standard (300-14) and rating calculations (301-14) are used to establish sound power levels.



Example of AMCA Standard 300-14 Test Output

TEST NAME : 18CDD11

POINT OF OPERATION 1	SPS = 0.65 %WOV = 94	APS = 0.0 BP = 29.2	RPM = 2100 TI = 74.8	CFMest = 5439 Density = 0.072
POINT OF OPERATION 2	SPS = 2.5 %WOV = 77	APS = 2.41 BP = 29.2	RPM = 2100 TI = 74.8	CFMest = 4439 Density = 0.072
POINT OF OPERATION 3	SPS = 3.99 %WOV = 59	APS = 3.71 BP = 29.2	RPM = 2100 TI = 74.8	CFMest = 3399 Density = 0.072

AMCA BAND NO.	1	2	3	4	5	6	7	8
CENTER FREQUENCY (HZ)	63	125	250	500	1000	2000	4000	8000
Lwi 1	79	80	88	86	81	81	80	74
Lwi 2	79	80	91	83	78	77	73	72
Lwi 3	81	81	87	81	76	74	72	73

The following data have been converted to A weighted sound powers.

AMCA BAND NO.	1	2	3	4	5	6	7	8
CENTER FREQUENCY (HZ)	63	125	250	500	1000	2000	4000	8000
LwA 1	53	65	80	83	81	82	81	73
LwA 2	54	65	83	80	78	78	74	71
LwA 3	55	65	78	78	76	75	73	72

Total A weighted sound power.

LwtA 1 89
LwtA 2 87
LwtA 3 84

Sones at 5 feet.

SONES 1 = 28
SONES 2 = 25
SONES 3 = 22

0 POINTS ARE WITHIN 6 dB OF THE BACKGROUND

THIS TEST DATA OBTAINED IN A LABORATORY ACCREDITED BY AMCA FOR AMCA STANDARD 300, REVERBERANT ROOM METHOD FOR SOUND TESTING OF FANS. DATA IS NOT CERTIFIED BY AMCA

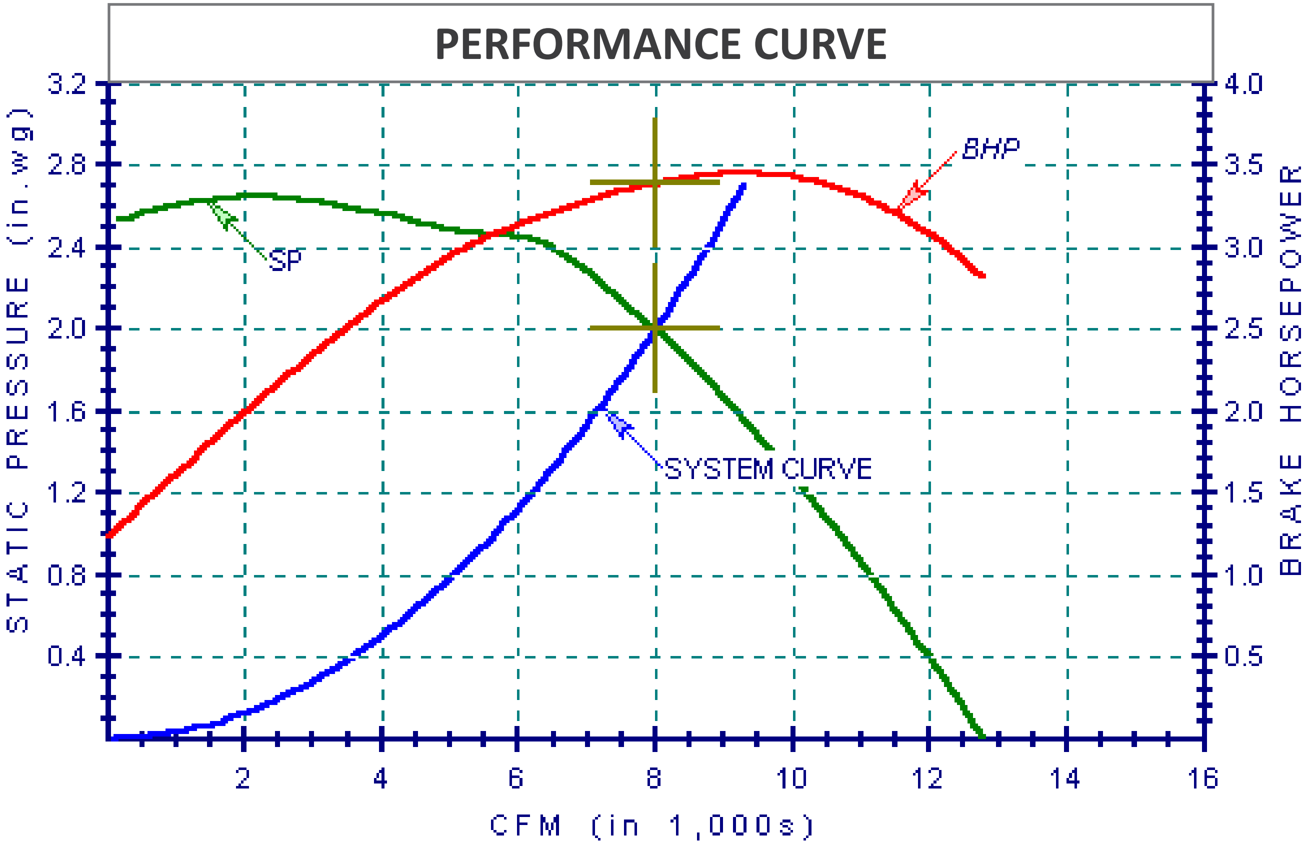
AMCA 300-14 Test Configurations

- **Typical Test Setups**
  - Total Sound (1)
  - Inlet Sound (2)
  - Outlet Sound (3)
  - Casing-Radiated Sound (SPECIAL)

- **Typical Test Installations**
  - A - Free Inlet, Free Outlet
  - B - Free Inlet, Ducted Outlet
  - C - Ducted Inlet, Free Outlet
  - D - Ducted Inlet, Ducted Outlet

Fan Sound Ratings – Example

Customer:	Fan Tag:
Job ID:	Model: 300 BAF-SW



CFM:	8,000
SP:	2 in.wg
RPM:	899
BHP:	3.39
Outlet Velocity:	1,547
Density:	0.075

Inlet Sound Power

Octave	Level
1	89
2	89
3	84
4	78
5	76
6	71
7	65
8	60

in db re 10^{-12} watts

4/19/02 15:41 #74

Fan Sound Specifications

- Fan sound specifications are normally based on sound pressure levels.
  - This value varies with the distance from the sound source and the environment surrounding the source.

- Sound specifications are intended to:
  - Limit annoyances
  - Prevent hearing and health damage
  - OSHA limit of 85 dBA for 8 hours is a pressure level

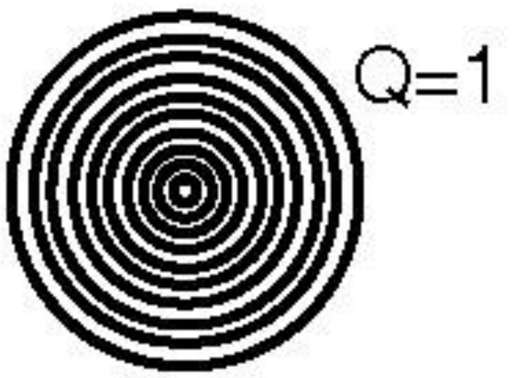
Determining Sound Pressure Levels

- **Can be a complicated calculation and is normally a job for an acoustician.**
  - Sound pressure varies with:
    - Distance
    - Reflectivity or absorption of surfaces
    - Number of nearby surfaces
    - Other sound sources
    - Frequency of the sound

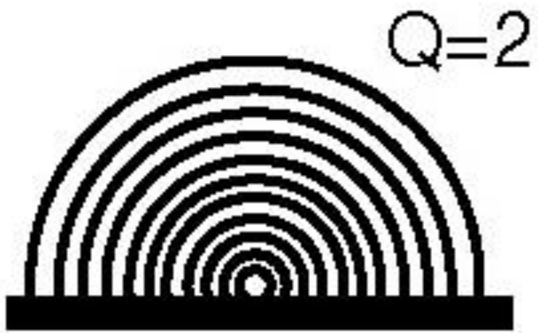
- **Sound pressure (dBA) can be estimated if the following values are known:**
  - Sound power level (LwA)
  - Directivity factor (Q)
  - Distance from source or sources (in feet)
  - Room constant (R)

Fan Sound Radiation

- Sound radiates spherically in the absence of reflective surfaces (Q=1).
- Sound radiates hemispherically with the presence of a single reflective surface (Q=2).



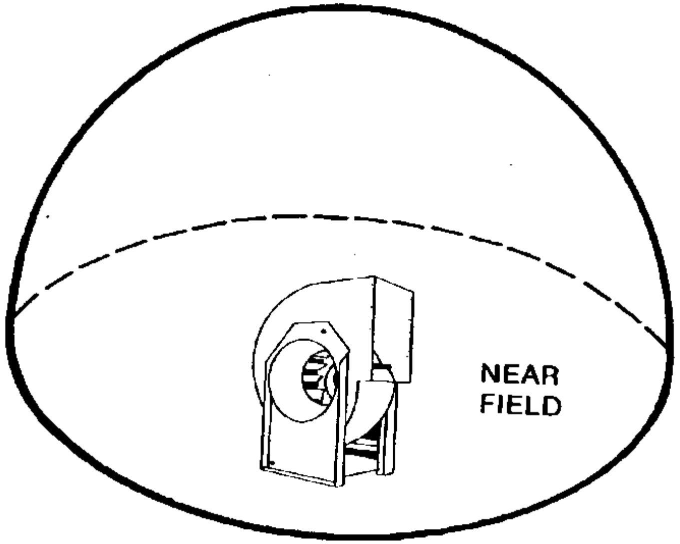
Uniform Spherical Radiation



Uniform Hemispherical Radiation

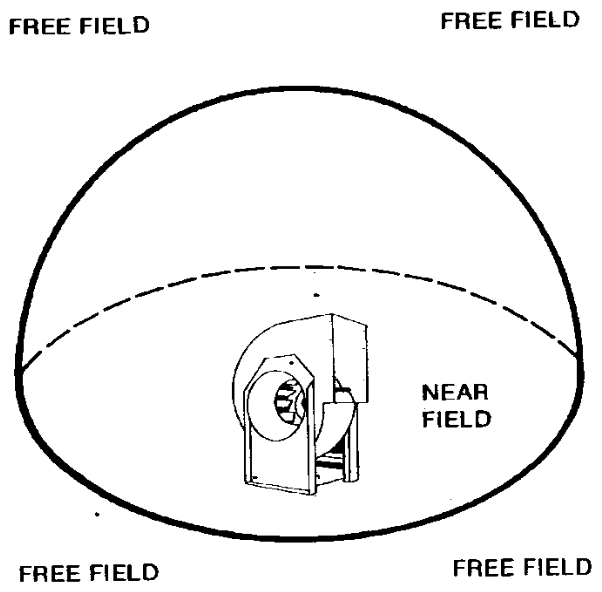
“Near Field” Conditions

- Near field conditions exist close to the fan.
- In the near field, sound generated at one area will tend to interfere with sound generated at other areas.
- Thus, near field measurements can be misleading.



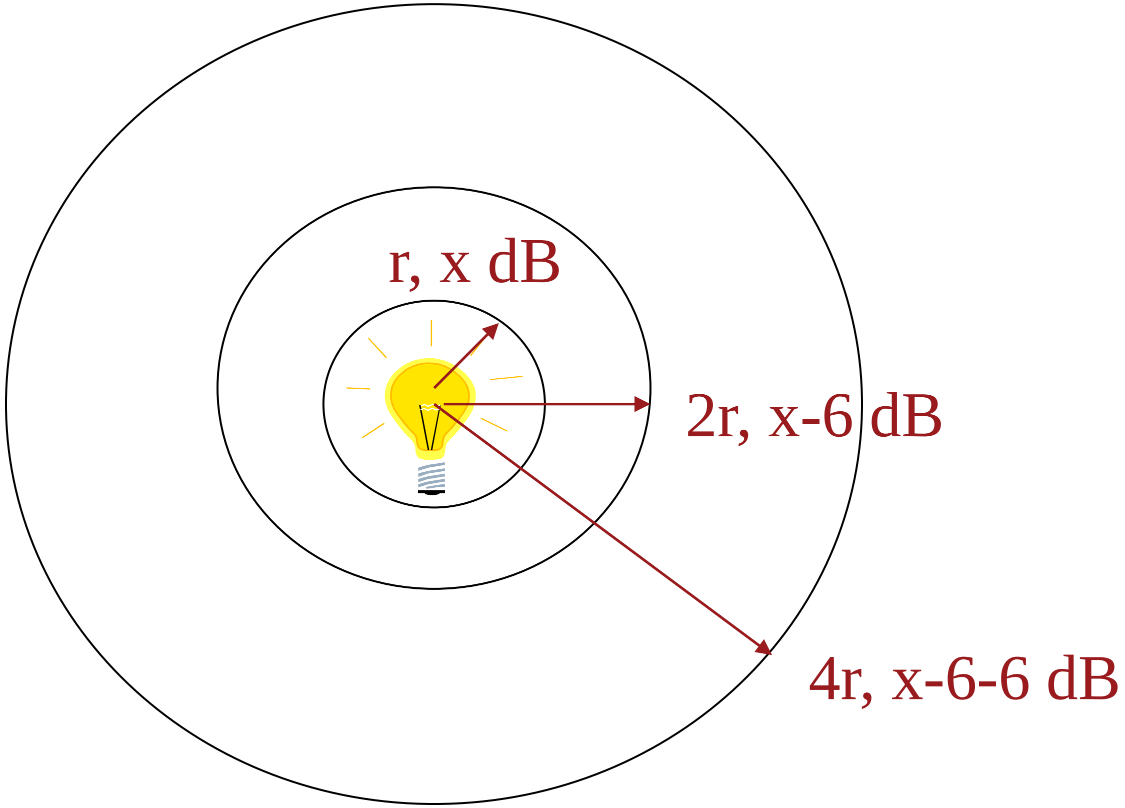
“Free Field” Conditions

- Free field conditions exist beyond the near field, considered to begin at least one wavelength away from fan.
- Free field sound radiates in a hemispherical pattern.



Sound Pressure

Sound pressure level will decay 6dB for each doubling of the distance from the fan.



“Reverberant Field” Conditions

- In a room, there are multiple reflective surfaces.
- The pressure will cease to decrease significantly beyond a certain distance.
- This area of relatively constant pressure is called the “reverberant field”.
- ANSI/AMCA Standard 300-14 Lp measurements require a reverberant field - similar to a sound lab.
- Lw (fan) is calculated from Lp (fan) by the method of substitution by using a calibrated reference sound source (RSS):

$$Lw\ (fan) = Lp\ (fan) + Lw\ (RSS) - Lp\ (RSS)$$

Directivity

Location

- Fans radiate varying sounds at different locations, despite being the same distance away.
- Being 3 feet in front of a speaker is louder than being 3 feet behind it.
- However, this effect is difficult to measure and usually ignored.

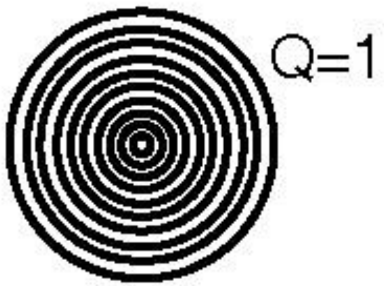
Reflective Surfaces

- Hard surfaces near the fan also affect directivity and are included in sound power estimates.
- It is usually assumed that all sound reflects, and that each additional wall doubles the pressure (adds 3 dB).

Directivity Factor

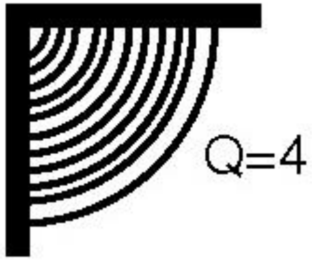
Number of reflective surfaces:

Q = 1 No reflecting surfaces (floating in ‘free space’)
Q = 2 One surface (commonly the floor)
Q = 4 Two surfaces (‘floating’ corner)
Q = 8 Three surfaces (‘fixed’ in a corner)



Uniform Spherical Radiation

Uniform Hemispherical Radiation



Uniform Radiation over 1/4 of Sphere

Typical Fan Application Installations

- Four types of typical fan application installations used for sound measurement reference: AMCA Publication 303-79):
  - Type A
  - Type B
  - Type C
  - Type D
- Note differences from test installations (AMCA 300-14).
- Sound critical applications require more refined methods.

Installation Type A

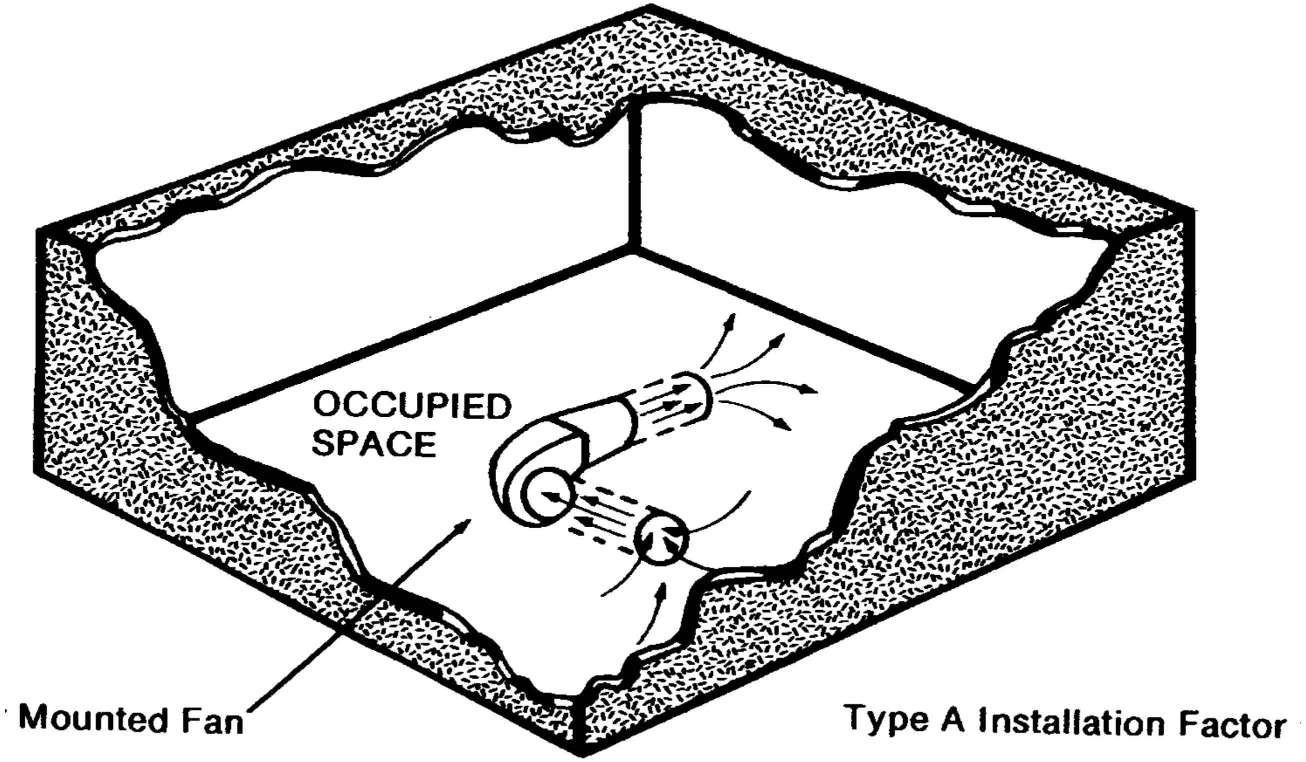
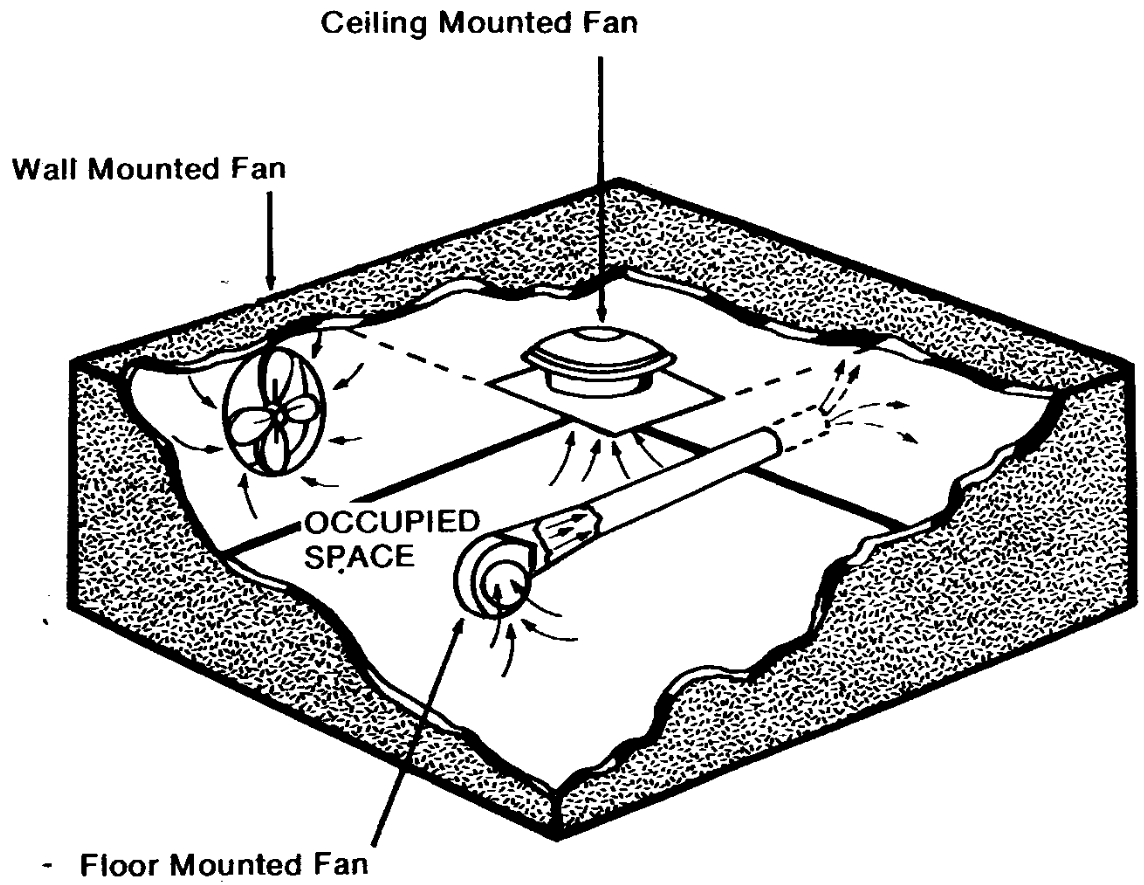


FIGURE 3

Installation Type B



Type B Installation = -3dB for ducted fans

= 0dB for non-ducted fans

FIGURE 4

Installation Type C

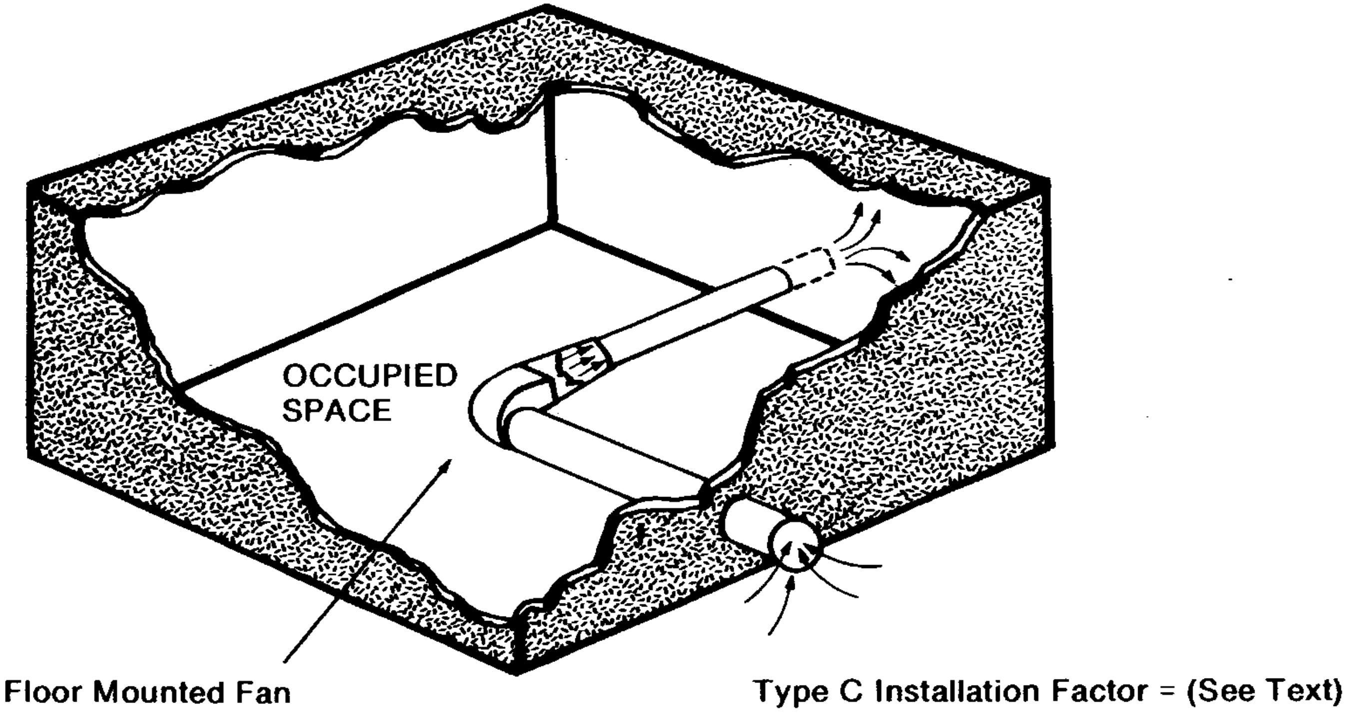
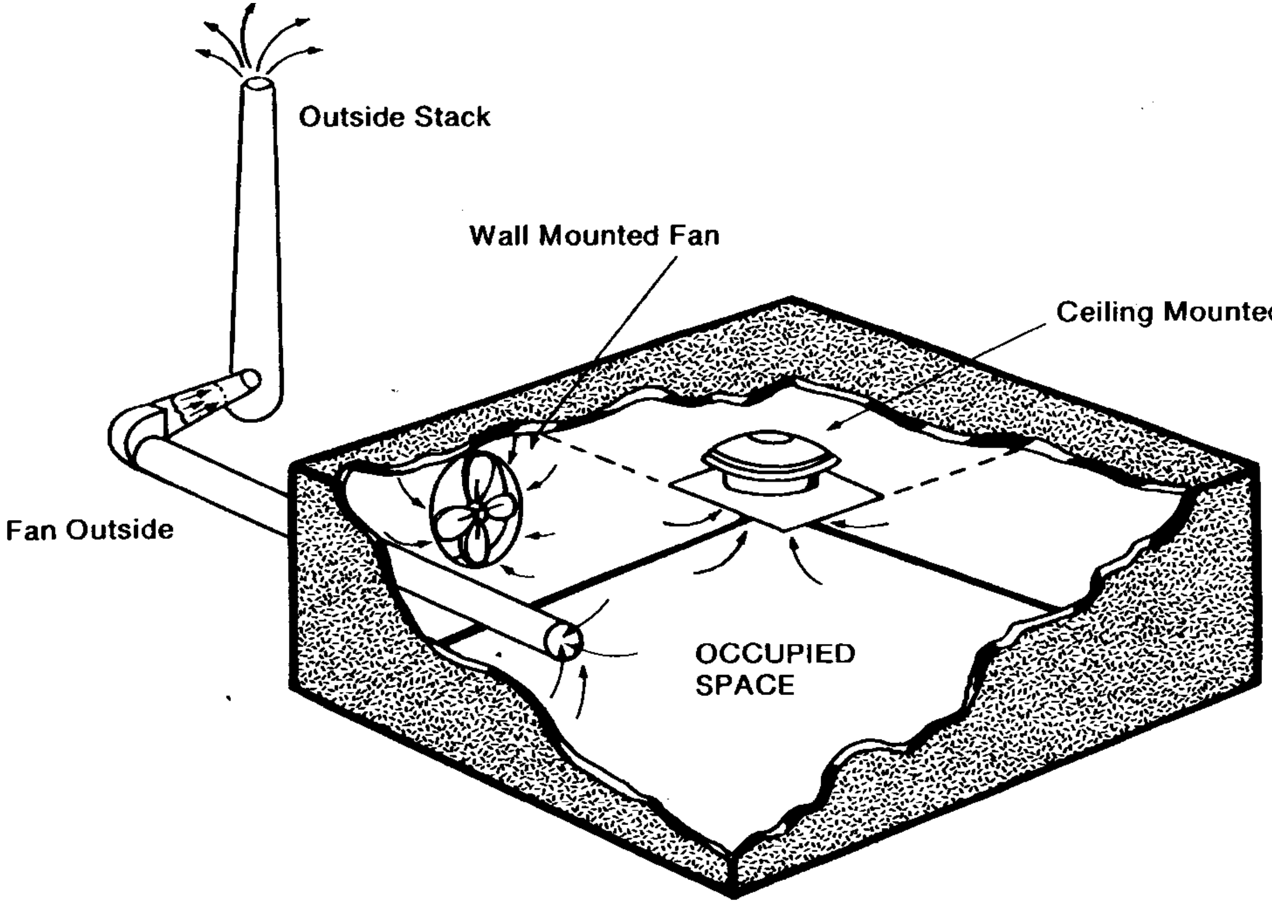


FIGURE 5

Installation Type D



Type D Installation Factor = -3dB for ducted fans
= 0dB for non-ducted fans

FIGURE 6

Estimating Sound Pressure From Sound Power

Equation for estimating sound pressure levels (ref AMCA 303-79):

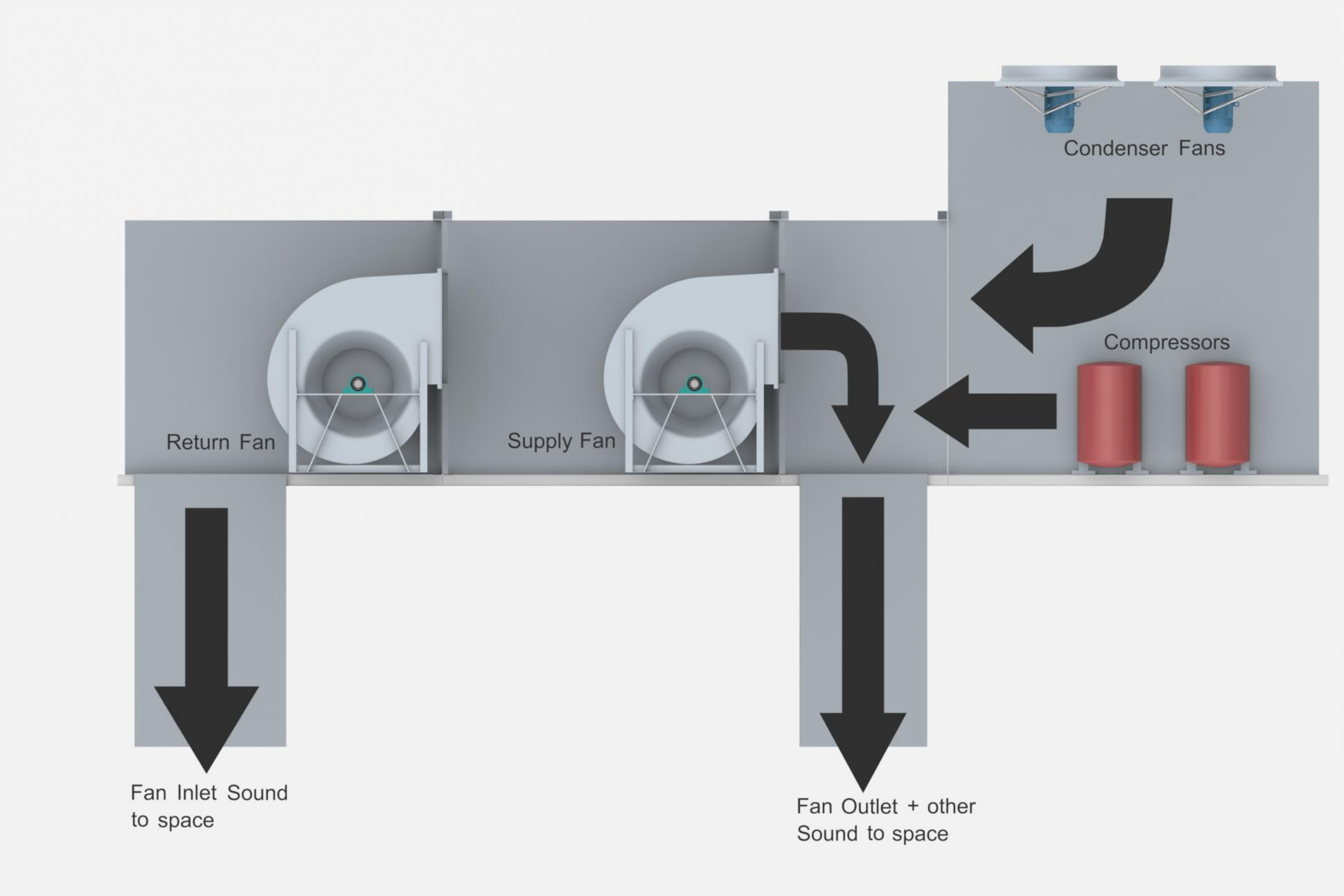
$$Lp = Lw - 10 \log10 \left[1 / \{(Q / 4\pi r^2) + (4 / R)\}\right] + 10.5$$

Where:
Lp = sound pressure (dB)
Lw = sound power (dB)
Q = directivity factor
r = radius from source (feet)
R = room construction = $[S \alpha / (1- \alpha)]$
S = surface area (square feet)
α = average sabine absorption coefficient

Sound Pressure Is NOT Guaranteed

- Sound pressure levels are NOT guaranteed.
- Best estimation requires values for “Q”, “r” and “R”
  - Q = directivity factor
  - r = distance from source (feet)
  - R = room constant (where possible)
- Installed sound pressure levels will depend on many factors of the environment which cannot be predicted.
- Even acousticians will not guarantee the Sound Pressure predicted from Sound Power.

Sound Sources



Noise Problems

Two types of noise problems:

- Those that we anticipate from our sound ratings
- Those emanating from some abnormal condition

Cures for noise anticipated from sound ratings:

- Select a different fan (Tip: Select fans with lower tip speed)
- Relocate the fan to where the noise is not a problem
- Add vibration isolators and/or flexible connectors
- Insulate or acoustically enclose the fan
- Add silencers or duct lining to the inlet and/or discharge

Noise Problems

Common sources of abnormal or unanticipated noise:

- Fan wheel unbalance
- Resonance of fan or attached components
- Rotating components rubbing on stationary parts
- Failing, misaligned or contaminated bearings (on fan or motor)
- Air leakage - Can allow sound leakage and also generate a whistle or hiss

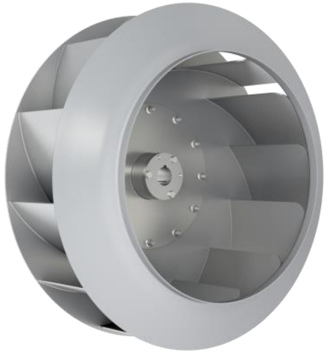
Noise Problems

Common sources of abnormal or unanticipated noise:

- Belts slipping
- Coupling misalignment
- Motor noise, especially with improper power supply and inverter drives
- Air turbulence
- Operation in surge
- Loose components
- High velocity air blowing over fixed components which are not part of the fan

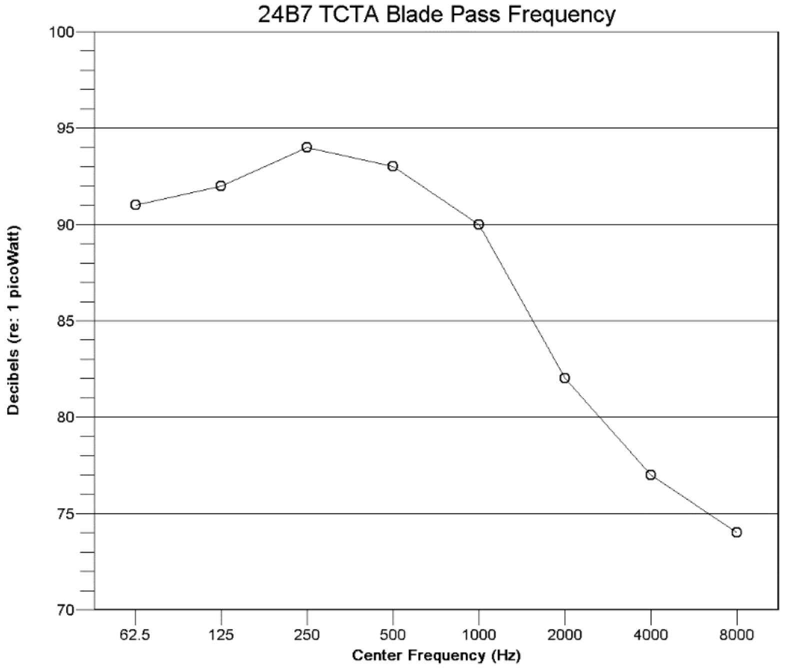
Blade Pass Frequency

- A pure tone produced when the blades of the fan wheel (impeller) rotate past a stationary object (housing cut-off in centrifugal fans, turning vanes in axial fans or a structural member).
- Calculation: (Number of blades x fan RPM) / 60 Hz
- If blade pass frequency matches the natural frequency of the ductwork it can excite the ductwork.
- This phenomena is called resonance, which will increase the noise level.



Blade Pass Frequency – Example

- Size 24”, tubeaxial fan (7 blades)
- 9,000 CFM, 1.5” SP, 1939 RPM
- BPF = (1939 RPM x 7 blades) / 60 = **226 Hz**
  226 Hz BPF falls into the 3rd octave band



Octave Bands	1	2	3	4	5	6	7	8
Level at Inlet	91	92	94	93	90	82	77	74
Frequency Range (Hz)	45 to 90	90 to 180	180 to 355	355 to 700	710 to 1400	1400 to 2800	2800 to 4600	5600 to 11200
Center Frequency (Hz)	63	125	250	500	1000	2000	4000	8000

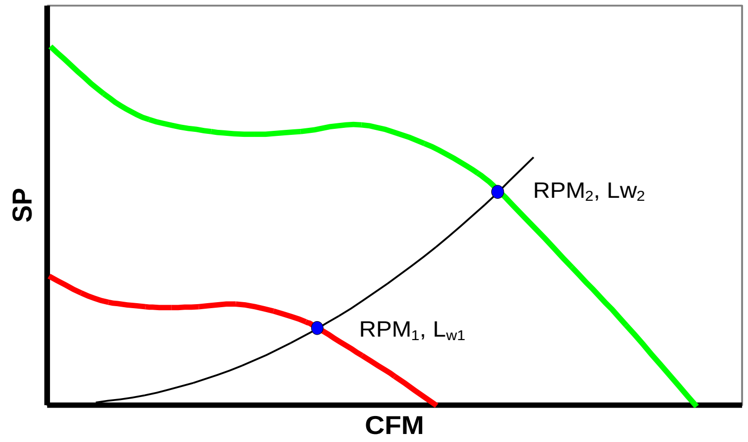
Sound Power Level in dB ref 10^{-12} watts

Noise Control Methods

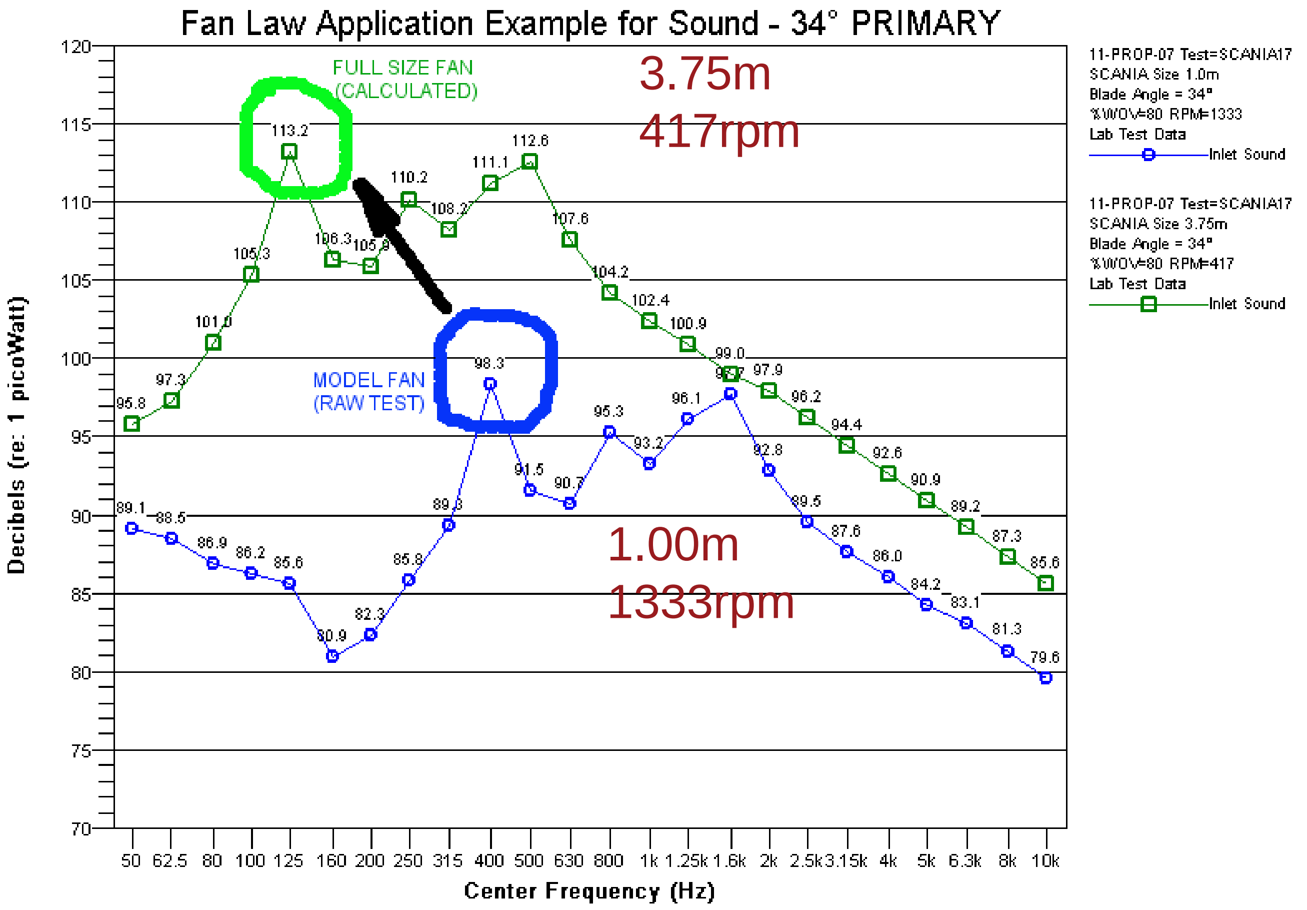
- **Source** – Often most cost effective but must be considered as part of the whole.
- **Path** – Adds cost to product; examples are:
  - Silencer - This reduction of sound is also referred to as “dynamic insertion loss”
  - Barriers or enclosures (better unit casing, duct walls)
  - Vibration isolators, etc.
- **Receiver** – Least effective, less likely to be accepted by others
  - Earplugs, earmuffs, etc.

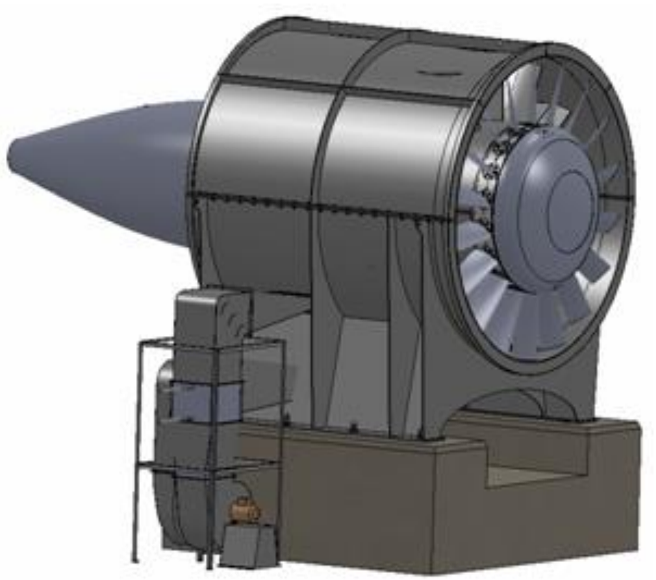
Fan Laws for Sound

- Apply if fans are geometrically
- $Lw_2 = Lw_1 + 70*\log_{10} (D_2/D_1)$
- $Lw_2 = Lw_1 + 50*\log_{10} (RPM_2/RPM_1)$
- ANSI/AMCA Standard 301-14 methods are used for estimating sound at different speeds along a constant system curve
- Rule of thumb: 10% speed change equals 2 dB



Example of AMCA 301-14 Calculations

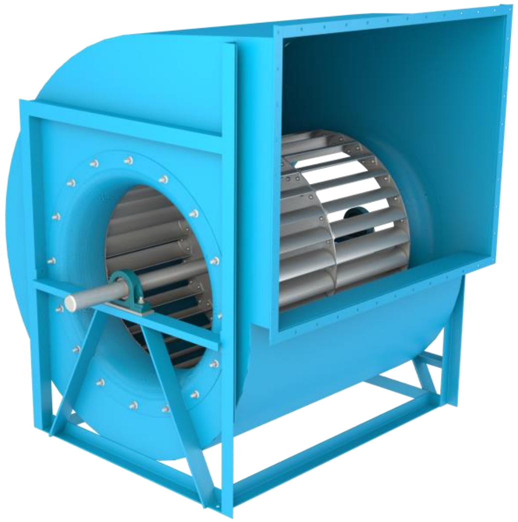




Sound Characteristics by Fan Type

Forward Curved Fans

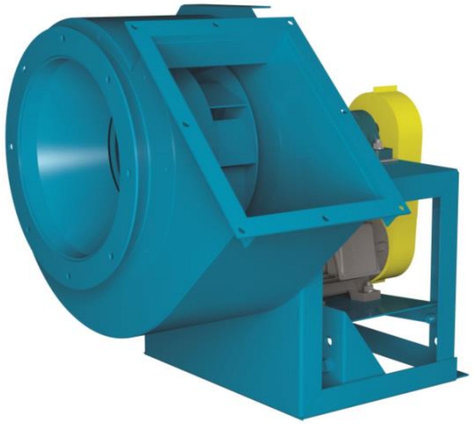
- Relatively insensitive to inlet flow distortions, including inlet guide vanes
- Wide operating range with a sharp stall onset
- No significant blade pass frequency tone amplitude
- Rumble at 31 and 63 Hz bands is common in applications
- Fan aspect ratio, staggering fan blades, fan cutoff spacing, spiral extension of the scroll all affect the sound



Sound Characteristics by Fan Type

Airfoil & Backward Inclined Fans

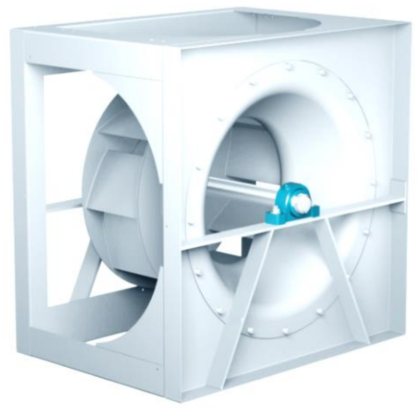
- Louder than forward curve fans at mid and high frequency
- More sensitive to inlet flow distortions including inlet guide vanes
- More significant blade pass frequency tone
- Narrower useful operating range (when compared to FC) with a ‘soft’ stall onset
- Usually has less low frequency rumble

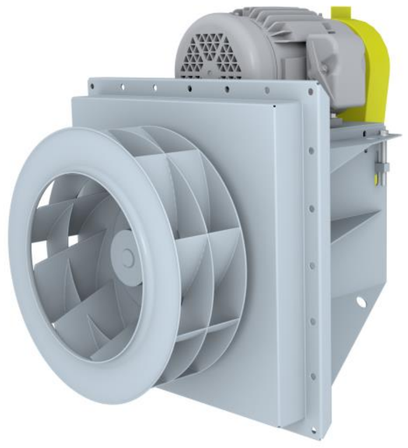


Sound Characteristics by Fan Type

Plug/Plenum Fans

- Less turbulence and lower pressure fluctuations entering the discharge duct than housed airfoil and backward inclined fans
- Generally require more power than housed centrifugal fans and generate higher sound levels, especially at lower frequencies
- Other characteristics are similar to conventional housed centrifugal

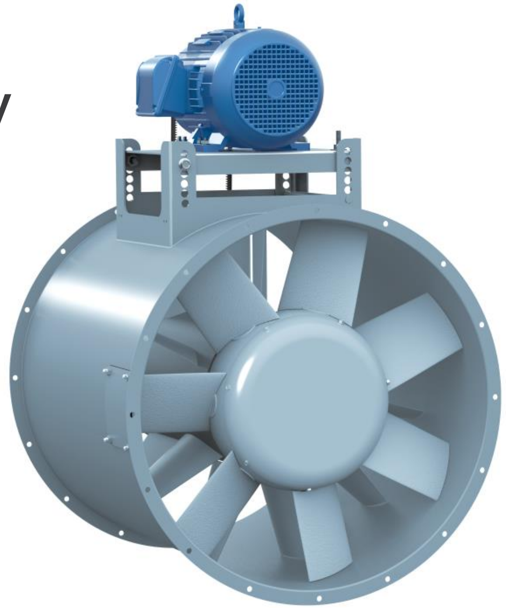




Sound Characteristics by Fan Type

Vaneaxial Fans

- Lowest amplitude at low frequency of any fan type
- Higher amplitudes at high frequency - can be easily attenuated
- Most sensitive fan type to inlet flow obstructions
- Blade pass frequency tone is relatively high amplitude
- Sharply defined stall region with greatly increased amplitudes



Sample Selection of Multiple Fan Types

Table below will change based on different operating point.

	Type	Dia. (in)	Speed (rpm)	BHP	SE % (Static Efficiency)	LwiA (Inlet Sound Power 'A')
1	Forward Curved- SW (Centrifugal)	30	476	5.09	61.7	89
2	Backward Airfoil – SW (Centrifugal)	36.5	650	3.82	80.0	77
3	Plenum	33	800	4.25	74.0	80
4	Tubular Mixed Flow	27	1074	4.48	70.2	81
5	Tubular Vaneaxial	28	1438	4.77	65.9	86
6	Propeller (Axial)	30	1998	4.92	54.4	103

All fans selected at peak SE (Static Efficiency) for Airflow=10,000 cfm, Static Pressure (SP)~2 iwc

Resources

- **AMCA International**: *www.amca.org*
- **ANSI/AMCA Standards** (Available for purchase)**:** *www.amca.org/store*
  > **300-14:** Reverberant Room Method for Sound Testing of Fans
  > **301-14:** Methods for Calculating Fan Sound Ratings from Laboratory Test Data
- **AMCA Publications** (Available for purchase)**:** *www.amca.org/store*
  > **303-79 (R2012):** Application of Sound Power Level Ratings for Fans
  > **311-16:** Certified Ratings Program — Product Rating Manual for Fan Sound Performance

Thank you for your time!

To receive PDH credit for today's program, you must complete the online evaluation, which will be sent via email following this webinar.

If you viewed the webinar as a group and only one person registered for the webinar link, please email Lisa Cherney (lcherney@amca.org) for a group sign-in sheet today. Completed sheets must be returned to Lisa by tomorrow, October 15.

PDH credits and participation certificates will be issued electronically within 30 days, once all attendance records are checked and online evaluations are received.

Attendees will receive an email at the address provided on your registration, listing the credit hours awarded and a link to a printable certificate of completion.

Questions?

NEXT PROGRAM

Join us for our next AMCA *insite*™ Webinar:

- Wednesday, October 28
- 1:00-2:00pm CT
- ***TOPIC: Vibration Isolation, Wind, and Seismic Restraint for Mechanical Equipment***
- Presenter: Lee Chiddention, HVAC Market Manager, AMCA Member Company

>> For additional webinar dates go to: *www.amca.org/webinar*