Eliminating Acoustical Barriers to Learning in Classrooms

What You Need to Know About Acoustics

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Workshop Presentation:
Implementing Classroom Acoustics Standards Locally

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WHAT CAN I DO TO MAKE OUR CLASSROOMS BETTER ?

The SHHH Mission

“Open the world of communication”

through

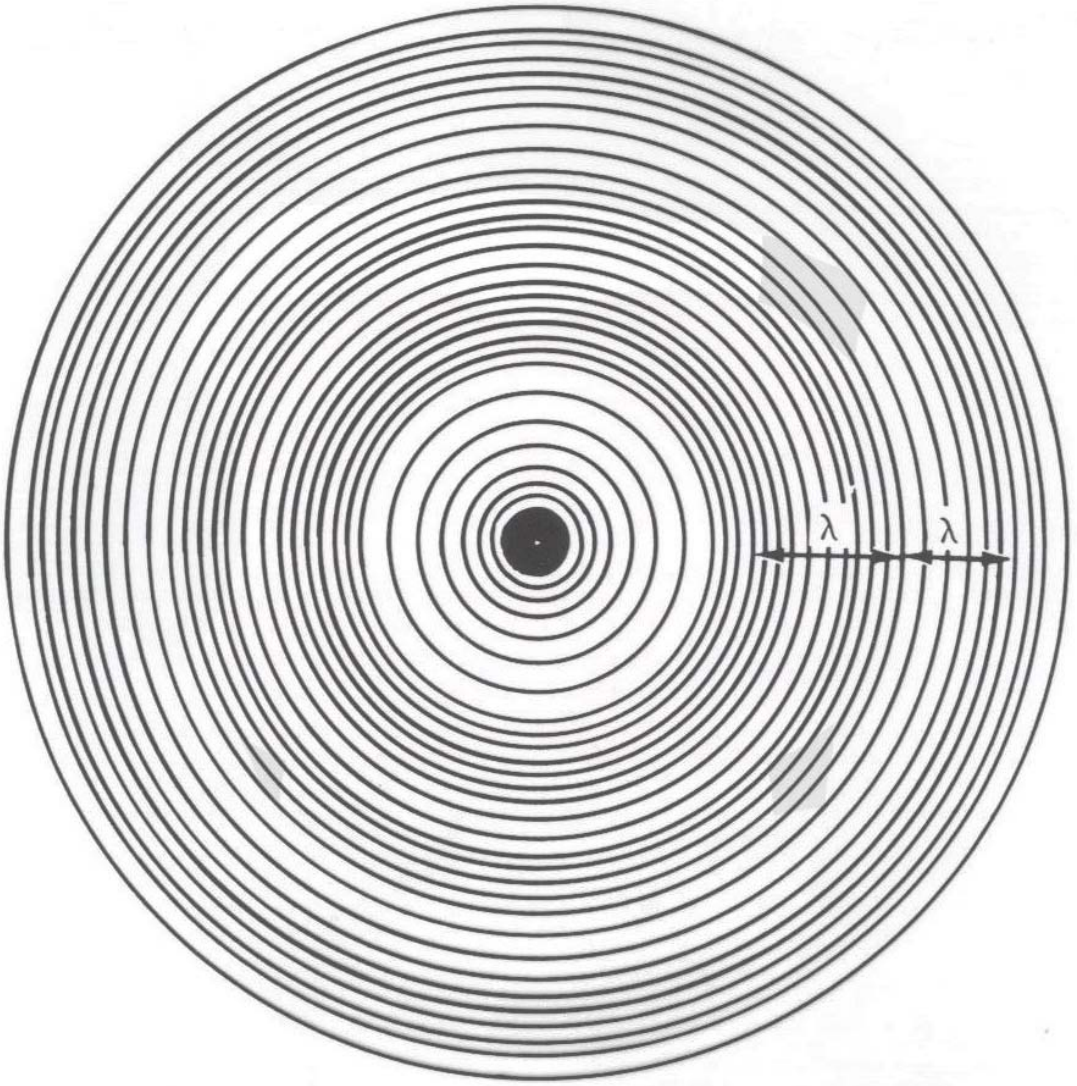
Information, Education, Advocacy and Support

WHAT IS ACOUSTICS?

The Science of Sound -- a branch of Physics

WHAT IS SOUND?

Organized vibrations of air molecules



Spherical waves radiated by a point source.

SOME ACOUSTICAL FACTS

Sound has two important qualities

Qualities that we can hear - and measure

Frequency

and

Level

ACOUSTICAL FACTS

Sound Frequency

- **Frequency -- also called "pitch"**
  low pitch (hum)
  high pitch (hiss)

- **Sound frequency is described by the measurement unit of "hertz" (Hz) or "cycles per second"**

- **Sound frequency is related to something called "acoustic wavelength" or "wave size"**

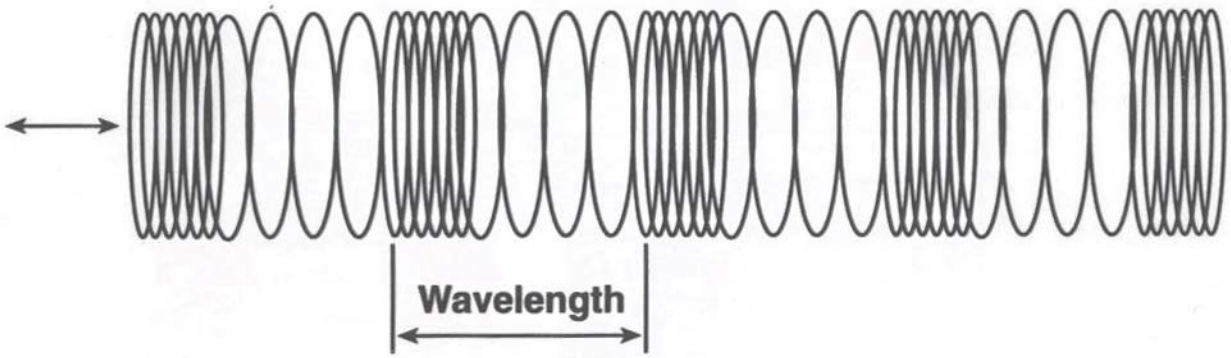
MORE ACOUSTICAL FACTS

What is the 'size' or dimension of sound?
(spacing between wave peaks)

- **Speed of Sound**
- **1100 feet per second at room temp.**

- **Acoustic wavelength**
  - **As frequency (pitch) goes higher, wavelength gets smaller.**
- **At 100 hertz wavelength is ~ 10 feet.**
- **At 1000 hertz wavelength is ~ 1 foot.**
- **At 10,000 hertz (10 kHz) wavelength is ~ 1 inch.**

Here, the rate is the ***velocity of sound***, which we give the symbol *c*. Therefore distance (λ) = rate (c) x time (τ).



$$\lambda = c\,\tau \text{ or}$$

$$c = \lambda f = 1100 \text{ feet/sec} = 344 \text{ m/sec.}$$

Diagram of a Slinky®, as a visible analog to sound wave propagation. Vibration of left end will lead to propagation of a compressed region to the right.

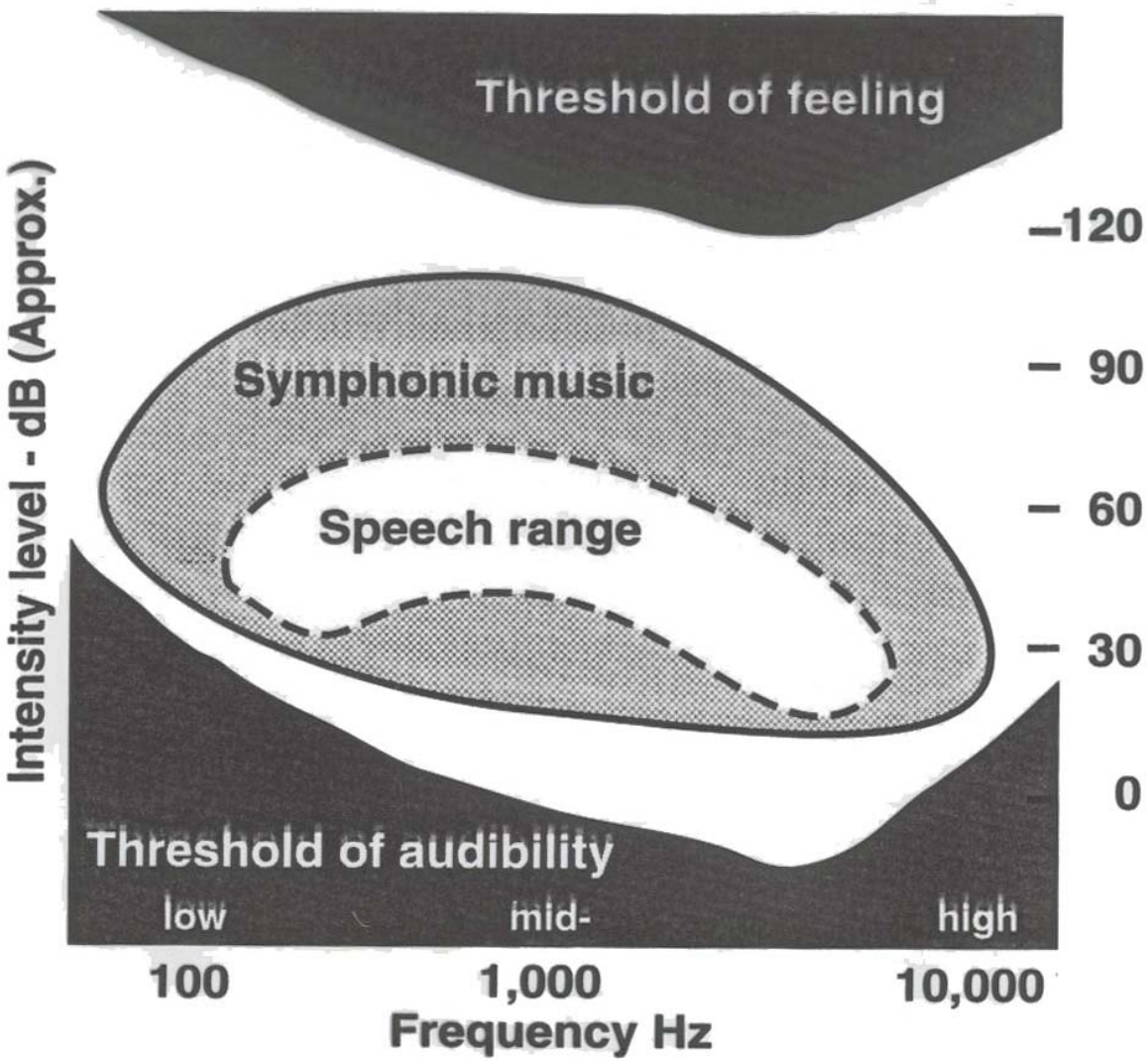
SOME ACOUSTICAL FACTS

Sound Level

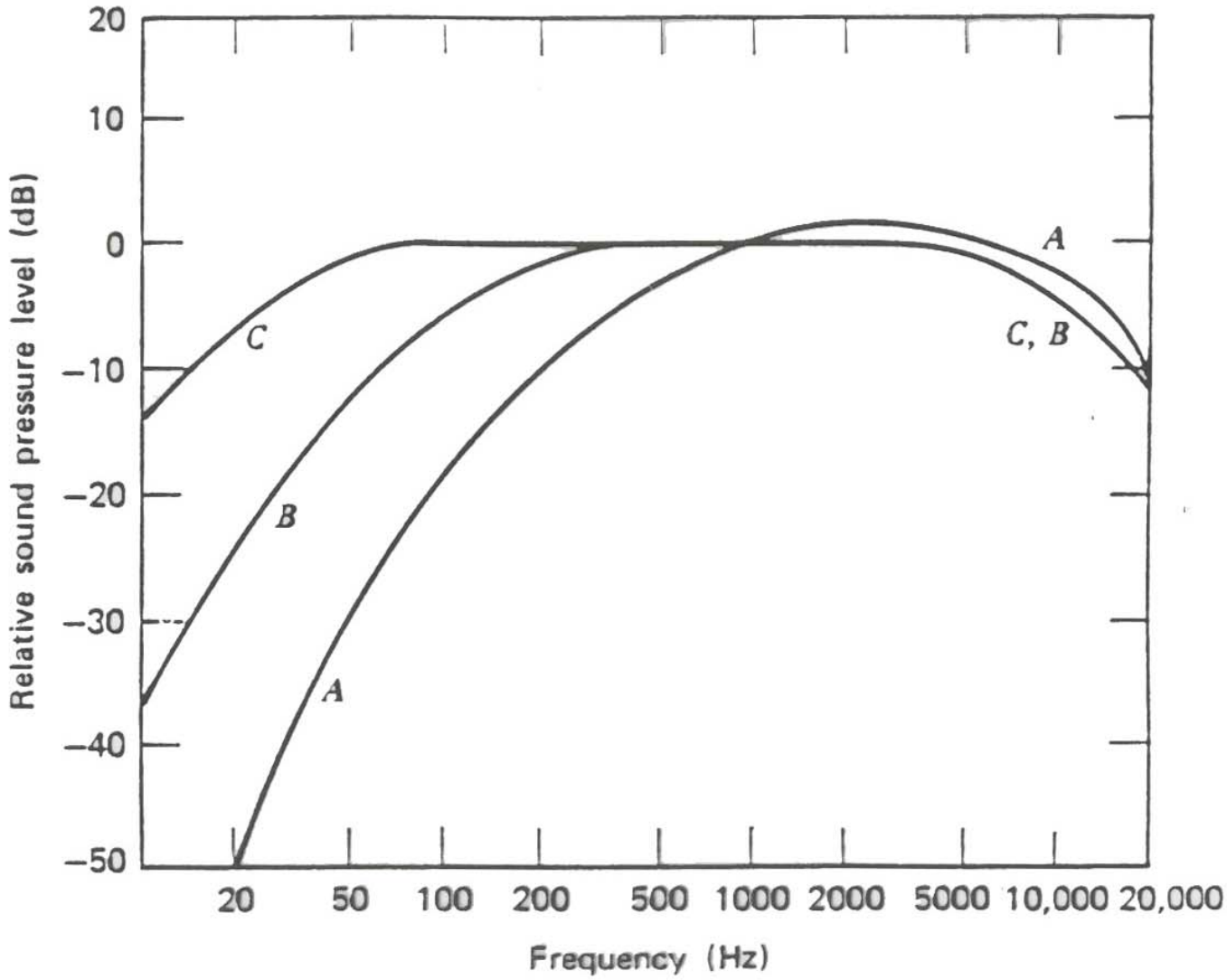
- **Sound Level -- also called "loudness" or "intensity"**

  low intensity (whisper)
  high intensity (jet plane take-off)

- **Sound level is described by the measurement unit of "decibel" (dB) named after A.G. Bell (telephone inventor and advocate for the Hearing Impaired)**



Sound intensity levels for different frequencies



International Standard *A*, *B*, and *C* weighting curves for sound level meters.

Sound Level

Definition of Sound Pressure Level

as given in decibels (dB)

$$SPL = 20 * \text{Log} (P_{acoustic} / P_0)$$

where P_0 = 20 micro-pascals
approximate "threshold of hearing"

ACOUSTICAL QUALITY OF LIFE

What contributes to acoustical quality

Noise

Communication

Aesthetics

WHAT IS NOISE?

Noise is *UNWANTED* sound!

Classroom Acoustics Standard

ANSI/ASA S12.60-2002

Maximum A-weighted 1-hour average
Steady background noise level

35 dB

sometimes you will see notation " 35 dBA "
This is equivalent to a quiet whisper

??? What is "noise level" in this room ???

Classroom Acoustics Standard

ANSI/ASA S12.60-2002

Maximum reverberation time

Sound in 500, 1000, 2000 Hz octave bands

0.6 seconds

?? What is "reverberation time" in this room ??

NOISE FROM ROOM VENTILATION (HVAC) SYSTEMS

Major cause of classroom noise

What type of system causes the most noise?

What is the noise like?

How does it affect the learning environment?

HVAC SYSTEMS:

- **Central mechanical systems**
  - **Large machinery may be placed away from classroom areas.**
  - **Conditioned air distributed by ducting.**
  - **Easier to install in new construction.**
  - **Can operate quietly.**

- **Individual room ventilators**
  - **Machinery located inside each room.**
  - **Easier to install as a renovation.**
  - **Generally noisy.**

HVAC Noise Sources:

- Air distribution fan (rumble, whoosh)
- Cooling unit compressor (hum, whine)
- Heat pump (hum, whine)
- Supply and return ducting/grills (hiss)

Affects of HVAC Noise on Learning:

- Cause of distraction, loss of attention (especially during on/off cycling)
- Loss of understanding -- missed words (poor speech intelligibility)
- Garbling of perceived speech
- Cause of listener fatigue
- Cause of vocal strain

CASE STUDY - WINDOW VENTILATORS

- **Recently renovated school**
- **Installed ventilator/heat pumps in each room (heating and cooling!!)**
- **Energy conservation program Sponsored by electric power company**
- **Complaints by teachers about noise**
- **Dispute between school, power company, pump manufacturer over responsibility**

BAC asked to conduct a noise survey

- Measured noise levels in 3 classrooms
- Noise measured both during and after class
- Metrics studied:
  - A-weighted level (dBA)
  - Speech interference level (SIL)
  - Balanced noise criteria rating (NCB)
  - Room criteria rating (RC)
- Tape recorded class activity
  with ventilator operating

Ventilator study technical results

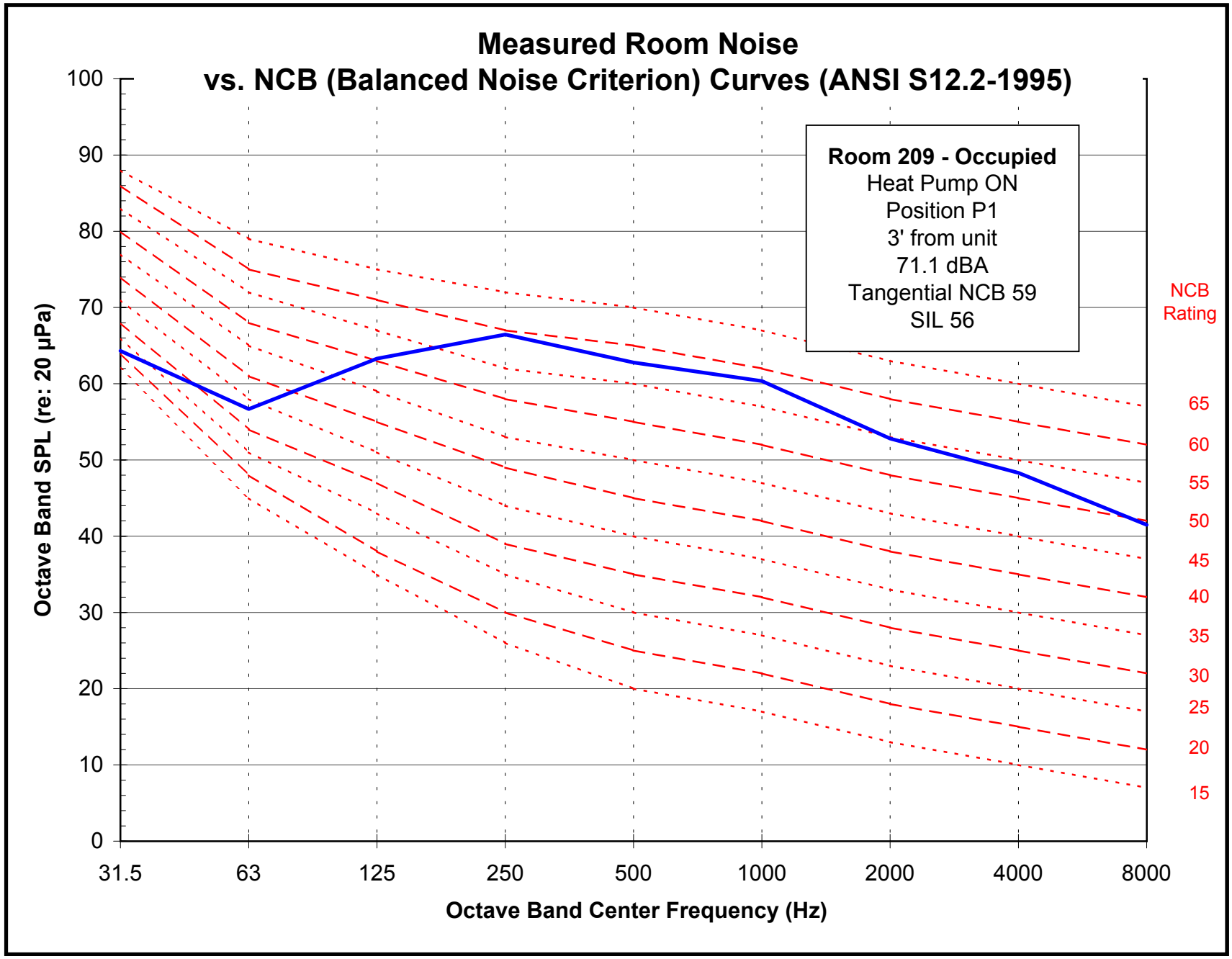
- **Classroom measured A-weighted level**

Occupied

71 dBA near (3 feet) ventilator

- **Recommended classroom noise -- 35 dBA**

More than 35 dB too high !!


Measured Room Noise
vs. NCB (Balanced Noise Criterion) Curves (ANSI S12.2-1995)
Room 209 - Occupied
Heat Pump ON
Position P1
3' from unit
71.1 dBA
Tangential NCB 59
SIL 56
NCB Rating
65
60
55
50
45
40
35
30
25
20
15
Octave Band SPL (re: 20 µPa)
100
90
80
70
60
50
40
30
20
10
0
31.5
63
125
250
500
1000
2000
4000
8000
Octave Band Center Frequency (Hz)

COMPARISON WITH HEAT PUMP MANUFACTURER NOISE DATA

- MFG claims levels corresponding to NCB 63
  -- roughly 70 dBA (5 feet from discharge grill)
- Actual noise lower than MFG expectation
- 70 dBA is considered acceptable ???

WHAT FINALLY HAPPENED ?

- **Expensive to fix *EACH UNIT (50 classrooms)***
- **No agreement on responsibility**
- **No action taken**

Problem still exists !!

Why is this horror story repeated over and over?

- **School districts need to reduce renovation and initial construction costs**
- **Plans are developed without considering *acoustical function* of learning spaces**
  - **You can't see it -- "*An Invisible Condition*"**
  - **Problems don't surface immediately, not until experienced**
- **Retrofit cost for noise control not in budget**

A Much Better Case Study

Design for Good Acoustics

CT International Baccalaureate Academy
CIBA -- East Hartford, CT
"*Public Prep School*"

Designed in 2001 -- Completed May 2003

Classroom noise level -- HVAC on -- 25 dBA !!
Classroom reverberation time -- 0.69 seconds

Classroom noise

is NOT

a technical problem !

In the ventilator case a “sound field” system would increase sound to intolerable levels.

The solutions are well known. The trick is to properly prepare and plan for quality learning in school environments.

Positive steps to be taken:

- **At discussion stage (Board of Ed) for new, expanded or renovated building:**

  Emphasize vital need for good acoustics
  - **Classroom**
  - **Auditorium**
  - **Gym**
  - **Cafeteria**

- **Make sure building committee understands and conveys message to architect/engineer**

More positive steps:

- **Reinforce acoustic priorities at several planning stages:**
  - **Building space programming**
  - **Building design**
  - **Preparation of bid documents**
- **Insert noise level guarantees into equipment purchase specifications**
- **Demand full documentation of noise control design during planning reviews**

Good acoustics in learning spaces are achievable.

CALL TO ACTION !!