Noise

CIH Review – PDC March 2012

Learning Objectives

- Understand the concept of the decibel, decibel determination, decibel addition, and weighting
- Know the characteristics of frequency that are relevant to human hearing
- Know the different types of sound and instruments to measure sound (application of these instruments)
- Understand basic OSHA and DoD noise guidelines
- Know the types of hearing loss and characteristics of each type

Introduction to decibel

- Acoustics is the study of sound and is a branch of Physics
- Sound occurs because vibrating surfaces cause compressions & rarefactions in the air
  - The compressions & rarefactions cause objects they strike to vibrate.
- Fundamental units of Physics:
  - Length = Displacement = Distance
  - Time
  - Mass
  - Force

Introduction to decibel

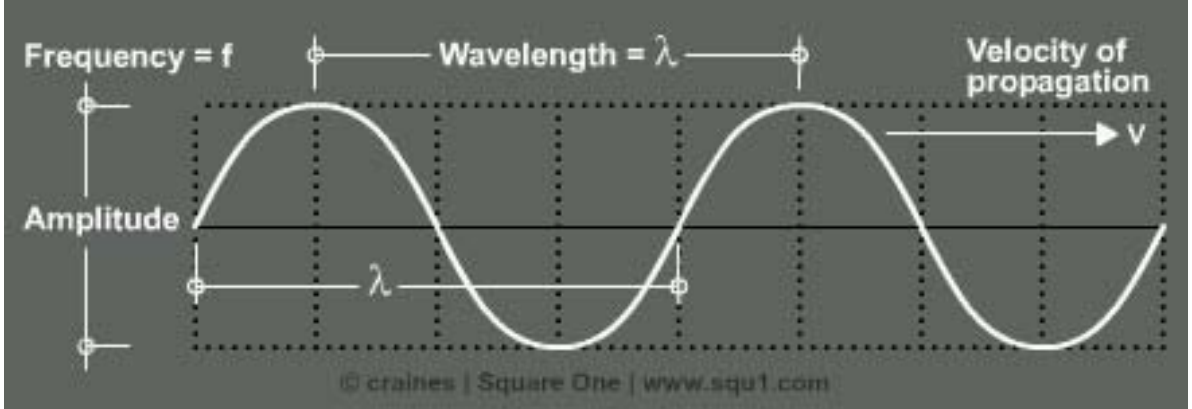
- Fundamentals of Physics
  - Distance traveled per unit time = Velocity or Speed
  - Change in Velocity = Acceleration or Deceleration
  - Pressure = Force per unit Area
  - Power = total output of work done = Intensity

Basic Elements of Sound

- Frequency = f = Hz = times/second or cycles/sec
- Period = t = time for 1 cycle of simple harmonic motion
- Wavelength = λ
- Amplitude = p^2 = pressure squared

$$C = \lambda * f$$

- Sound Transmission
  - Propagation through an elastic medium
  - Important factors
    - Density
    - Temperature



Amplitude

Refers to the difference between maximum and minimum pressure. In a sound wave, pressure fluctuations are symmetrical about the current atmospheric pressure (as measured by a barometer). For simplicity, and because this value can take hours to change, a reference value of zero is normally used. Thus maximum pressure is given as a positive value and minimum as a negative.

Frequency

Refers to the number of pressure peaks that pass a particular point in space over a period of one second. Thus a 1kHz (1000Hz) sound would have 1000 waves pass a point each second.

*pitch

Wavelength

Refers to the physical distance between successive pressure maxima and is thus dependant on the speed of sound in the medium divided by the frequency of the wave. This relationship is given by:

$$V = \lambda * f$$

Relation of Physical Attributes to Perception

- Intensity (Amplitude) ~ Loudness
- Frequency ~ Pitch
- Complexity ~ Timbre

The Decibel

- The decibel (dB) is used to describe levels of acoustic power, sound pressure, hearing thresholds, etc...
- The decibel is a dimensionless unit related to the logarithm of the ratio of a measured quantity to a reference quantity.
- Thus, two powers, one of which is ten times the other, will differ by 1 bel. (Ex: A 360-horsepower car is 1 bel (or 10 decibel) more powerful than a 36-horsepower motorcycle)

The Decibel

dB(A) - A weighting, approximates the human ear's response to different sound frequencies.

dB(B) - B weighting, utilized in research

dB(C) – C weighting, utilized to calibrate sound level meters; approximates human ear's response to high frequencies

$P_0 = 0.00002\ N/m^2$

A and C curves equal at 1000 and close at 2000, 3000, and 8000 Hz

3 Ways to Measure Noise

- Power - (Watt = $p^2/S/\rho c$);
  - analogous to an electrical power rating
- Intensity - (Watt/m^2 or dB); magnitude and direction
- Pressure - (Pa or N/m^2); magnitude
  - Decibel
    - one tenth of a bel
    - bel (named after Alexander Graham Bell)

Sound Power vs. Sound Pressure

$$L_w \text{ or PWL} = 10 * \text{LOG}\left(\frac{\text{Actual Wattage}}{\text{Reference Wattage}}\right) dB$$

$$L_p \text{ or SPL} = 20 * \text{LOG}\left(\frac{\text{Actual Pressure}}{\text{Reference Pressure}}\right) dB$$

$W_0 = 10^{-12}$ Watts

$P_0 = 20\ \mu\text{Pa}$ or $0.0000\ \text{N/m}^2$

Source	Sound Power in Watts	dB (Re 10E-12 Watts)
Saturn rocket	100,000,000	200
After burning jet engine	100,000	170
Centrifugal fan at 500,000 cfm (849,000 cu m/hr)	100	140
75 piece orchestra	10	130
Large chipping hammer	1	120
Blaring radio	0.1	110
Auto on highway	0.01	100
Food blenders-upper range	0.001	90
Dishwashers-upper range	0.0001	80
Voice-conversational level	0.00001	70
Quiet-Duct silencer, self-noise at +1000 fpm	0.00000001	40
Voice-very soft whisper	0.000000001	30
Lowest audible sound for persons with excellent hearing	0.000000000001	0

What kinds of sounds (noise) are there?

- Continuous
  - Continuous sounds are sounds that are either uninterrupted or that have maxima at intervals of less than one second.
  - A hammer striking the same nail once every 0.5 seconds is a continuous noise source.
- Intermittent
  - Sounds that have maxima (peaks) at intervals of one second or more.
  - A hammer striking a nail every 1.5 seconds is an intermittent noise source.
- Impulse
  - Sometimes referred to as an impact sound; a single, independent sound.
  - A hammer striking a nail.

- Exposure to continuous noise sources is considered more hazardous than exposure to intermittent noise sources of the same sound level because the intermittent exposure allows the ear to have a brief rest period between peaks.

Sound Level Meter

Converts sound pressure to electronic signals

- Type 1 – precision measurements in the field
  - Can have an octave band analyzer
- Type 2 – general purpose field measurements
- Type 0 – laboratory standard

- SLM components
  - -Microphone
  - -Attenuator
  - -Amplifier
  - -Indicating meter

Sound Level Meters

- Type 1 accuracy within 1 dB
- Type 2 accuracy within 2 dB
- Settings
  - Slow – 1 sec averaging
  - Fast – 0.125-sec averaging
  - Peak – accurate for 100 microsecond

- Microphones
  - Dynamic – mylar, vibrates with sound
  - Ceramic – sends out piezoelectric signal, can be distorted
  - Condensor – capacitor, measures voltage across gap

Octave Band Analysis

TABLE 4.2

Comparison of 1-octave and ⅓-octave bands

1 Octave			⅓ Octave		
Lower cutoff frequency (Hz)	*Center frequency (Hz)*	*Upper cutoff frequency (Hz)*	*Lower cutoff frequency (Hz)*	*Center frequency (Hz)*	*Upper cutoff frequency (Hz)*
11	16	22	14.1	16	17.8
			17.8	20	22.4
			22.4	25	28.2
22	31.5	44	28.2	31.5	35.5
			35.5	40	44.7
			44.7	50	56.2
44	63	88	56.2	63	70.8
			70.8	80	89.1
			89.1	100	112
88	125	177	112	125	141
			141	160	178
			178	200	224
177	250	355	224	250	282
			282	315	355
			355	400	447
355	500	710	447	500	562
			562	630	708
			708	800	891
710	1,000	1,420	891	1,000	1,122
			1,122	1,250	1,413
			1,413	1,600	1,778
1,420	2,000	2,840	1,778	2,000	2,239
			2,239	2,500	2,818
			2,818	3,150	3,548
2,840	4,000	5,680	3,548	4,000	4,467
			4,467	5,000	5,623
			5,623	6,300	7,079
5,680	8,000	11,360	7,079	8,000	8,913
			8,913	10,000	11,220
			11,220	12,220	14,130
11,360	16,000	22,720	14,130	16,000	17,780
			17,780	20,000	22,390

Octave – range of frequencies extending from a frequency to double that frequency

Octave Band – the center frequency

Associated with Type I SLMs for sound booth calibration and detailed sound analysis

$$f_2 = 2f_1$$

$$f_c = (f_1 f_2)^{1/2}$$

http://hyperphysics.phy-astr.gsu.edu/sound/acont.html

Octave Band Analysis

Name of Octave Band (Center Frequencies (Hz)	A-Weighting of Octave Band (dB)	C-Weighting of Octave Band (dB)
31.5	-39.4	-3.0
63	-26.2	-0.8
125	-16.1	-0.2
250	-8.6	0.0
500	-3.2	0.0
1000	0.0	0.0
2000	+1.2	-0.2
4000	+1.0	-0.8
8000	-1.1	-3.0

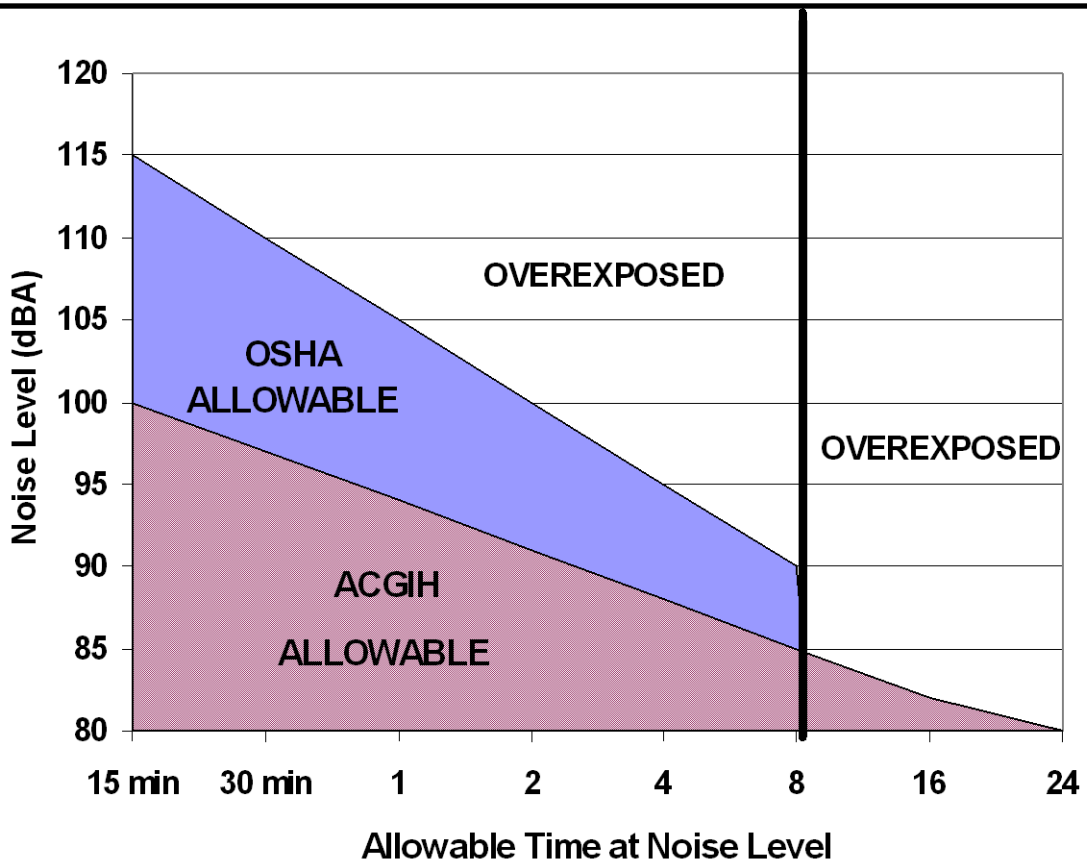
Human Frequency Range

- Hearing frequency range for most humans approximately 16 - 20,000 Hz
- Real upper limit for most adults is about 11,000 Hz
- Speech Recognition Frequencies between 500 - 2000 Hz

Hazardous Noise Limits

		DoD
	OSHA	ACGIH
8 hr Criterion	90 dBA	85 dBA
Exchange Rate	5 dBA	3 dBA
Hear. Cons. Prog.	85 dBA	

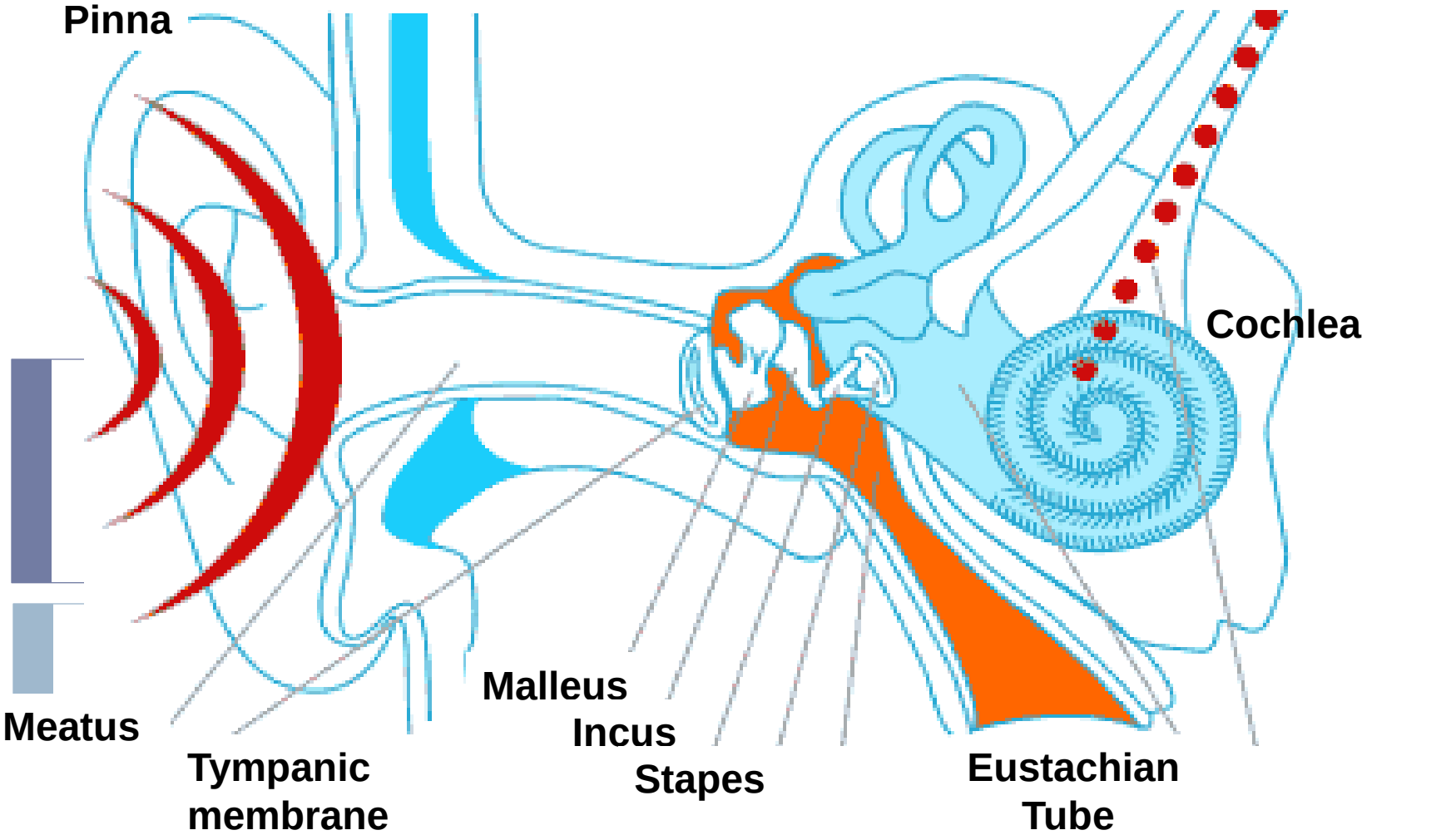
Hrs	OSHA (dBA)	ACGIH (dBA)
24		80
16		82
8	90	85
4	95	88
2	100	91
1	105	94
30 min	110	97
15 min	115	100



- OSHA Max 115 dBA steady-state; Max 140 dBA impact noise
- Exchange rate: for every 3 or 5 dBA respectively, reduce permissable duration time by 50 %
- Other government agencies have their own standards

Anatomy of Hearing

Transmission of Sound



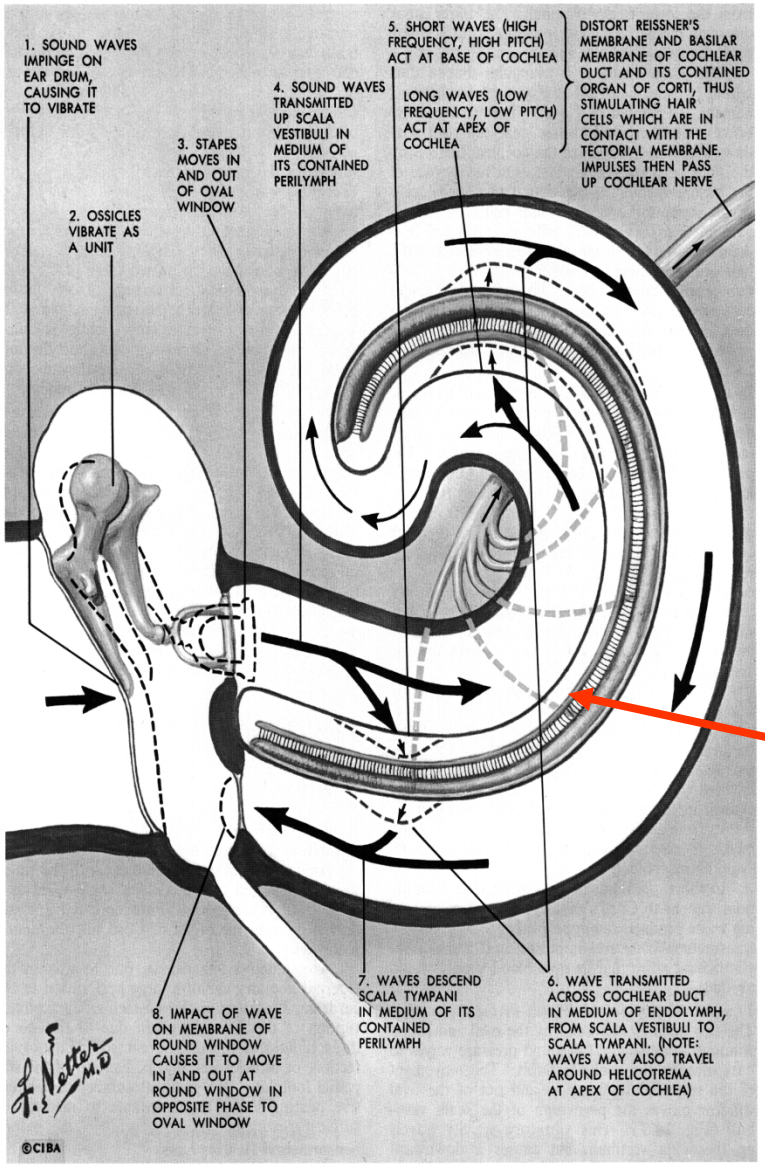
Hearing Loss

- **Sensorineural** - hearing loss induced by noise exposure; irreversible
- **Presbycusis** - loss of hearing due to aging
- **Conductive** - loss between the outer ear and the cochlea; may or may not be irreversible
- **Sociocusis** - loss due to **social habits** (background noise)

- **Temporary Threshold Shift (TTS)** – hearing loss from short term exposure to noise; recovers after hours or days of quiet. Too many TTSs leads to permanent threshold shift

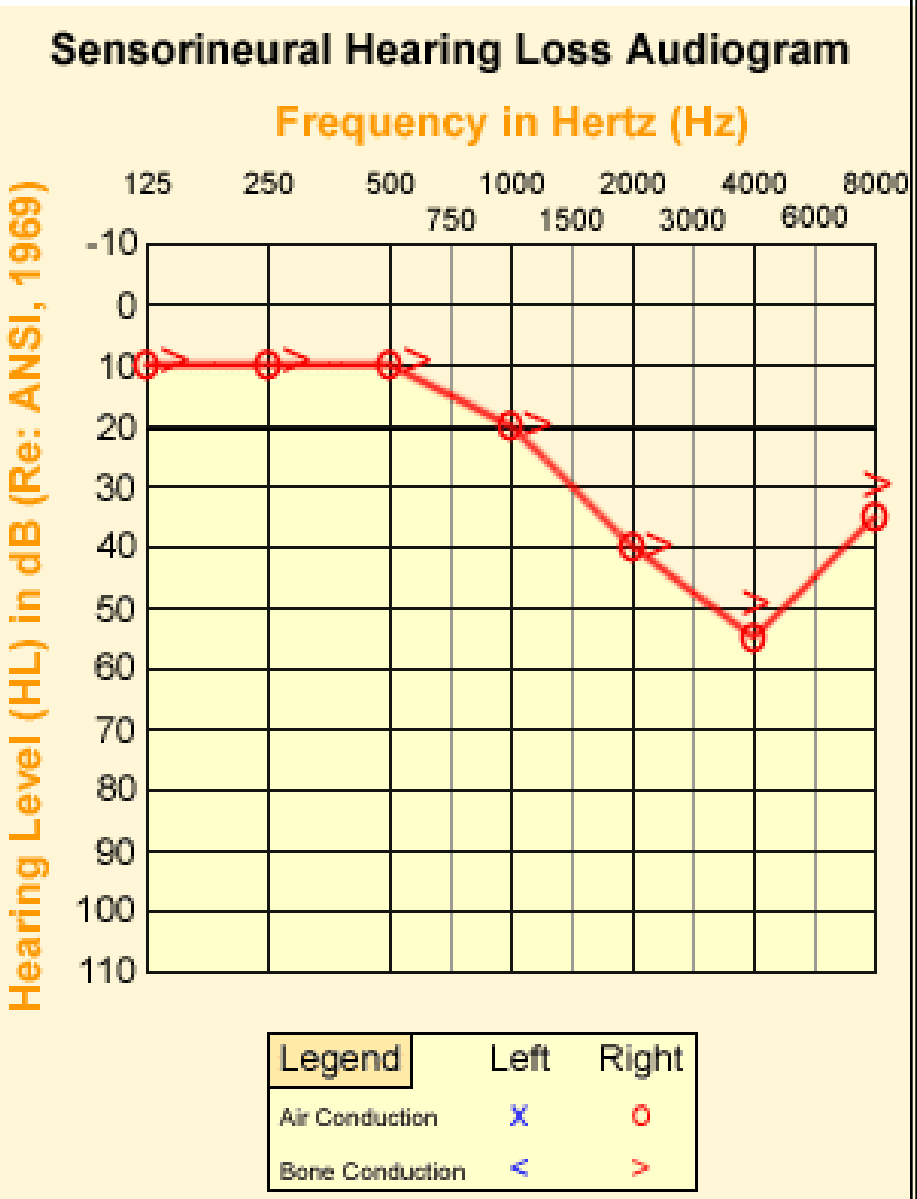
- **OSHA/DoD Standard Threshold Shift (STS)** - **avg of >10 dB** drop from baseline at 2,000, 3,000 & 4,000 (corrective action)

Hearing Loss

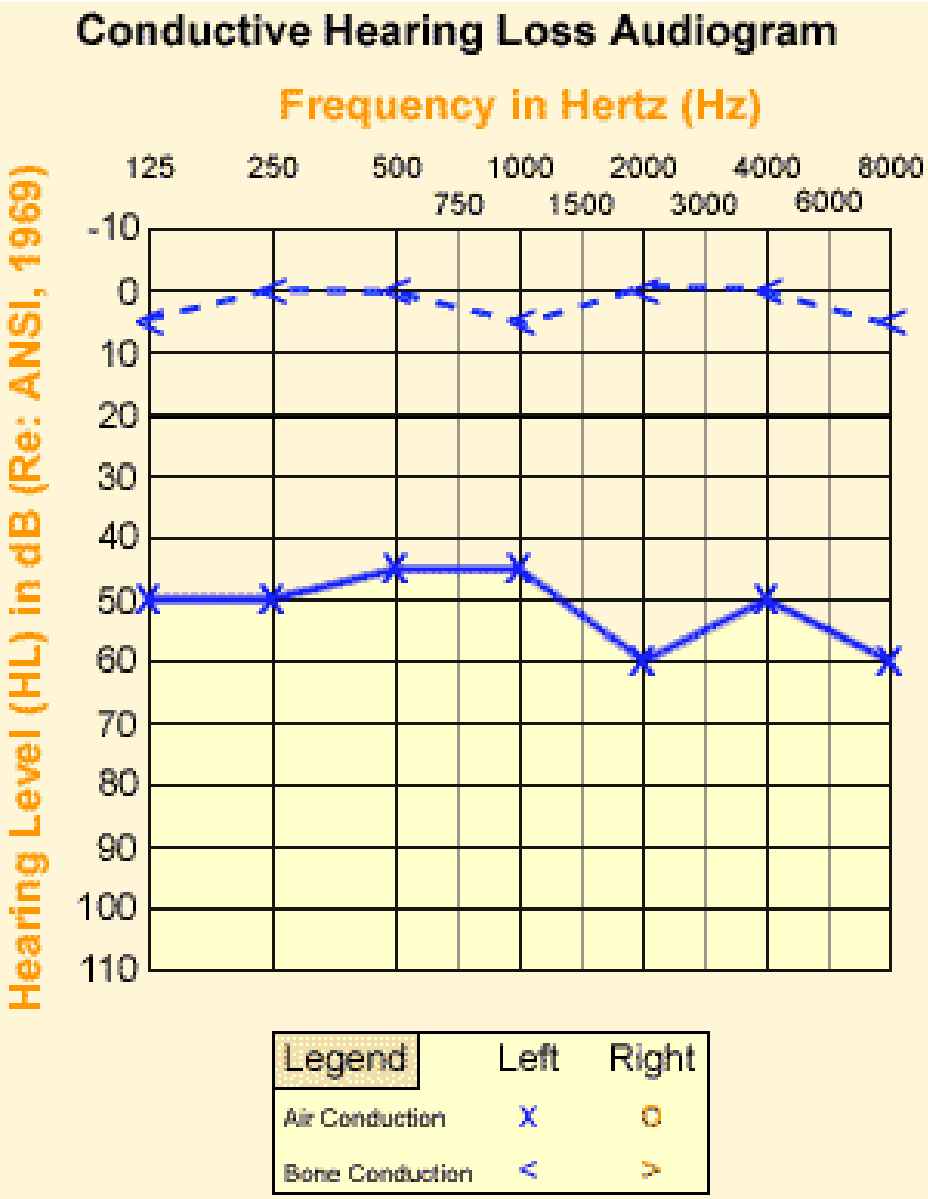


Nerves for 4000 Hz located near the bend

Classic Noise Induced Loss

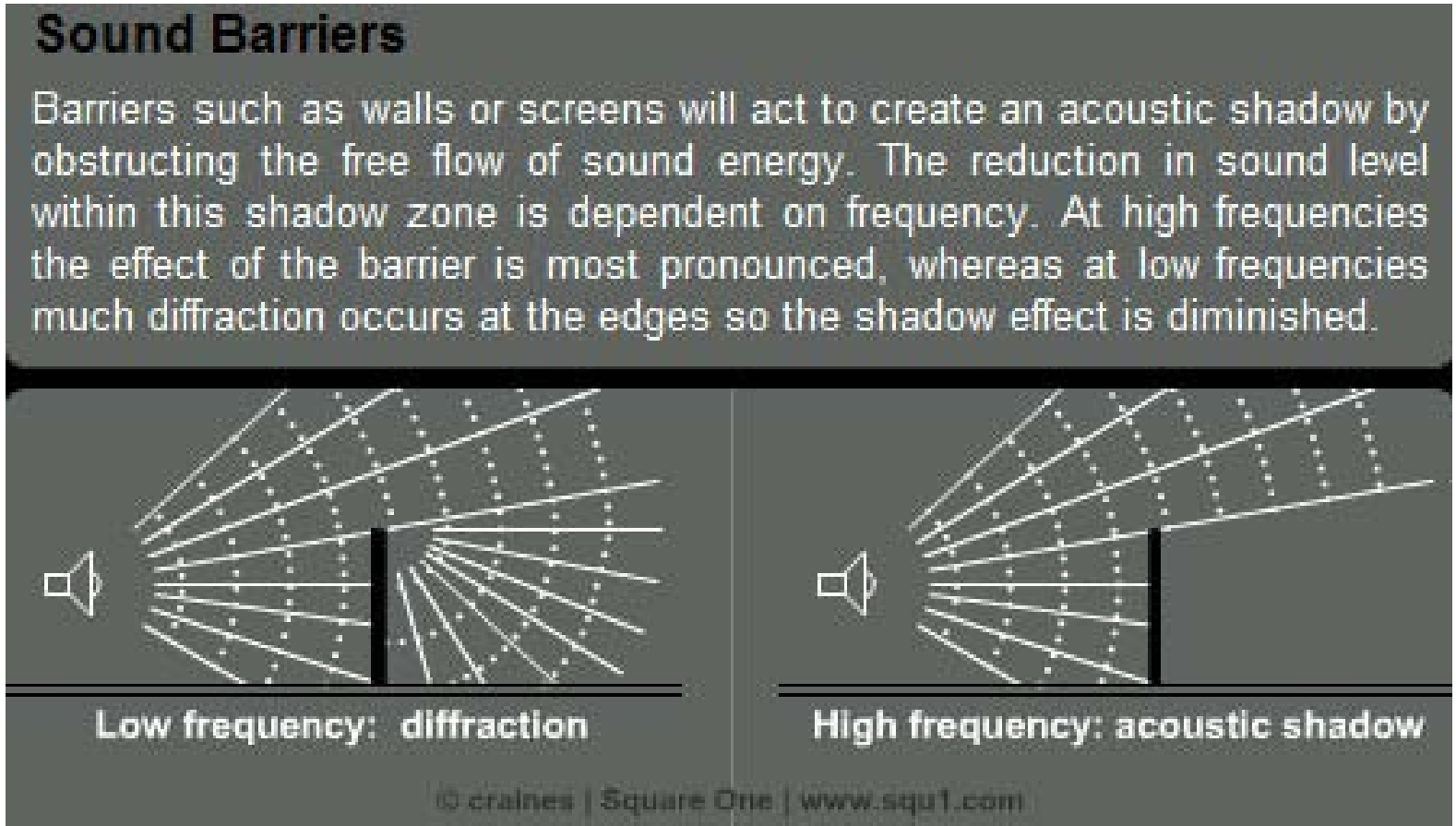


Ear drum rupture, blockage, wax



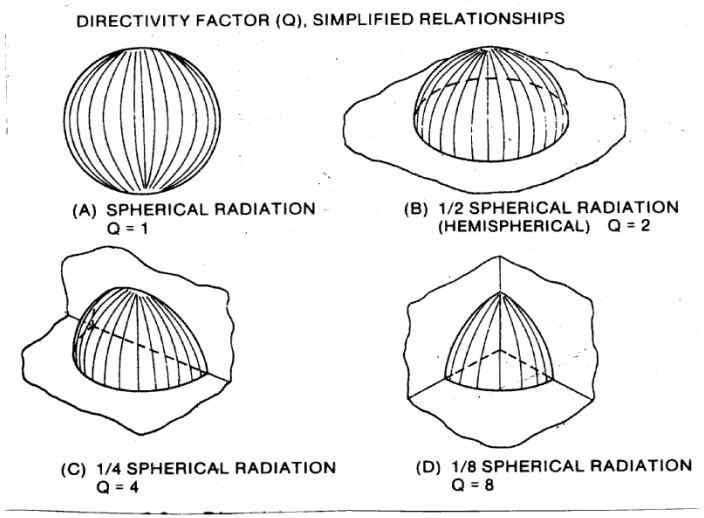
Engineering: Sound barriers (or shielding)

- Low frequency is difficult to abate
- High frequency - solid barriers with absorbing material can work

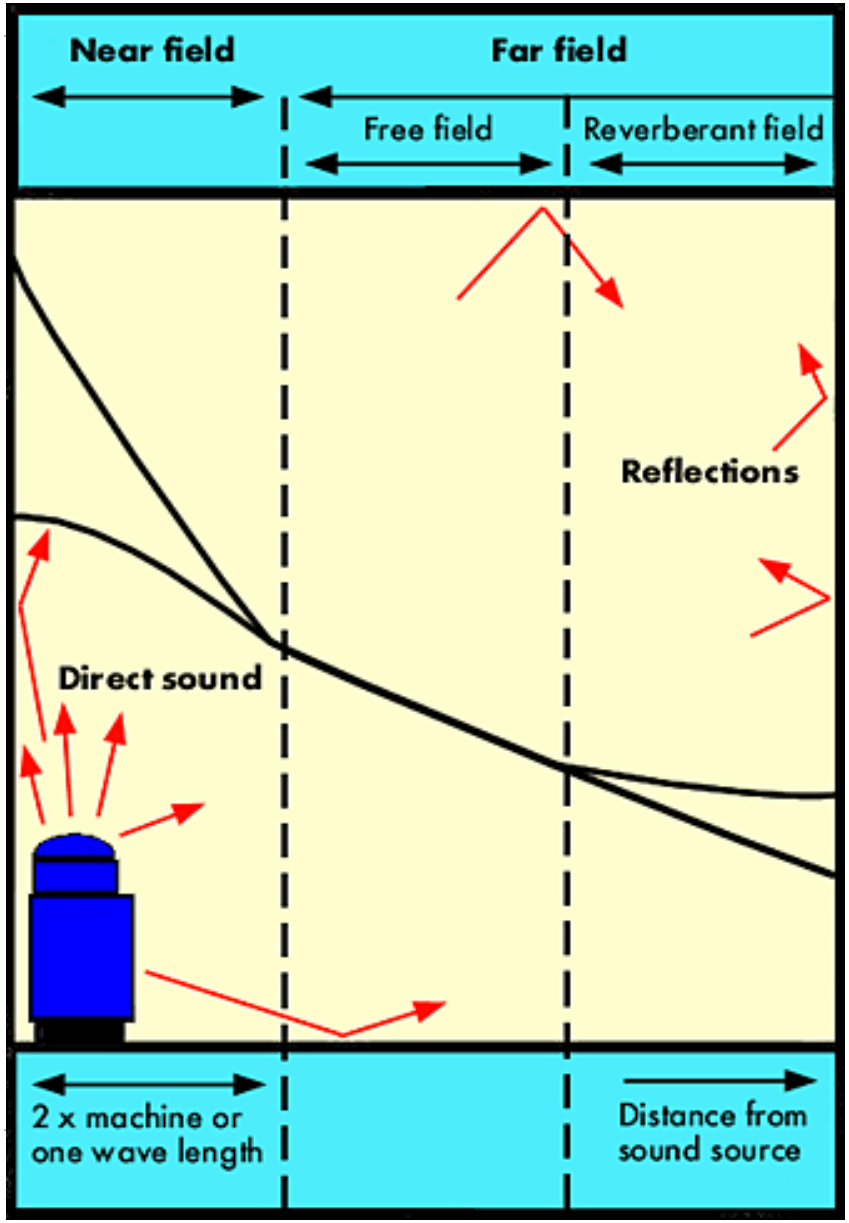


Engineering: Determine Fields

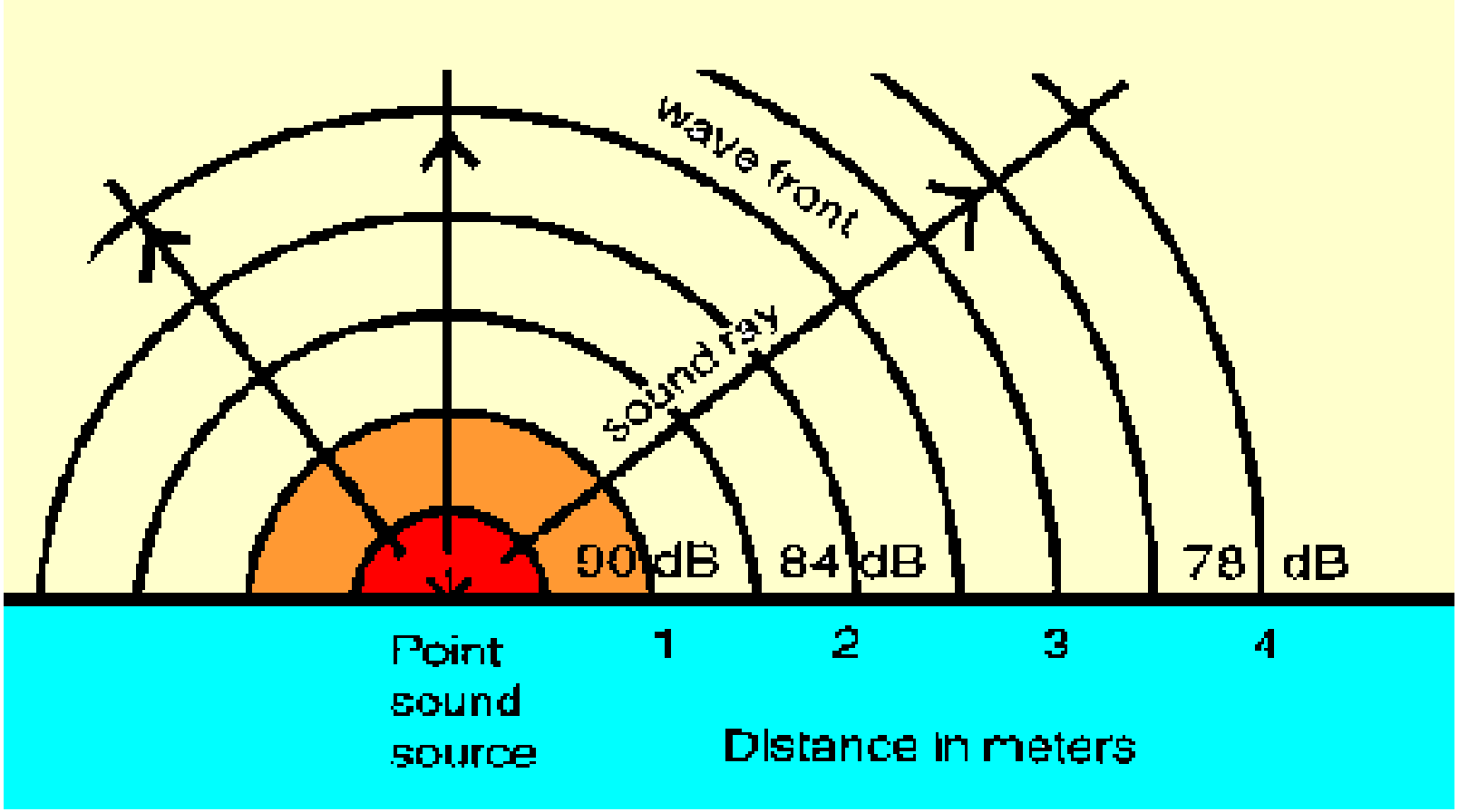
- Reflecting walls or ceilings make noise control more difficult



$$DI = 10 \log_{10} Q$$



Distance from the source; important for identifying noise hazardous areas and personnel exposed



Generally, sound intensity decreases by 6 dB when distance from the source is doubled

A noise radius must be identified from a noise source to where there is no longer hazardous noise

Decibel Addition

Difference Between Levels	Add To Higher Level
0-1 dB	3 dB
2-4 dB	2 dB
5-9 dB	1 dB
10 dB	0 dB

Add
98 dB
100 dB

102 dB

Add
94 dB
98 dB
100 dB
80 dB

102 dB

103 dB

Decibel addition dB(A)-Weighted

Octave Band (Hz)	Low Freq Noise	A-Weight per Octave	dBA
31.5	100	-39.4	61
63	100	-26.2	74
125	100	-16.1	84
250	90	-8.6	81
500	90	-3.2	87
1000	80	0.0	80
2000	60	1.2	61
4000	60	1.0	61
8000	60	1.1	61

Difference Between Levels	Add To Higher Level
0-1 dB	3 dB
2-4 dB	2 dB
5-9 dB	1 dB
10 dB	0 dB

89 dBA

90 dBA

If the measured sound level of a noise is much higher on C-weighting than on A-weighting, much of the noise energy is probably low frequency.

Equations

$$L_{eq} = 10 * \log_{10}(1/T \sum_{i=1}^{N} (10^{L_i/10} t_i))$$

L_{eq} = Equivalent continuous sound

Administrative: Compute 8-hr TWA; limit work time in noise hazardous environment

$$\text{Dose (D)} = \frac{C_1}{T_1} + \frac{C_2}{T_2} + \frac{C_3}{T_3} \ldots$$

C = exposure at noise level
T = time allowed at noise level
Hazard if Dose > 1 (Over the TWA of 90 dB(A)
Hear. Cons.Prog. > 0.5

$$\text{TWA} = 16.61 * \log_{10}(\text{D}) + 90\ \text{dB(A)}$$

$$\text{TWA}_{eq} = 10 * \log_{10}(\text{D}) + 85\ \text{dB(A)}$$

		DoD
	OSHA	ACGIH
8 hr Criterion	90 dBA	85 dBA
Exchange Rate	5 dBA	3 dBA
Hear. Cons. Prog.	85 dBA	

Hrs	OSHA (dBA)	ACGIH (dBA)
24		80
16		82
8	90	85
4	95	88
2	100	91
1	105	94
30 min	110	97
15 min	115	100

- A worker is exposed to 85 dBA for 2 hrs; 90 dBA for 2 hrs; and 100 dBA for 1 hrs. Did he/she exceed the 8-hr TWA? Should he/she be placed in a Hear. Cons. Prog.?

$$\text{OSHA Dose} = \frac{2}{8} + \frac{1}{2} = 0.75$$

$$\text{ACGIH Dose} = \frac{2}{8} + \frac{2}{2} + \frac{1}{0.25} = 5.25$$

DataChem Questions Reviewed

- During review course, we discussed the following review questions from the DataChem software:
- 1555, 1556, 1559, 1562, 1563, 1567, 1580, 1586, 1596, 1597, 1598, 1599, 1600, 1608, 1618, 1622, 1630, 1631, 1634, 1646, 1647, 1648, 1649, 1651