N.C. Department of Labor
OSH Division

- ***Fundamentals of Noise***

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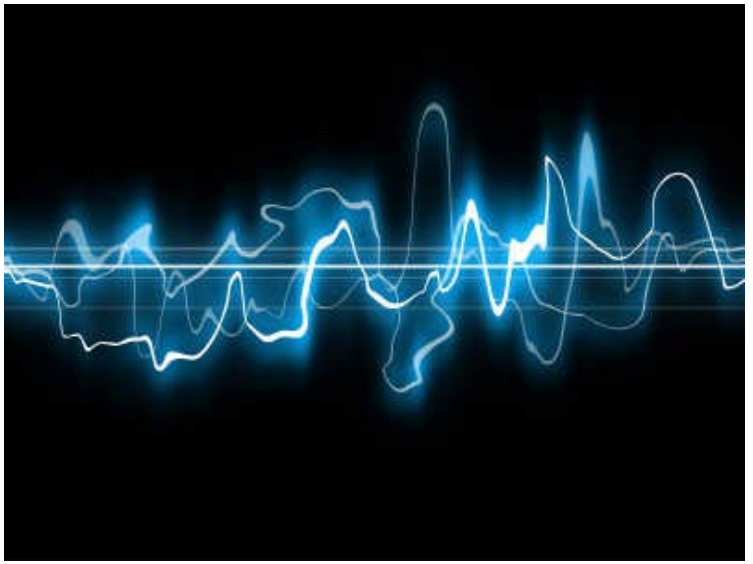
Objectives

- Fundamentals of noise
- Anatomy of the ear
- Noise measurement instrumentation
- Requirements of OSHA's noise regulation
- Enforcement guidelines
- Types of hearing loss
- Evaluating an audiogram
- Proper methods of noise control

What is Sound?

- Defined as a vibratory disturbance in pressure (above and below atmospheric pressure) of a medium which is detectable by the human ear.



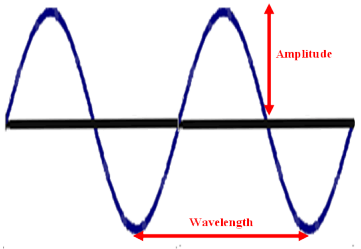
What is Noise?

- Defined as sound that carries no information and whose intensity generally varies randomly over time.

- Noise is also described as “undesirable / unwanted sound”.

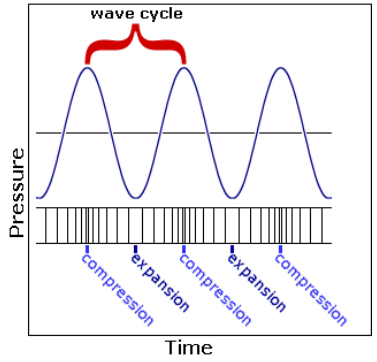
Wavelength

- Measured distance (feet or meters) between two analogous points on two successive parts of a wave.
- Greek letter lambda (λ) used to express wavelength.
- Number of wavelengths per second equals frequency.



Frequency

- Rate at which variation in normal atmospheric pressure occurs.
- Expressed as Hertz (HZ) - synonymous with cycles or waves per second.
- Number of waves per second is frequency.

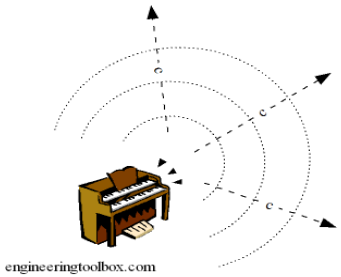


Human Hearing

- Frequency range for young adults with good hearing is usually between 20 - 20,0000 Hz

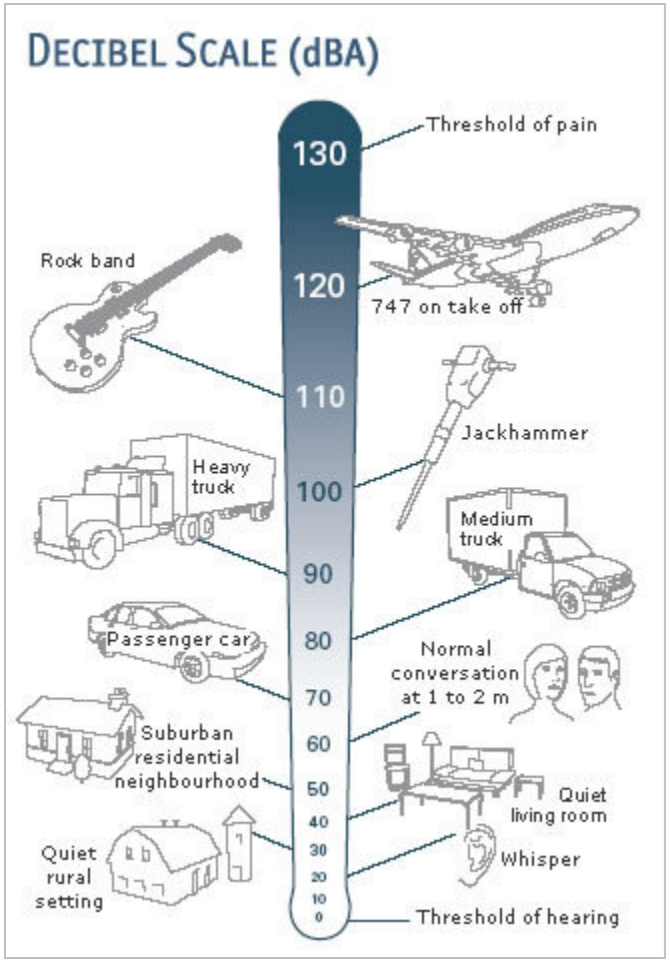
Velocity

- Velocity at which analogous points on successive parts of a sound wave pass a given point is called the speed of sound (c)
- Speed of sound is always equal to the product of the frequency wavelength ($c=f\lambda$)
- Speed of sound increases as the medium becomes more dense and less compressible;
  - In air at 72° F, c is about 1130 ft/sec
  - e.g., c of steel = 16,500ft/sec



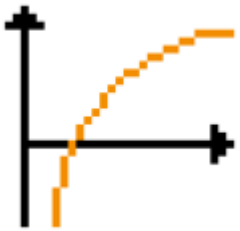
Decibel (dB)

- The decibel scale is a logarithmic function named after Alexander Graham Bell.
- A dimensionless unit used to express the logarithm of the ratio of a measured quantity to a reference quantity.
- Decibels are referenced to 20 micro Newtons/m^2 (threshold of hearing at a reference tone of 1000 Hz).



Why Logarithms???

- The ratio between the threshold of pain and the threshold of hearing in humans is 10,000,000.
- Therefore a relative scale is more practical than an absolute scale
- Using the same ratio on the dB scale is 0 - 140 dB.



Types of Noise

- **Continuous noise**
  - Variations in noise levels are at intervals of 1 second or less.

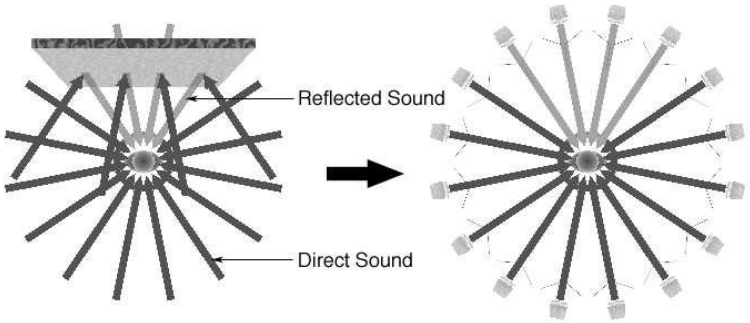
- **Impulse/Impact noise**
  - Less than ½ second in duration and do not repeat more often than once per second.

Combining Decibels

Difference in dB Values	Add to Higher Value
0 or 1 dB	3 dB
2 or 3 dB	2 dB
4 to 9 dB	1 dB
10 dB or more	0 dB

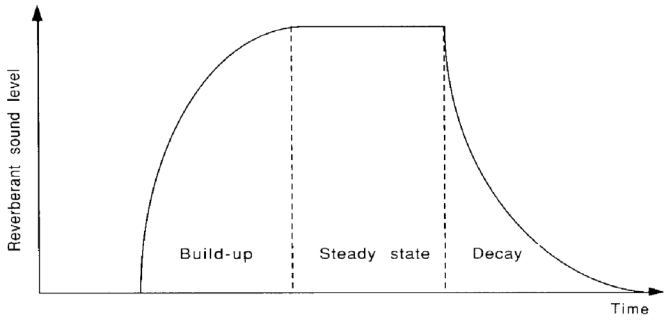
Sound Fields

- **Free Field**
  - Uniform sound propagation from a point source with no sound-reflecting obstacles in the sound field.
  - Sound pressure level decreases 6 dB for each doubling of distance from the point source (inverse square law)

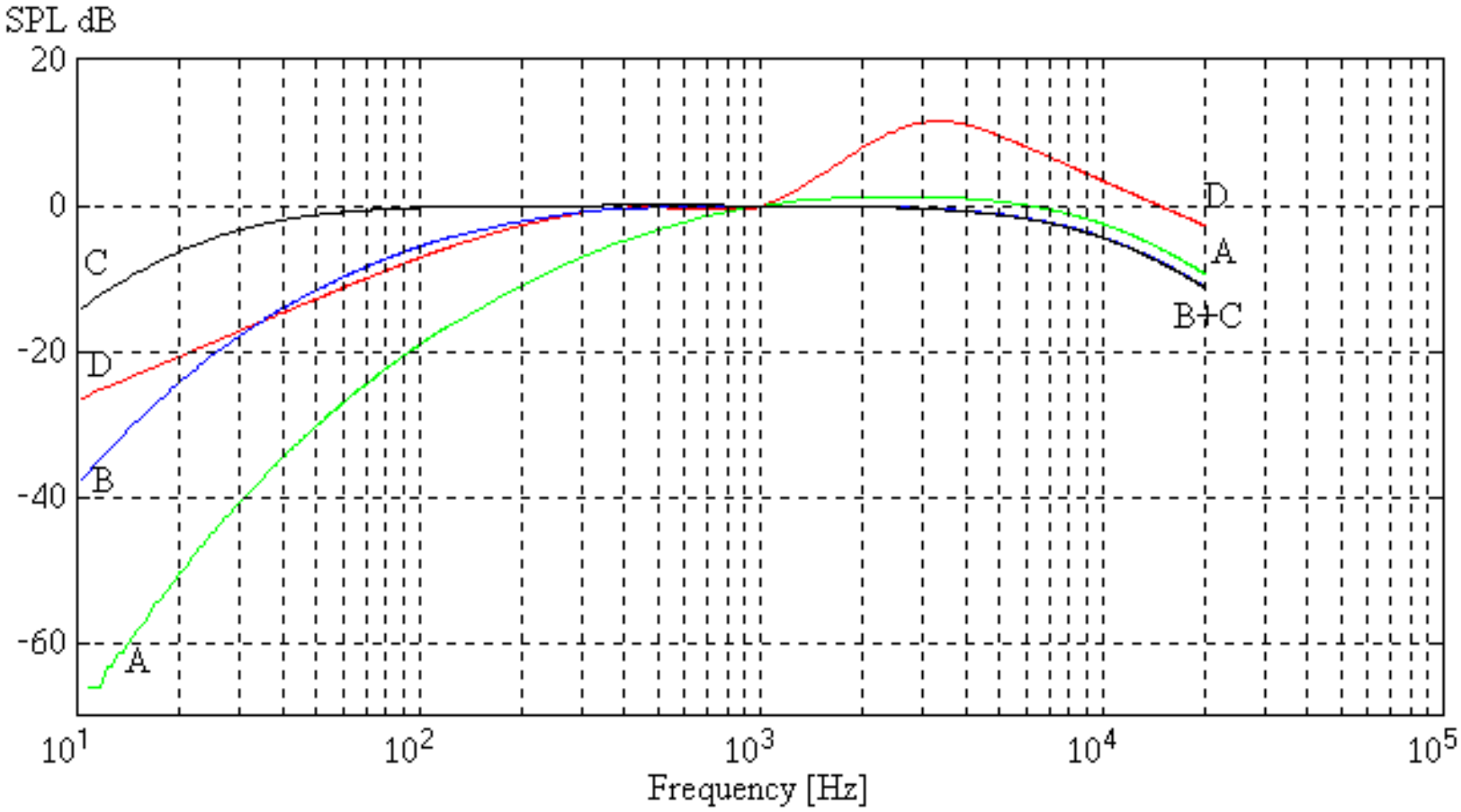


Sound Fields

- **Reverberant Field**
  - Sound is repeatedly reflected in a room by the walls, floor, and ceiling
  - Sound at a given position is made up of direct sound and reflected sound
  - Far from the source, the reflected sound dominates, and this region is called the reverberant field

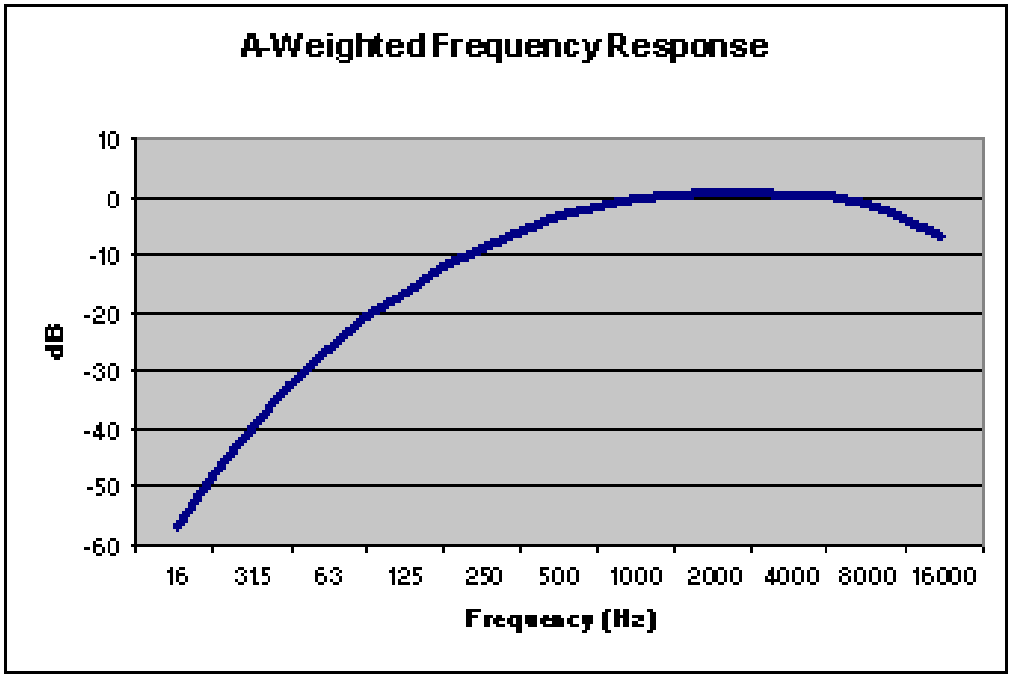


Sound Pressure Weighting



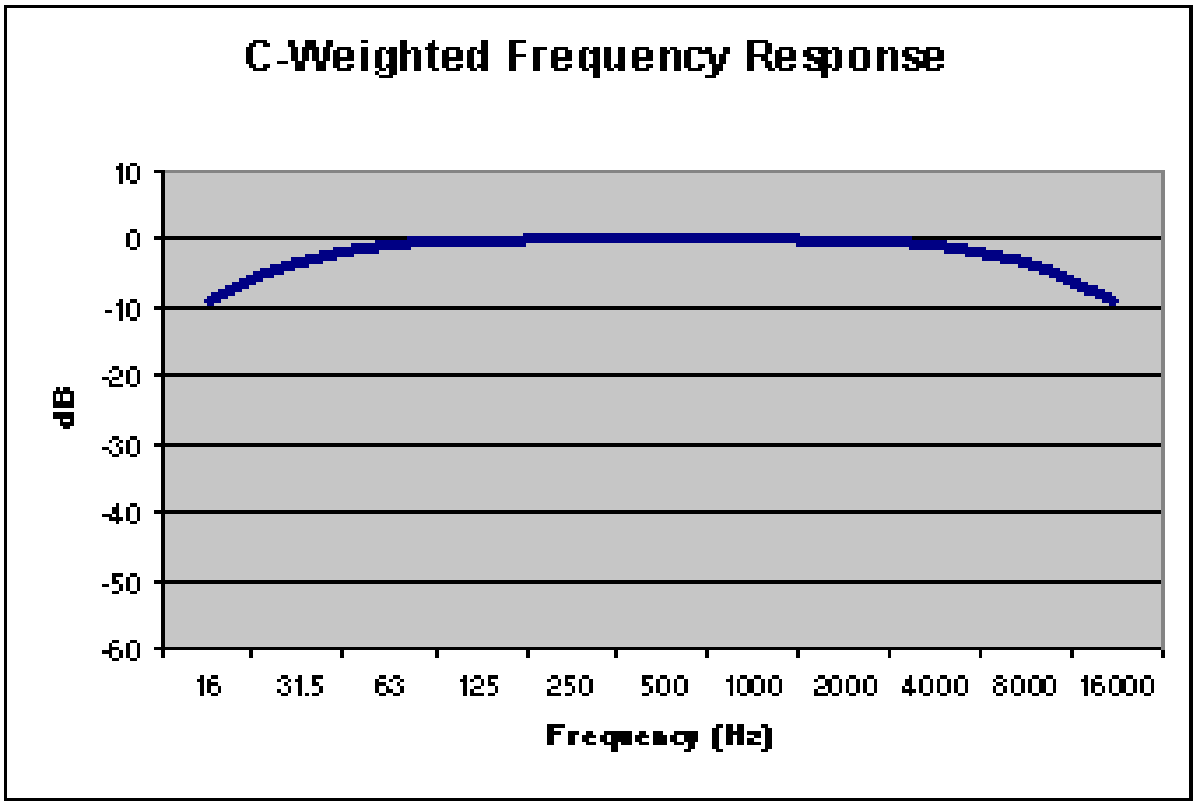
A-Weighting

- Reduces low frequency noise reception and increases high frequency noise reception.

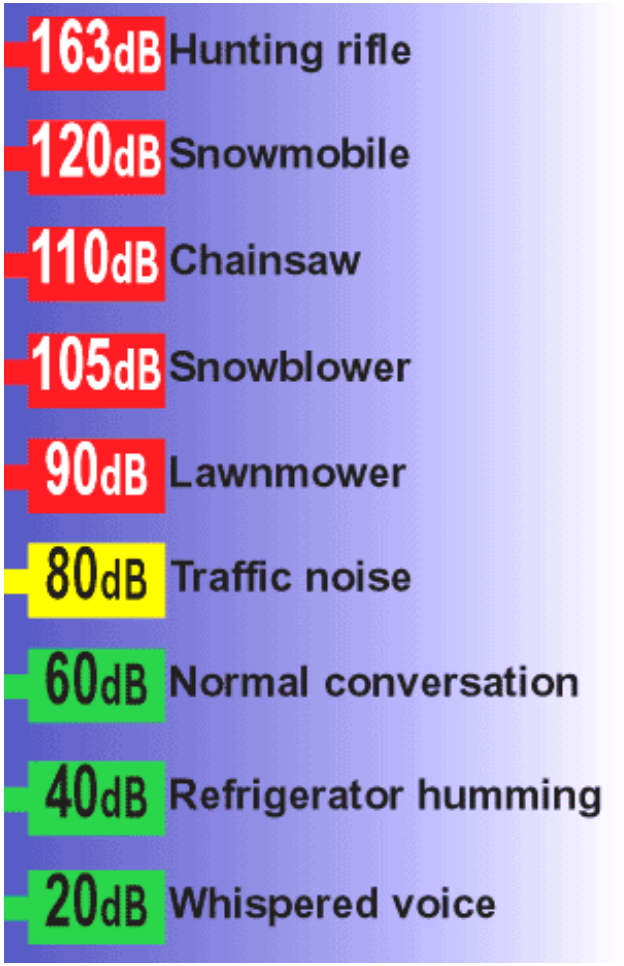


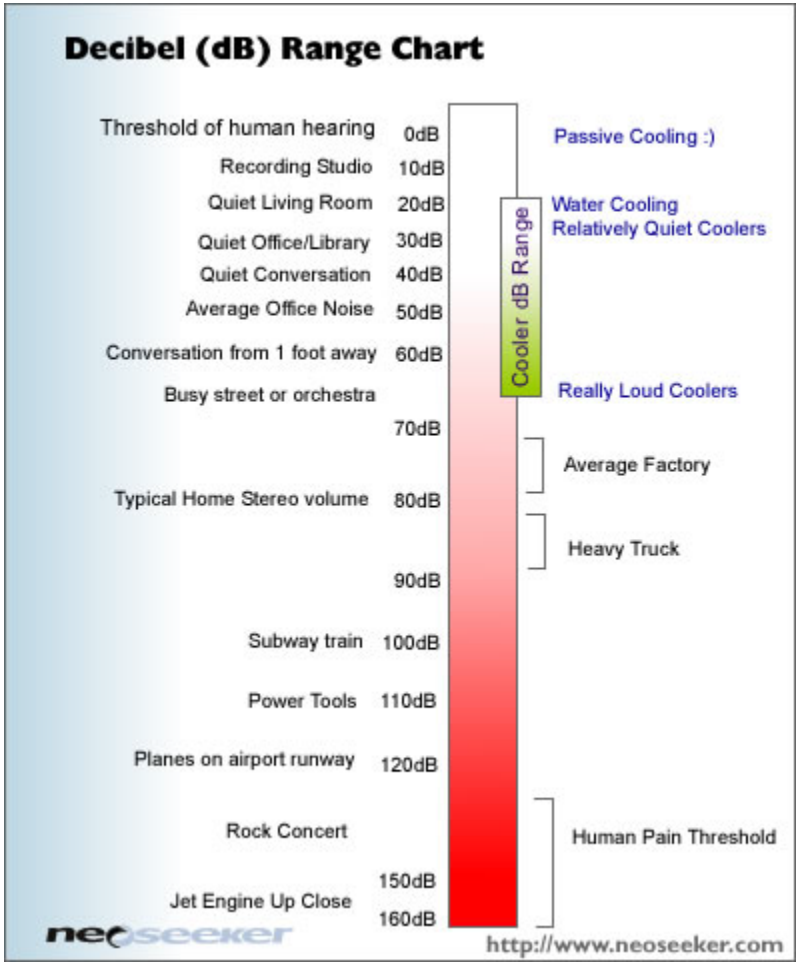
C-Weighting

- Attempts to measure actual noise levels.



Typical “A” Measured Sound Levels

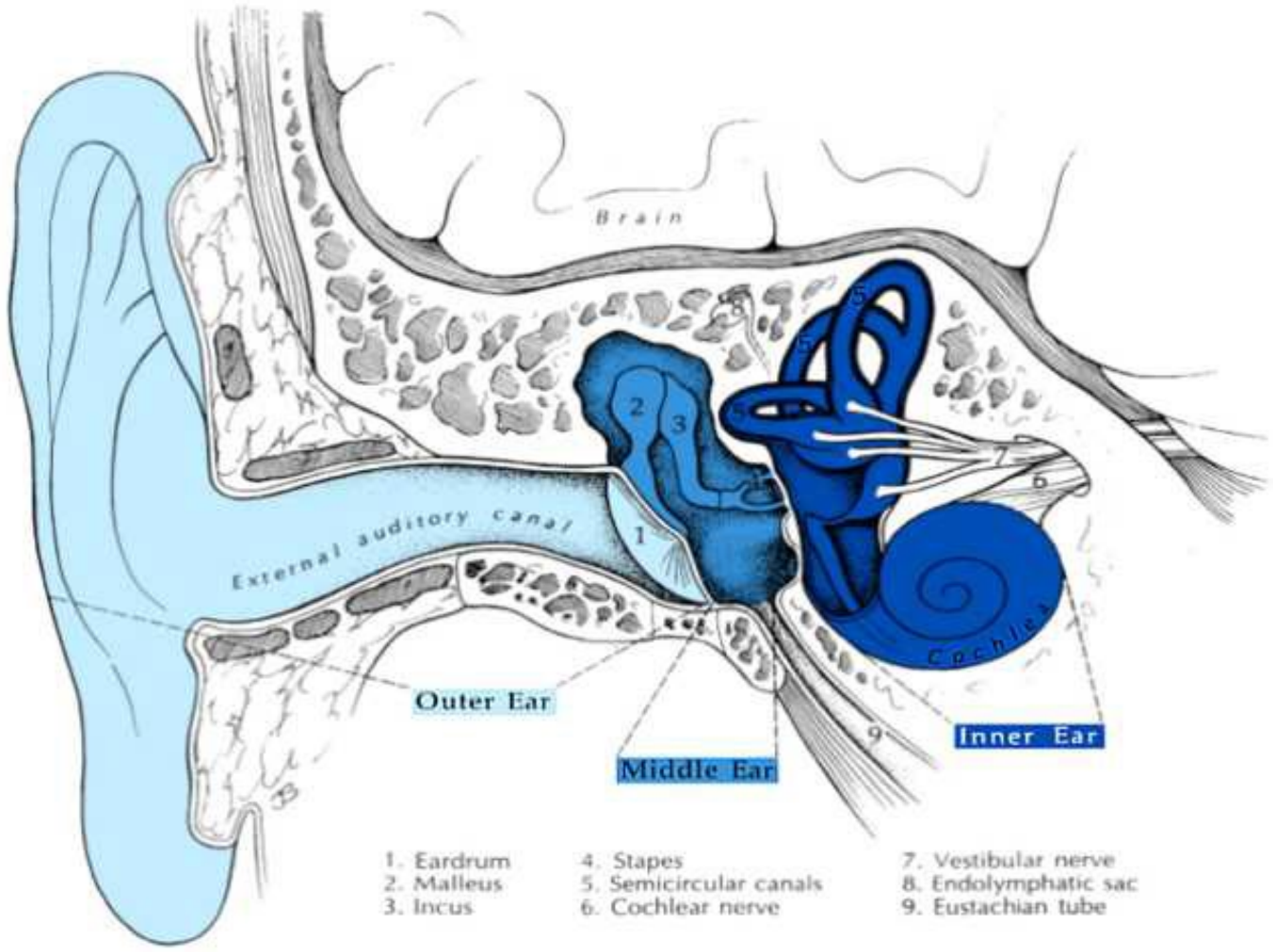




Sound Levels Effects

190 dB	Death
170 dB	Blow out ear drums
160 dB	Deaf in 100 microseconds
120 dB	Pain occurs
115 dB	For 20 min, threshold drop
100 dB	Permanent hearing loss
80 dB	Okay

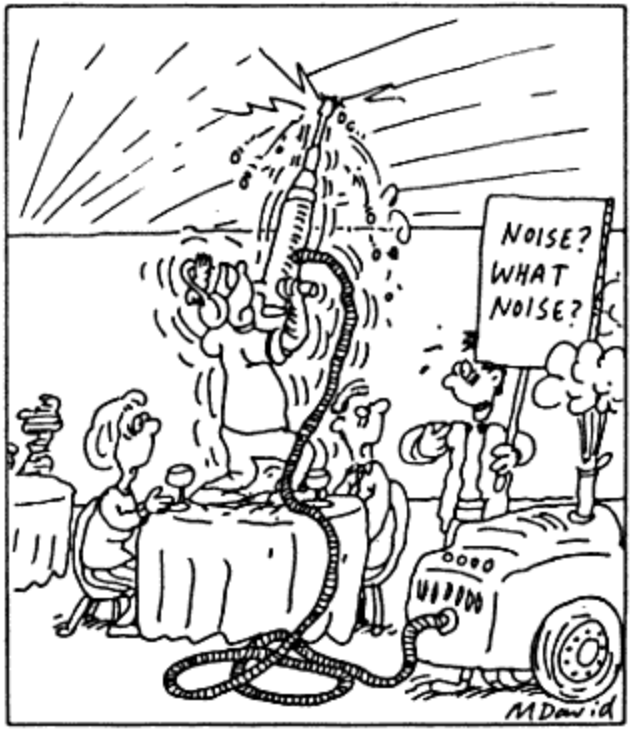
Anatomy of the Ear



Measuring Noise

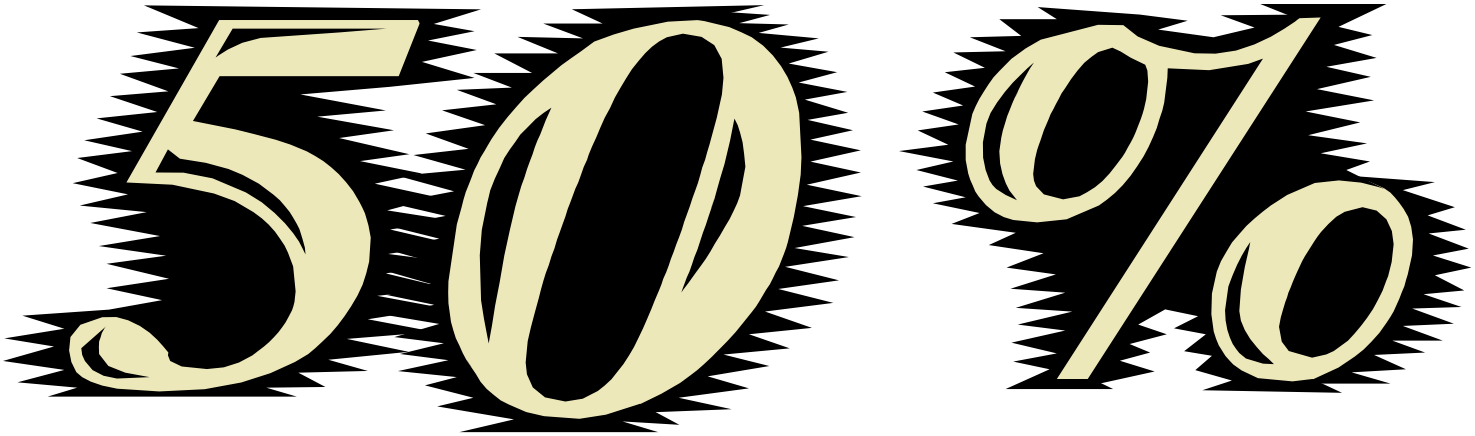
Definitions

- **Criteria Level -** Continuous sound level at which the dosimeter will read 100 percent
- **Exchange Rate -** Increment of decibels that requires the halving of exposure time
- **Threshold -** Sound level above which the dosimeter turns on and integrates noise into the measured exposure



OSHA Exchange Rate

- As you increase noise by 5 dB, you must cut exposure in half.



Noise Instrumentation

- Sound level meter
- Octave band analyzer
- Dosimeter

Noise Equipment

- **Sound Level Meter**
  - Basic instrument to measure sound pressure variations in air.
  - Simply a microphone mounted on an amplifier with a meter to indicate the level of sound pressure at the microphone
  - ANSI S1.4-1983 Type 2, “Specifications for Sound Level Meters”.
  - Set at “A” weighting scale, slow response

SLM Response

TIME CONSTANTS	
Slow	**1000 milliseconds**
Fast	**125 milliseconds**
Impulse	**35 milliseconds**
Peak	**50 microseconds**
NOTE: Human ear averaging time is approximately 30-100 milliseconds	

Noise Equipment

- **Noise Dosimeter**
  - Instrument which integrates sound pressure over time and directly indicates a noise dose. Used for personal exposure monitoring.
  - ANSI S1.25-1978 “Specifications for Noise Dosimeters”.
  - 90 dBA criterion level, 5 dB exchange rate, 80 dBA or 90 dBA threshold gate

Noise Equipment

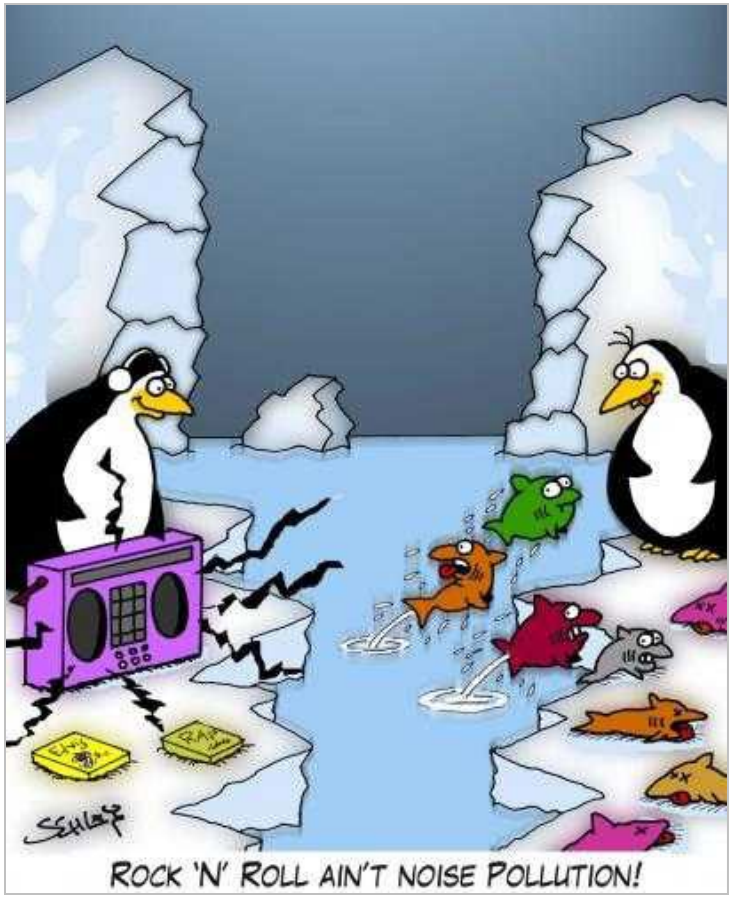
- **Octave Band Analyzer**
  - Instrument used to determine where the noise energy lies in a frequency spectrum. Generally used as a diagnostic tool to help find appropriate engineering controls to reduce noise levels.
  - Can be used to evaluate hearing protectors
  - ANSI S1.11- 1986

To Sample or Not?

- SLM readings
- Duration of exposure (How many hours does equipment run?)
- Employee proximity to equipment
- Multiple noise sources?
- Hearing conservation program?
- Complaint?

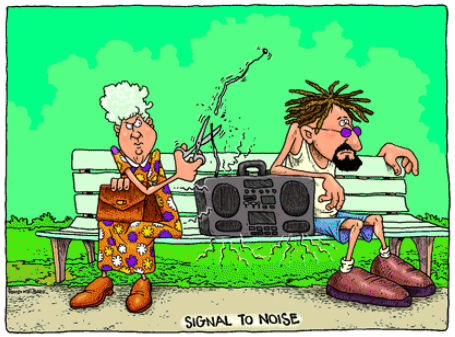
Sampling Protocol

- Follow the manufacturer's instruction booklet for proper sampling technique, microphone placement, calibration, charging, etc.
- Make sure equipment is properly calibrated and battery function is adequate
- Make sure microphone is in employee's hearing zone



Sampling Protocol

- When noise levels are different for two ears, the higher level must be used
- Note situations which can interfere with equipment operation
- Obtain at least 5 random SLM readings noting time and job function during reading
- Record information as required on OSHA-92



Requirements - OSHA's Noise Regulation

- 29 CFR 1910.95 – General Industry
- 29 CFR 1926.52 – Construction Industry

General Industry

29 CFR 1910.95

- Woodworking
- Textiles
- Food processing
- Machining operations

Hearing Conservation Program 29 CFR 1910.95(a)-(b)

- **PEL** - 90 dBA 8-hour TWA
- **AL** - 85 dBA 8-hour TWA
- Maximum exposure (for example) - 115 dBA for 15 min
- Maximum impact or impulse noise - 140 dBA
  - How can this be measured?
  - When would you cite it?

Hearing Conservation Program 29 CFR 1910.95(b)

- If exposures exceed 90 dBA as an 8-hour TWA
  - Feasible administrative or engineering controls shall be utilized.
  - If such controls fail to reduce sound levels to below the PEL, PPE shall be provided and used.

Hearing Conservation Program

29 CFR 1910.95(c)

- Employer shall administer a continuing effective hearing conservation program when noise exposures equal or exceed an 8 hour TWA of 85 dBA.
  - Does this program have to be in writing?
- In determining **exposure**, no regard is given to hearing protector attenuation.
  - Where does hearing protection attenuation come into play?

Monitoring

29 CFR 1910.95(d)

- Develop a monitoring program
- Develop a sampling strategy

Monitoring

29 CFR 1910.95(d)

- Is dosimetry required?
- Can an employer comply with (d) by using an SLM?
  - How?

Employee Notification

29 CFR 1910.95(e)

- Employer shall notify each employee exposed at or above 85 dBA of the monitoring results.
  - How would you recommend this be accomplished?

Audiometric Testing Program

29 CFR 1910.95(g)

- Establish and maintain an audiometric testing program.
- Baseline audiogram
- Mobile test van exception

NOTE: *Audiograms should be preceded by 14 hours without workplace noise exposure*

Audiometric Testing Program

29 CFR 1910.95(g)

- Follow-up procedures
- Revised baseline
- Standard threshold shift

Audiometric Test Requirements 29 CFR 1910.95(h)

- This section sets the criteria for how the tests should be conducted and what standards audiometric test equipment shall meet.

Hearing Protectors

29 CFR 1910.95(i)

- Shall be available to employees exposed at or above 85 dBA
- Shall be required for those employees:
  - Exposed at or above 90 dBA
  - Exposed at or above 85 dBA (no baseline)
  - Who have an STS

Hearing Protector Attenuation

29 CFR 1910.95(j)

- Hearing protectors shall:
  - Attenuate to an 8 hour TWA PEL of 90 dBA
  - Attenuate to an 8 hour TWA PEL of 85 dBA, for those with a STS
  - Be reevaluated whenever noise exposures increase to determine adequacy.

Training

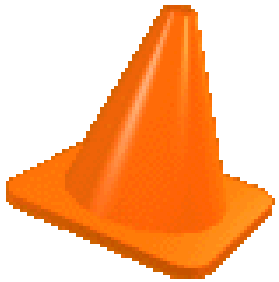
29 CFR 1910.95(k)

- Shall be instituted for employees exposed at or above 85 dBA
- Shall be repeated at least annually, or as needed and include:
  - Effects of noise on hearing
  - Purpose of hearing protectors
  - Instruction and proper selection, fitting, use, and care
  - Purpose of audiometric test and explanation of the procedures and results.

Construction Noise Sources

29 CFR 1926

- Earth moving equipment
- Power tools (nail guns, etc.)
- Abrasive blasting
- Jack hammers
- Air compressors
- Pneumatic nail guns, staple guns
- Confined space



Construction Industry

29 CFR 1926

- Hearing Conservation Program required at 90 dBA
  - What is required in a construction hearing conservation program?

Enforcement Guidelines

Noise Enforcement

- Refer to Technical Manual Section II: **Chapter 5**
- Use 80 dBA threshold for Hearing Conservation
- Use 90 dBA threshold for PEL
- Use SLM for impact noise

Interpreting Dosimeter Readings Using 80dBA Threshold Level

Dosimeter Reading	Compliance with PEL	Compliance with AL
<50%	Within PEL	Within Al
50% - 66%	Within PEL	Inconclusive
>66%	Within PEL	Over AL

Interpreting Dosimeter Readings Using 90dBA Threshold Level

Dosimeter Reading	Compliance with PEL	Compliance with AL
<50%	Within PEL	Inconclusive
50% - 66%	Within PEL	Inconclusive
66% - 100%	Within PEL	Over AL
100% - 132%	Inconclusive	Over AL
>132%	Over PEL	Over AL

Noise Enforcement

- Pre and post- calibrate equipment
- Take at least 5 random SLM readings
- Obtain information for OSHA-92
- Take appropriate photographs
- Note types and NRR of hearing protection used; is it being used properly?

Noise Enforcement

- Note type and location of noise sources adjacent to employee sampled
- Copy data before you leave site
- Note breaks, lunch hours, machine down time
- Typical work day?

Noise Enforcement

- **Hearing Protector Attenuation -** Compliance: NRR-7 (for spectral uncertainty)
- **Approximately Field Attenuation -** Recommend NRR-7 X 50%
- **Dual protection:** (NRR -7) + 5

Note: *NRR is for higher-rated protector*

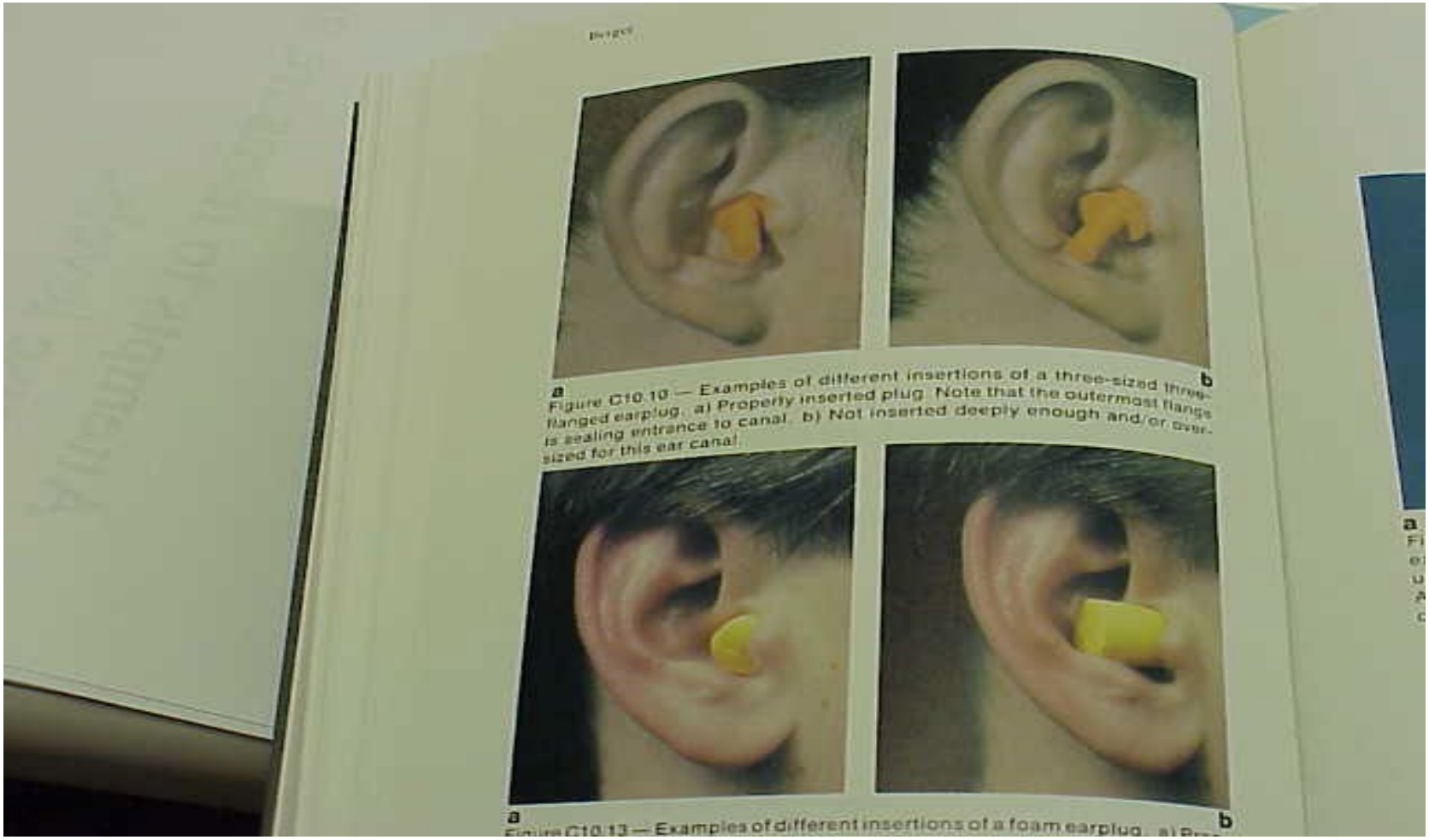
Noise Enforcement

- **Serious Citation -** Exposure Dose 132% *and*:
  - HP not provided or utilized correctly and/or
  - HCP is deficient or non-existent

- **"Other" Citation -** Exposure Dose 66% *and:*
  - HCP is non-existent or deficient in some element

Note: *If effective HP, HCP and no feasible administrative or engineering controls exist, then no citation will be issued.*

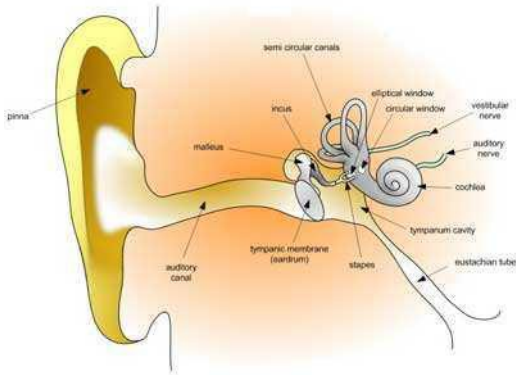
Insertion of Ear Plugs



Types of Hearing Loss

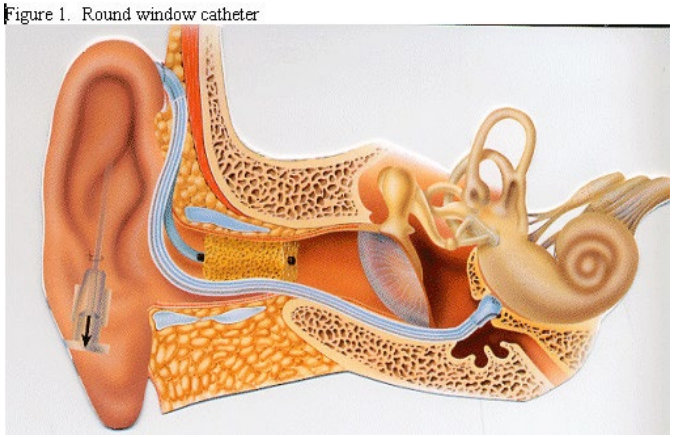
Types of Hearing Loss

- **Conductive hearing losses**
  - Wax build-up
  - Foreign objects
  - Infections
  - Rupture of ear drum
  - Accidents with sharp blow to head
  - Some medical conditions



Types of Hearing Loss

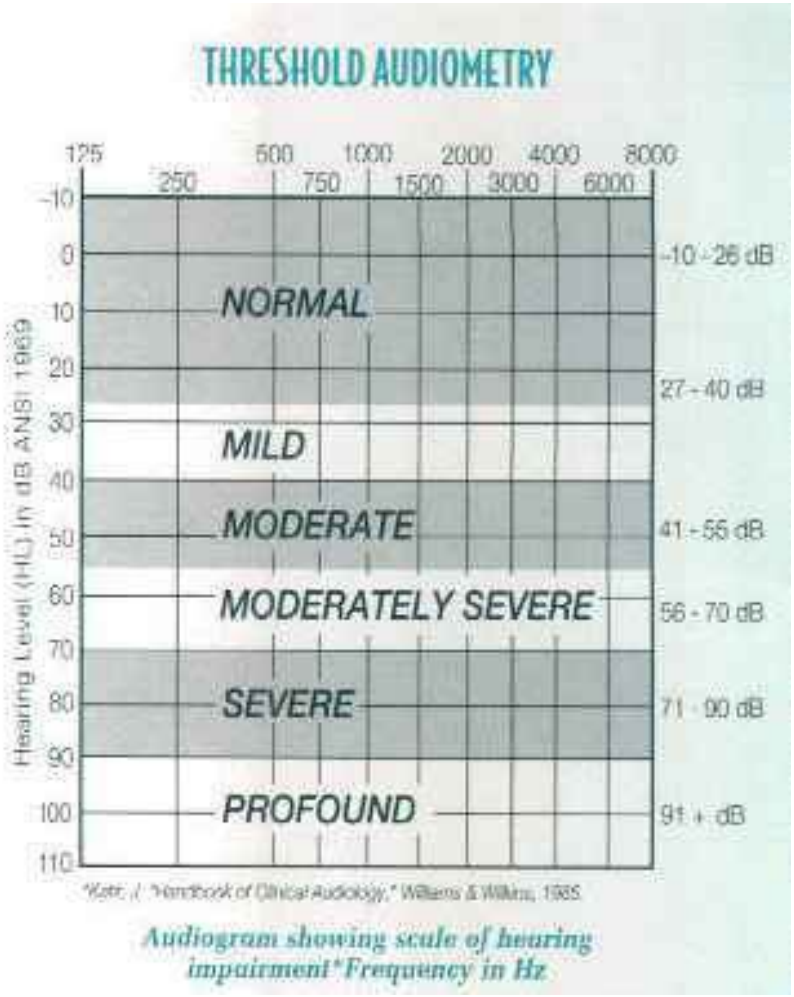
- **Sensori-neural hearing loss**
  - Presbycusis
  - Disease
  - Ototoxic drugs
  - Noise-induced hearing loss



Noise-Induced Hearing Loss

- **Immediate acoustic trauma**
  - Cochlear structures are mechanically broken apart by the pressure wave
  - Extremely intense sound levels
  - Gradually progressive
  - Temporary threshold shift
  - Permanent threshold shift

Degree of Hearing Loss

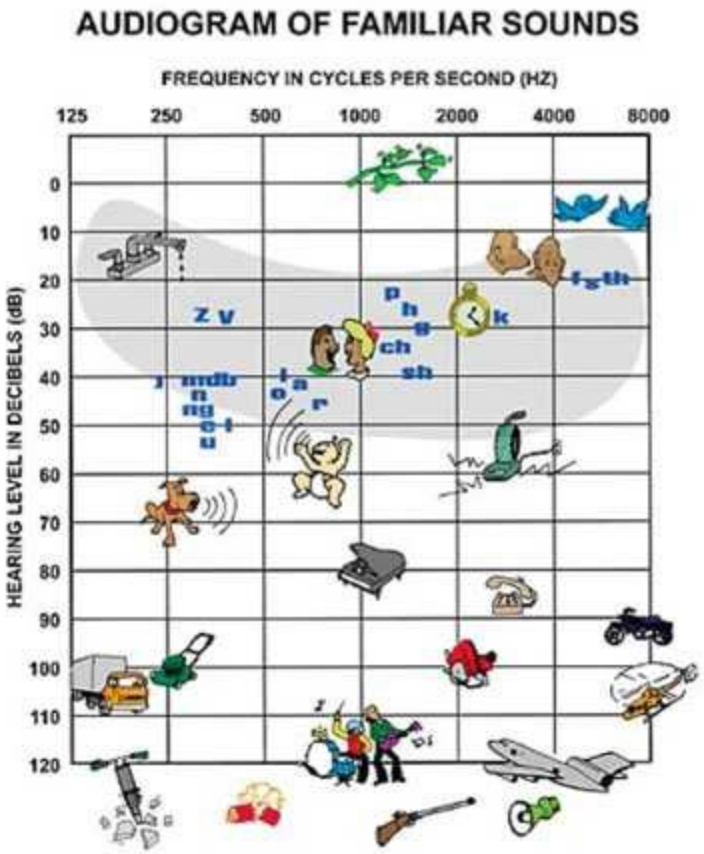


Audiogram showing scale of hearing impairment

Auditory Effects of Noise

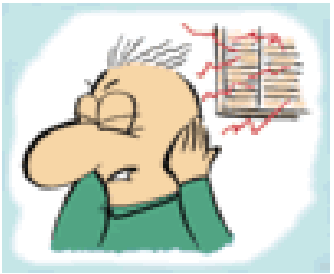
- **Temporary effects**
  - Interference with communication and perception of warnings
- **Permanent effects**
  - Tinnitus, recruitment
  - Safety concerns
  - Social isolation

Evaluating an Audiogram

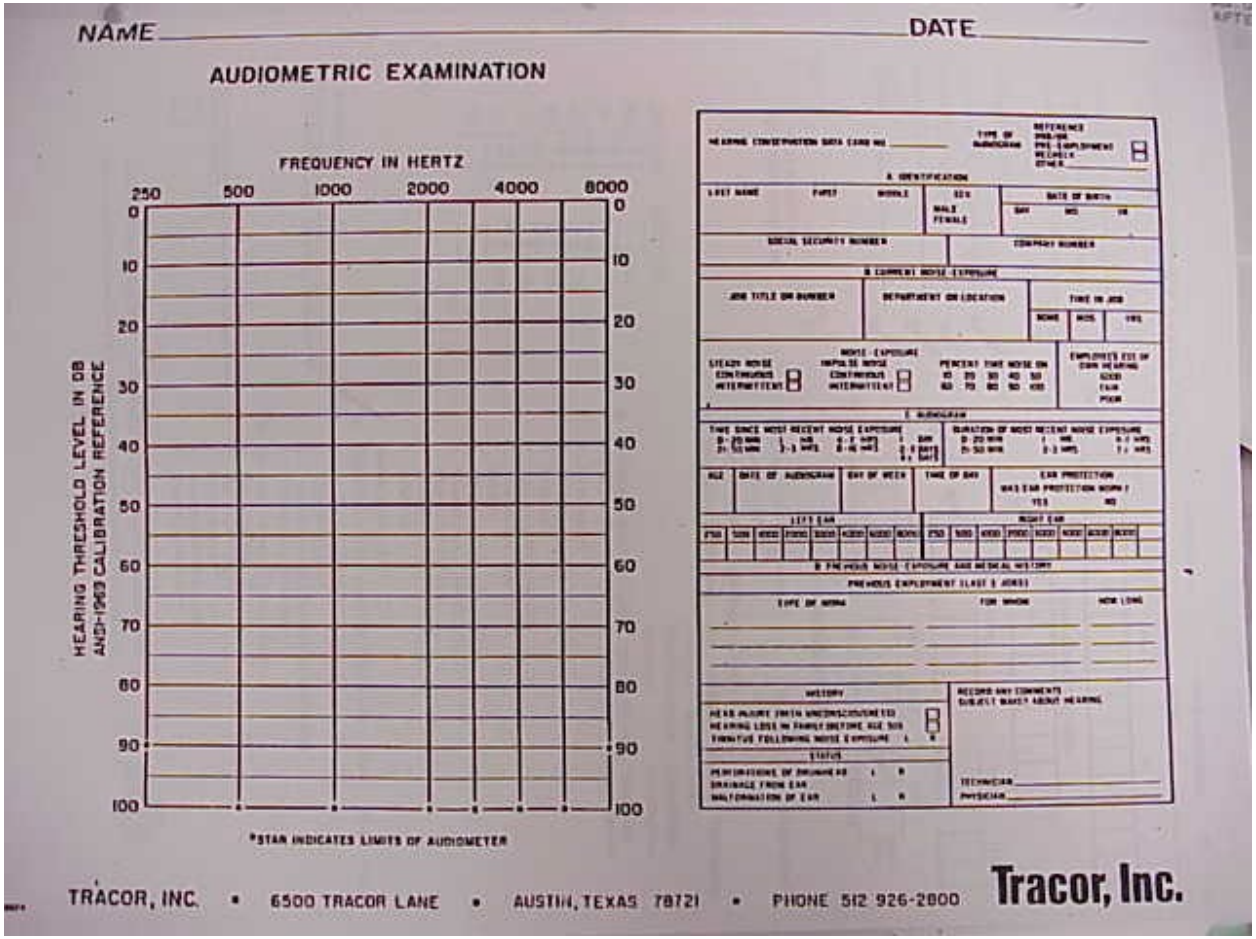


Evaluating an Audiogram

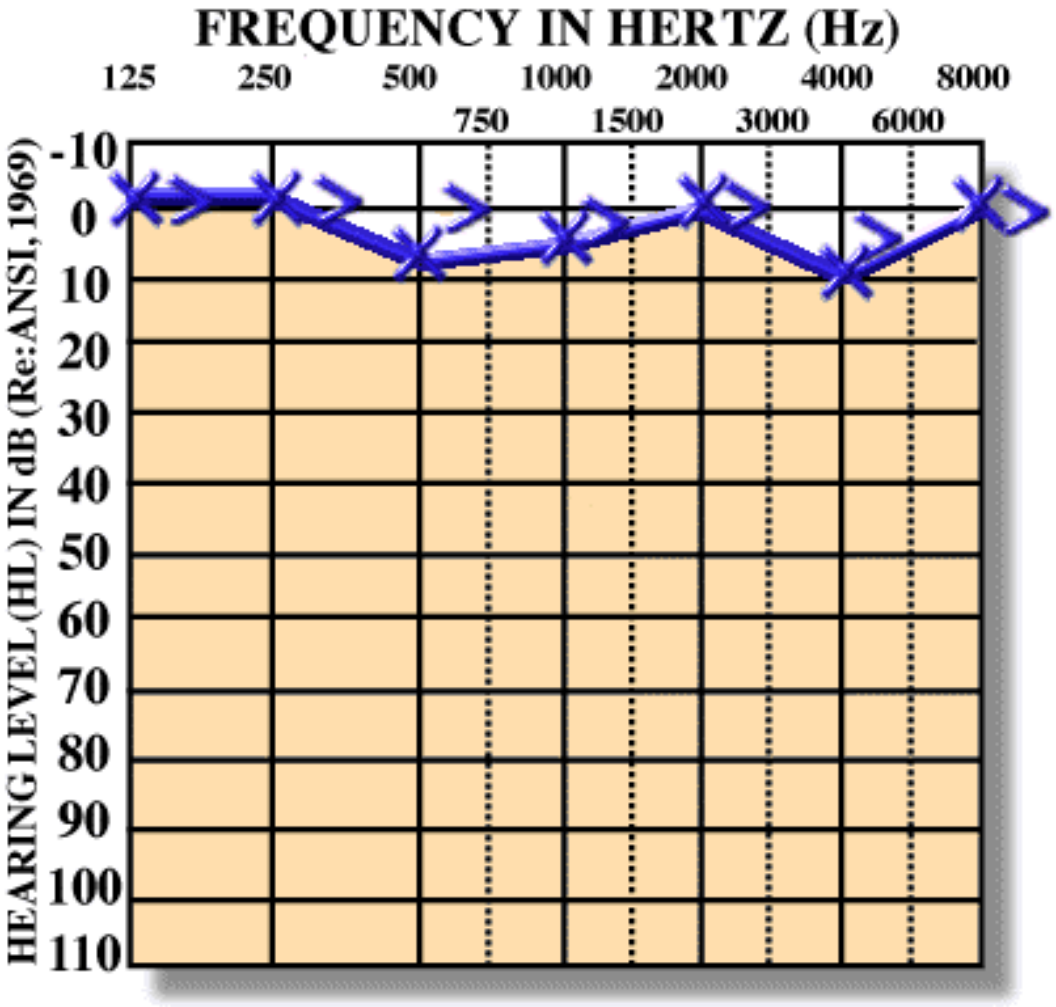
- Check for baseline audiogram
- Evaluate for threshold shift in the 2,000/3,000/4,000 Hz range
- If average of shift in above range is ≥10dBA then a STS has occurred (apply age correction if necessary).
- Check 200 Logs for STS.



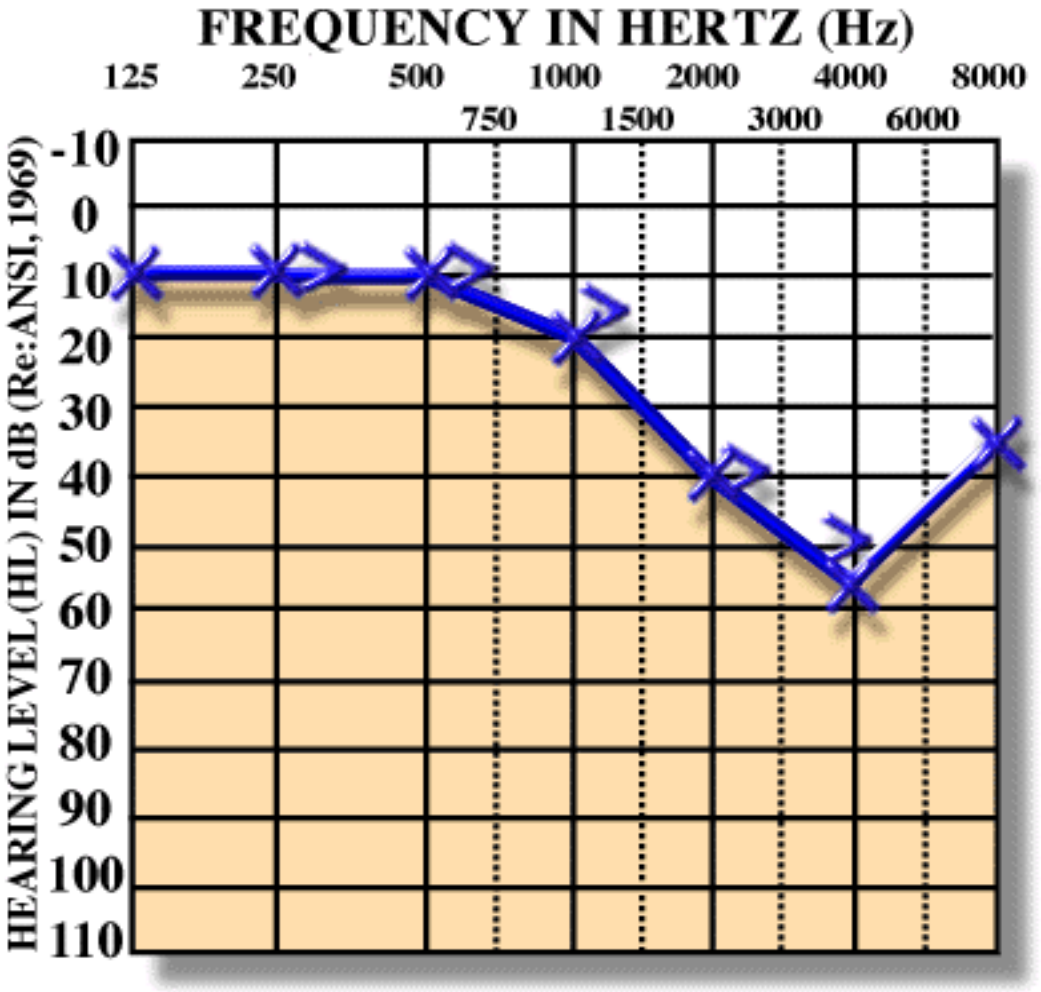
Audiometric Examination Report



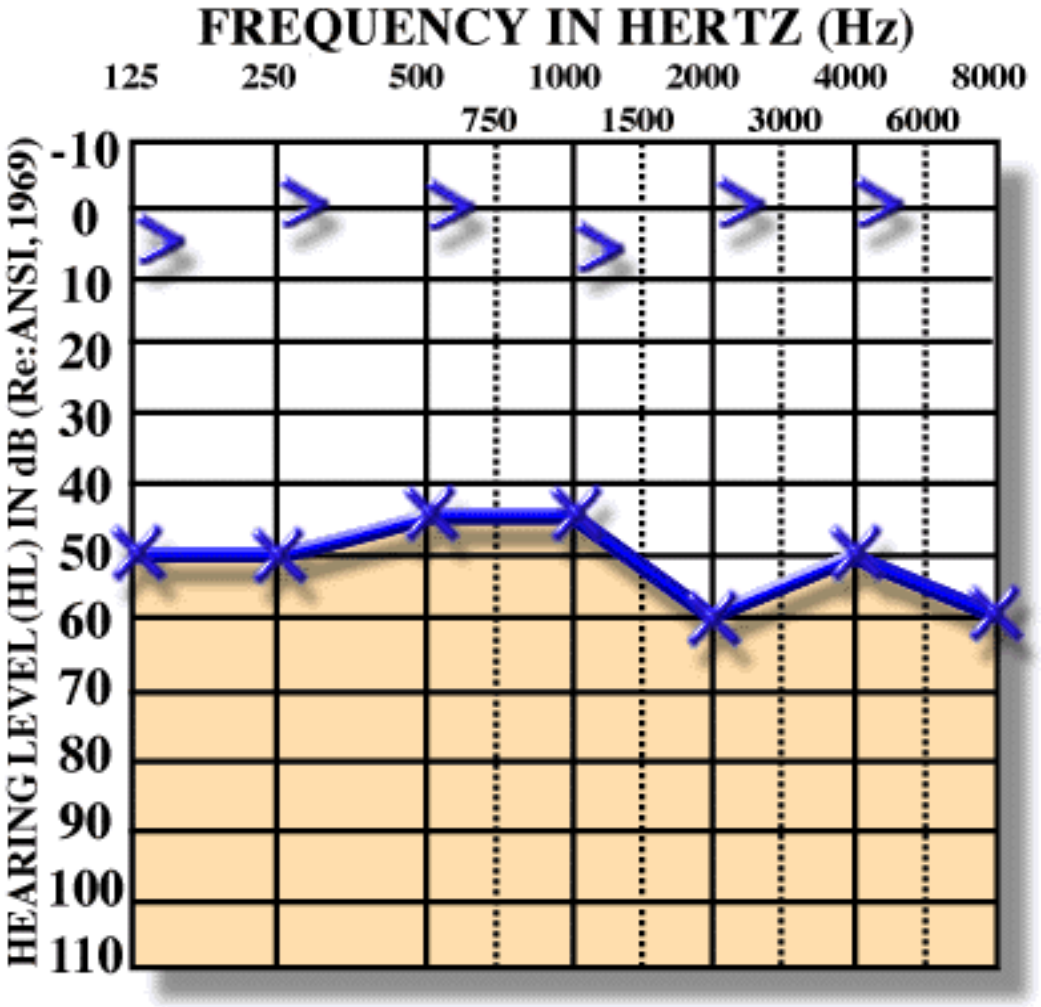
Normal Hearing



Sensorineural Hearing Loss



Conductive Hearing Loss



Proper Methods of Noise Control

Noise Control

- **Noise engineering controls**
  - Replacement
  - Source modification
  - Path modification

Noise Control

- **Replacement**
  - Quieter equipment
  - Quieter processes
  - Quieter materials

Noise Control

- **Source modification**
  - Reduce driving force
  - Reduce response of vibrating surface
  - Reduce area of vibrating surface
  - Use directivity of source
  - Reduce velocity of fluid flow

Noise Control

- **Path modification**
  - Enclosures
  - Shields of barriers
  - Room absorption
  - Lined ducts and mufflers

Air Noise

- Approximately 50% of all high noise sources are due to compressed air
- Generally in the 2000 Hz to 8000 Hz bands
- Can be controlled below 90 dB in nearly all cases
- Most common sources are blow-offs and pneumatic valves

Duct Silencers

Compressed Air Silencer

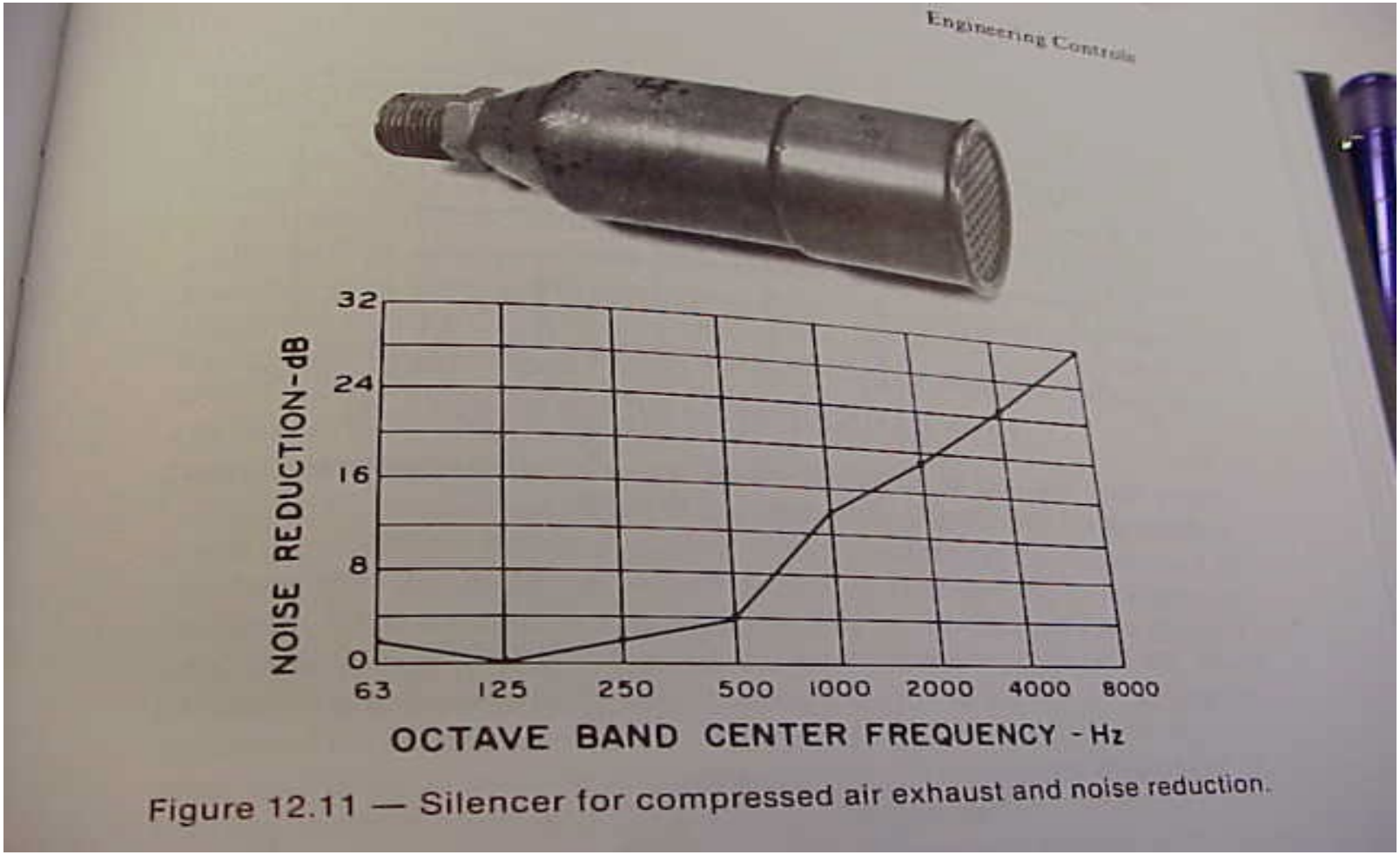


Figure 12.11 — Silencer for compressed air exhaust and noise reduction.

Pneumatic Muffler

Air Silencers and Vibration Mounts

High Thrust Air Silencers

Low Frequency Mounts

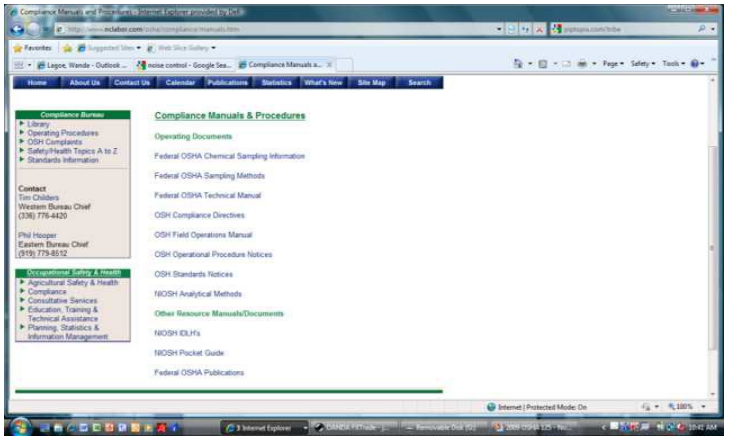
Noise Curtains

Expansion Joints/Fan Connector

Sound Absorption Baffles and Wall Panels

Resources

- OSHA Technical Manual
- FIS (search DOL intranet)
- Internet (USDOL, NIOSH, etc.)
- Library (check DOL intranet)

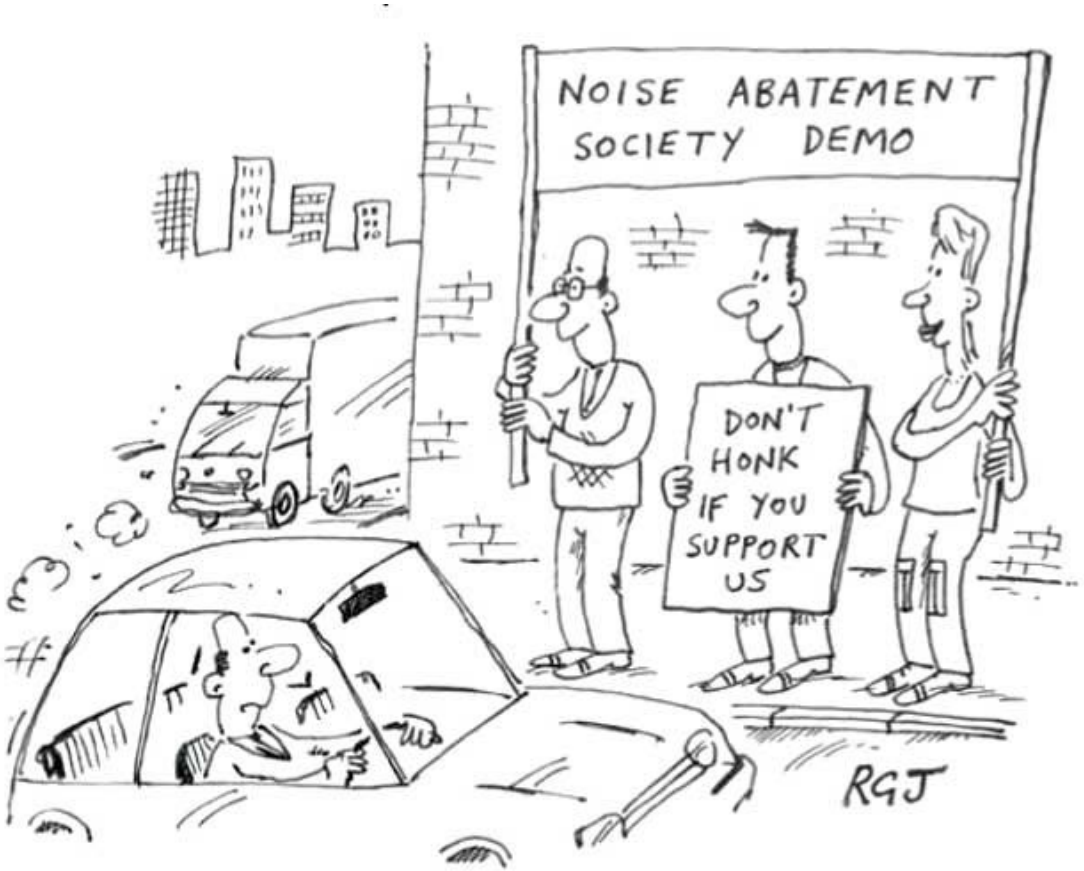


Resources

- NIOSH Technical Report - Compendium of Materials for Noise Control (80-116)
- NIOSH Criteria for a Recommended Standard (98-126)
- Noise and Hearing Conservation Manual (Berger,Ward, Morrill, Royster; 4th edition)

National Institute for Occupational Safety and Health NIOSH

Case Studies



Case Studies

- For each of the following case studies:
  - What OSH violations are present?
  - What is the hazard?
  - Which employees are exposed?
  - How many?
  - What is the assessed severity and probability?
  - What are some abatement recommendations?

Case Study #1 – Groups 1 & 2

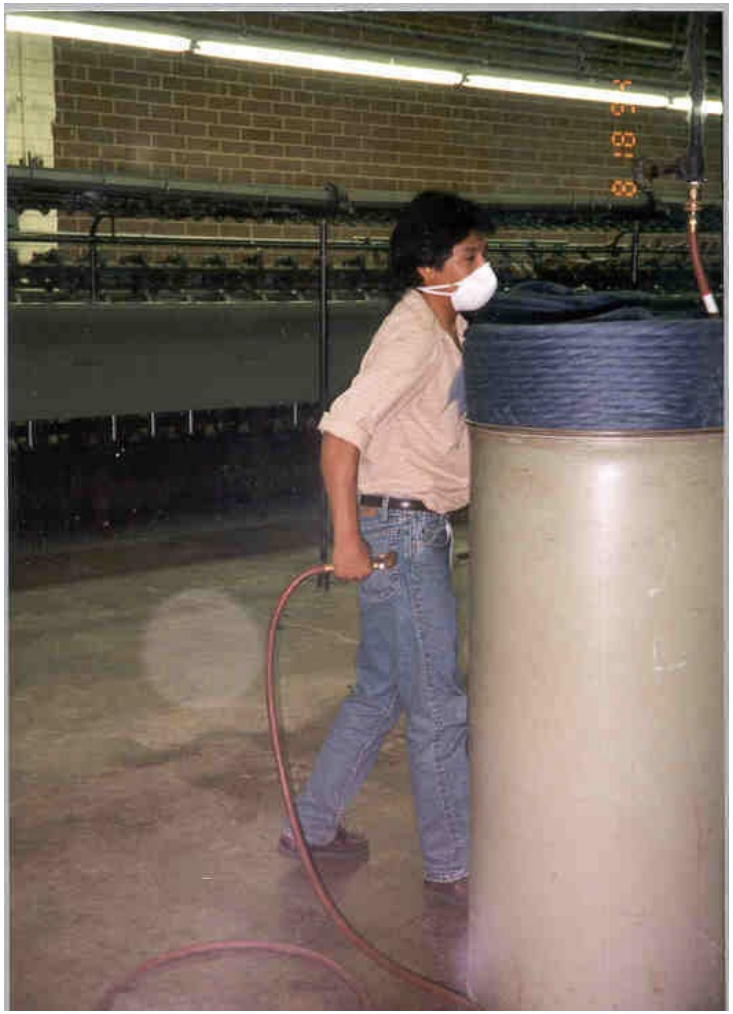
- Employees at a yarn manufacturing facility are exposed to noise in various departments including carding, drawing, roving, and spinning.
- The facility operates three 8-hour shifts each day.
- Employees operate the textile machinery and wear EAR foam ear plugs as shown in the following photos.
- Audiograms were conducted for a few employees three years ago, but none since.
- The company has a written hearing conservation program.
  - Noise monitoring was conducted with Type-2 Quest Dosimeters

Case Study #1

Dose	Employee #1 Carding	Employee #2 Maintenance	Employee #3 Roving	Employee #4 Ring Spinning
Dose – LTL	120.75	53.24	75.8	199.12
Dose – HTL	99.6	39.15	59.2	172.31
Lavg – LTL	91.64	87.07	88.2	94.84
Lavg – HTL	90.3	84.84	86.4	93.78
Ltwa – LTL	91.4	85.52	88.0	95.03
Ltwa – HTL	90.03	83.3	86.2	93.98
Peak	143	128.6	118.2	123.0
Run Time	7:41	6:25	7:44	8:09

Case Study #1

Case Study #1



Case Study #1

Case Study #1

Case Study #1

Case Study #2 – Groups 1 & 2

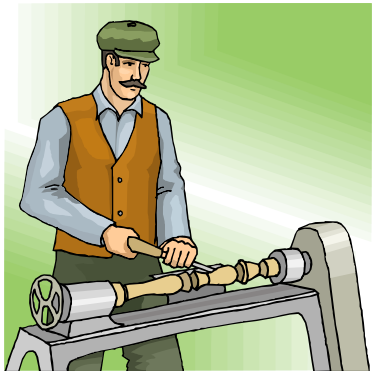
- Three employees operate a corrugating machine at a cardboard manufacturing plant.
- One 8-hour shift is utilized, and the company has a full hearing conservation program.
- The company says they are aware of the noise problem, but that it will cost about $600,000 to enclose the corrugating machine.

Case Study #2

Dose	Machine Operator
Dose – LTL	376.45
Dose – HTL	374.24
Lavg – LTL	99.56
Lavg – HTL	99.52
Ltwa – LTL	99.56
Ltwa – HTL	99.52
Peak	115.4
Run Time	8:00

Case Study #3 – Groups 1 & 2

- Employees at a small woodworking shop operate a variety of machines in the manufacture of table legs.
- The company has no hearing conservation program.
- Employees work four ten-hour shifts each week.



Case Study #3

Dose	Lathe Operator	Sander
Dose – LTL	169.24	138.94
Dose – HTL	137.20	112.42
Lavg – LTL	92.25	90.97
Lavg – HTL	90.73	89.44
Ltwa – LTL	93.80	92.37
Ltwa – HTL	92.28	91.45
Peak	114.7	120.8
Run Time	9:55	9:43

Case Study #3

Case Study #3

Case Study #3

Case Study #3

Case Study #4 – Groups 3 & 4

- Employees operating jet and atmospheric dye machines at a textile dyeing and finishing plant are exposed to noise throughout their 8-hour shifts.
- The company has a partial hearing conservation program.
- Ear plugs are provided, but generally not used by employees (and not required).
- Audiograms are conducted annually when the test van comes to the plant.
- The OSHA 300 logs showed 3 STS's (out of 40 Dye Room employees tested).
- Monitoring by the HCO was shorted by about 90 minutes when the employee sampled went home sick.

Case Study #4

Dose	Jet Dye Machine Operator	ATM Dye Machine Operator
Dose – LTL	56.45	64.84
Dose – HTL	12.41	9.54
Lavg – LTL	87.37	86.92
Lavg – HTL	76.44	73.10
Ltwa – LTL	85.88	86.87
Ltwa – HTL	74.95	73.05
Peak	109.8	112.4
Run Time	6:30	7:57

Case Study #5 – Groups 3 & 4

- Employees at a paper recycling plant shred and re-bale cardboard and wastepaper for sale to other companies.
- The workers feed paper onto the conveyor and it is dumped into the shredder.
- Hearing protection was not worn on the first day of the inspection but was used during the noise monitoring.
- No other elements of a hearing conservation program were in place.
- Some of the laborers in this area were working for a temp company and had been there for about a 1 ½ months.

Case Study #5

Dose	Baler	Laborer	Laborer
Dose – LTL	91.0	157.8	161.8
Dose – HTL	62.9	144.3	147.6
Lavg – LTL	89.4	93.5	93.6
Lavg – HTL	86.7	92.8	92.9
Ltwa – LTL	89.3	93.3	93.5
Ltwa – HTL	86.7	92.6	92.8
Peak	126.7	135.0	132.7
Run Time	7:57	7:55	7:59

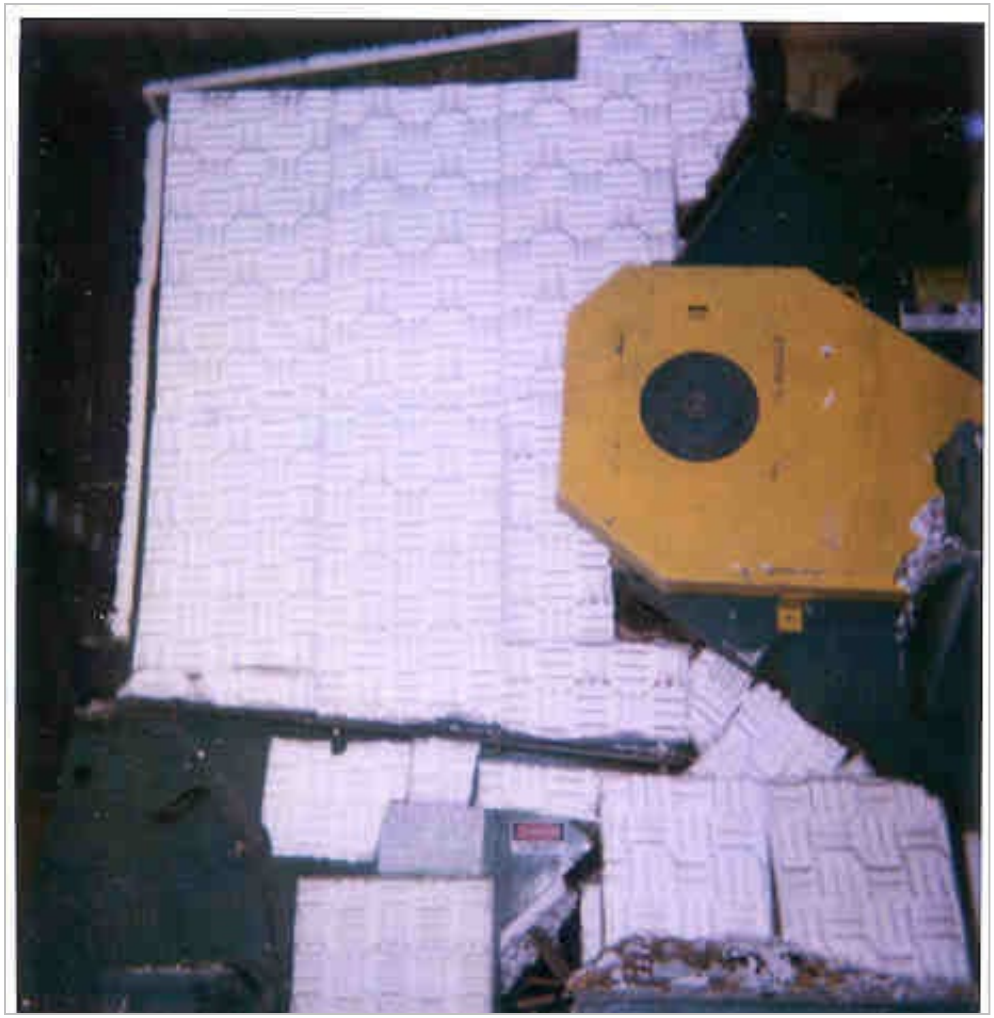
Case Study #5

Case Study #5

Case Study #5

Case Study #5

Following Abatement



Following Abatement

Following Abatement

Following Abatement

Case Study #6 – Groups 3 & 4

- Employees at a road construction site are operating a rock drill.
- They utilize ear plugs properly (NRR=24) and receive baseline audiograms.
- However, annual audiograms, initial monitoring, and training are not conducted.
- Exposure monitoring showed a Dose-HTL of 627% as measured over 8 hours.

Case Study #6

Thank You For Attending!

Final Questions?

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