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AGENDA FOR NOISE AND HEARING CONSERVATION

:
DAY 1

8:30 - 8:45	Introduction and Course Overview
8:45 - 9:30	Math Overview Related to Noise Problems
9:30 - 10:30	Physics of Sound
10:30 - 10:45	Break
10:45 - 11:15	OSHA Noise Standard and the Hearing Conservation Amendment (HCA), 29CFR1910.95 & 1926.52
11:15 - 11:35	Anatomy of the Ear
11:35 - 12:00	Human Response to Noise and Hearing Loss
12:00 - 1:00	Lunch
1:00 - 2:30	Instrumentation and Measurements of Noise and Related Calculations
2:30 - 2:45	Break
2:45 - 4:00	Instrumentation Laboratory, Hands on Experience in the Use, Measurement, and Calibration of Sound Level Meters, Noise Dosimeters and Octave Band Analyzers
4:00 - 4:45	ACGIH Threshold Limit Value(TLV), the 3 dB Exchange Rate, the 85 dB Criterion Level, and Comparison of ACGIH TLV to Other Risk Rating Criteria

DAY 2

8:30 - 9:30	Developing a Hearing Conservation Program
9:30 - 10:30	Noise Control Methods; Traditional Methods and the Newest Technologies, Including Active Noise Cancellation

10:30 - 10:45	Break
10:45 - 12:00	Feasibility of Engineering Controls Compared to Personal Protective Equipment (PPE)
12:00 - 1:00	Lunch
1:00 - 2:30	Concept of Noise Surveys: Purposes, Methodologies, Data Interpretation and Presentation
2:30 - 2:45	Break
2:45 - 3:15	Compensibility of Occupational Noise Induced Hearing Loss
3:15 - 4:00	Personal Protective Equipment; Functions, Selection, Performance, Management of Program, Evaluation
4:00 - 4:45	Audiology and Audiometry as it Relates to the HCA Including the Relationship of Hearing Loss and Verbal Communication

OBJECTIVES

- Understanding of the noise standard;
- Understanding the basic physics of sound;
- How to use the appropriate equipment to assess noise;
- Basic noise control measures and limitations;
- Audiometric testing requirements;
- Anatomy/physiology of the ear;
- Hearing protection (pros and cons).

Resources Available from the Division of Safety & Hygiene (DSH) Libraries

(800) 644-6292 (614) 466-7388

library@bwc.state.oh.us

www.ohiobwc.com

Safety training:

- Safety talks, outlines and scripts - DSH Safety leader's discussion guide, Training Center's One-hour safety presentations, reference books, web resources
- Videos – hundreds of safety and health topics
- Books and articles on training techniques

Machine and equipment safety:

- Safety standards (ANSI, NFPA, CGA)
- Books and articles on power presses, material handling equipment, lockout/tagout, etc.

Sample written programs:

- DSH program profiles and sample written programs
- Reference books
- Internet resources

Illness and injury statistics:

- Statistics from the U.S. Bureau of Labor Statistics
- National Safety Council's *Injury Facts*
- National Institute of Occupational Safety & Health (NIOSH) studies

Hazard communication and chemical safety:

- Chemical safety information
- Material safety data sheets (MSDSs)
- Sample written programs
- Videos
- Internet resources

Safety standards

- American National Standards Institute (ANSI) standards (including standards for construction, machinery and equipment, personal protective equipment)
- National Fire Protection Association (NFPA) fire codes (including the Life Safety Code and the National Electrical Code)
- Compressed Gas Association (CGA) standards

Other topics of interest (books, articles, magazines, videos and standards):

- Confined spaces
- Electrical safety
- Job safety analysis
- New employee orientation
- Powered industrial trucks
- Respiratory protection
- Safety culture
- Scaffolds

Directories and lists of vendors of safety equipment

Occupational Safety & Health Administration (OSHA) regulations

Manual of Uniform Traffic Control Devices (MUTCD)

Recommendations of useful Internet sites

BWC publications

INTERNET WEB SITES
FOR
OCCUPATIONAL SAFETY & HEALTH INFORMATION
April 2005

GENERAL

NATIONAL SAFETY COUNCIL (NSC)
http://www.nsc.org/

The NSC has a user friendly web site for innovative and current information on home, farm and community, on the road and workplace safety and as well statistical data and charts.

NORTH DAKOTA WORKFORCE SAFETY & INSURANCE
http://www.workforcesafety.com/

For workplace safety, North Dakota's WSI site puts forth their "safe operating procedures" page where they give information on accident and near miss reports, substance abuse, material handling and storage, walking and working surfaces, and safety program development and orientation.

OCCUPATIONAL & INDUSTRIAL SAFETY RESOURCES
http://www.khake.com/page59.html

Maintained by a Vocational Information Center, this web site provides links to occupational and industrial safety with lists of directories, national centers, hotlines and help lines as well as specific area coverage such as emergency, disaster and natural hazards, and tool, machine and equipment safety options.

OKLAHOMA STATE UNIVERSITY
http://www.pp.okstate.edu/ehs/

The Department of Environmental Health & Safety at OSU offers an online safety resource library that is constantly being updated with topics from A-Z including specific areas of safety such as fire, construction, HAZCOM and training. Go to the "Links Library" option.

SAFETY DIRECTORY
http://www.safetydirectory.com/

Safety Directory.com is an Internet gateway to occupational health & safety sites. This web site is indexed with information on industry specific topics, training, illness and injury, as well as safety publications and resources.

FEDERAL GOVERNMENT

CENTERS FOR DISEASE CONTROL & PREVENTION (CDC)
http://www.cdc.gov/

The CDC is always a good resource for current medical issues throughout the United States. Health topics from A-Z give an in-depth look at most communicable diseases as well as topics such as safe driving, violence, and air pollution, and workplace safety and health topics.

FEDERAL EMERGENCY MANAGEMENT ASSOCIATION (FEMA)
http://www.fema.gov/

For up-to-date information on active disasters and emergencies nationwide access this web site first. Publications include options for emergency preparedness and prevention, response and recovery, disaster fact sheets, and public awareness information.

NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY & HEALTH (NIOSH)
http://www.cdc.gov/niosh/homepage.html

NIOSH's web site provides current information on many services as well as safety research, including ergonomics programs, respirators, and mining safety. At the chemical page you will find databases and other helpful resources, information on personal protective equipment, as well as government agency web sites of interest.

OCCUPATIONAL SAFETY & HEALTH ADMINISTRATION (OSHA)
http://www.osha.gov

OSHA'S official web site includes media releases, online publications, statistics, standards & directives, "Technical Links," training center courses, "hot topics," and "what's new" as well a very useful A-Z index page.

INTERNATIONAL RESOURCES

HEALTH & SAFETY EXECUTIVE (HSE)
http://www.hse.gov.uk/

The United Kingdom has an international safety web site with a good deal to offer on occupational safety & health. Drop down boxes offer A-Z industry information, health and safety topics, tools, research, as well as publications and statistics.

ERGNET
http://www.sunderland.ac.uk/~ts0gli/ergnet.htm

The University of Sunderland in the UK is an international web site directory of "places for ergonomics and human factors". Featuring lists of sources such as societies, organizations, government bodies, institutes, centers and laboratories, this site also gives links to journals, a research database and other general ergonomic sites.

OHIO

OHIO EPA (OEPA)

http://www.epa.state.oh.us

At the official web site for Ohio's Environmental Protection Agency; use the "Topic Index" to find regulations and information on permits, hazardous waste, pollution prevention, wastewater, wetlands, and much more.

OHIO STATE LIBRARY/OHIOLINK
http://winslo.state.oh.us

At **OhioLink**, a statewide library and information network, you can search the State Library of Ohio's collection for the BWC's Division of Safety & Hygiene library books as well as other Ohio College and university library collections. Also available at this web site are searchable versions of Ohio Administrative laws and rules, electronic databases, and other Ohio library directories.

SPECIFIC (BY SUBJECT)

CONSTRUCTION
http://www.cdc.gov/elcosh/index.html

CDC's **eLCOSH** is a comprehensive library of construction-related safety information presented in both English and Spanish with items listed under trade, hazard, job site, and others. Also see: The Construction Industry Safety Council, a Center to Protect Workers' Rights resource center at ***http://www.buildsafe.org/RSC.htm*** for OSHA publications in PDF and hazard alerts.

ERGONOMICS
http://www.ergoweb.com

ERGOWEB provides current information on ergonomics and human factor science. Offered are: research, case studies, reference material and a forum for questions, answers and discussion.

LABORATORY SAFETY
http://safety.science.tamu.edu/

Texas A&M University College of Science is an optional choice for safety in the laboratory information. From hazard identification to waste disposal this web site offers thorough coverage of laboratory safe practices.

MATERIAL SAFETY SHEETS
http://www.ilpi.com/msds/index.html

This web site offers many solutions for finding MSDS (100 free sites) as well as chemical manufacturers and suppliers, pesticides including fertilizers, government sites, and other miscellaneous locations for chemical data. Also check any toxicological effects at *http://www.atsdr.cdc.gov/toxprofiles/* and health and safety information on household chemical ingredients at *http://householdproducts.nlm.nih.gov/*.

MOTOR CARRIER SAFETY PROGRAMS

http://www.fmcsa.dot.gov/safetyprogs/saftprogs.htm

The Federal Motor Carrier Safety Administration (FMCSA), an administration within the U.S. Department of Transportation, regulates and supports the Nation's interstate commercial carrier industry. The FMCSA web page offers several safety programs in PDF format such as brake safety, fatigue, HAZMAT safety, speed management, sharing the road safely, and other insurance and licensing information.

RADIATION
http://www.physics.isu.edu/radinf/

The Radiation Information Network offers a web site that is in-depth with information on radiation topics and issues. In addition to what's new in the field and general information there are regulatory, organizational and society links as well as research and educational resources available to access.

SAFETY STATISTICS
http://stats.bls.gov/

Occupational health and safety statistics by industry and occupation can be researched for injuries, illnesses, and fatality data at this web site starting with the "Overview of BLS Statistics on Worker Safety and Health" page.

SAFETY BRIEFINGS, MANUALS, PRODUCTS & PROGRAMS

OSHA POWERPOINT SAFETY PRESENTATIONS
http://esf.uvm.edu/siripp t/powerpt.html

An extensive safety PowerPoint presentation library is available at this web site featuring A-Z topics such as accident investigations, bomb threats, chemical spills, construction, electrical, hand tools, emergency response, fire safety, forklifts, JSA, laser, OSHA compliance, PPE, razor knife safety, safe lifting, and many more.

SAFETY PUBLICATIONS & VIDEO RESOURCES
http://www.cbs.state.or.us/external/osha/standards/pub.htm

A valuable resource for safety resources, the Oregon State's Department of Consumer and Business Publications web site is packed with downloadable information. Areas covered are agriculture, asbestos abatement, occupational exposures, HAZCOM, HAZMAT, HAZWOPER, safety practices, writing manuals and programs, tools of the trade, workers' compensation and ergonomics.

Saving You Time and Research

Requests for copies of OSHA standards, information on starting a safety committee, a video on accident investigation techniques -- these are some of the thousands of inquiries BWC's Division of Safety & Hygiene (DSH) libraries receive each year.

DSH has two libraries to serve you:

- The central library in the William Green Building in downtown Columbus;
- The resource center and video library located at the Ohio Center for Occupational Safety and Health (OCOSH) in Pickerington.

Both libraries are open 8 a.m. to 4:45 p.m., Monday through Friday. Your need for information does not require a visit to the library. You can phone, fax, or e-mail your requests and receive a quick response.

The central library provides free information services on the topics of occupational safety and health, workers' compensation and rehabilitation.

The OCOSH resource center provides similar services for those who visit OCOSH for meetings and training center classes.

The video library offers an extensive collection of videotapes to supplement your organization's safety and health training program. It is a convenient and popular source for Ohio employers to borrow quality occupational safety- and health-related training aids.

Visit our Web site at **www.ohiobwc.com.**

Central library
30 W. Spring St., Third Floor
Columbus OH 43215-2256
1-800-OHIOBWC
(614) 466-7388
(614) 644-9634 (fax)
library@bwc.state.oh.us

OCOSH resource center
13430 Yarmouth Drive
Pickerington OH 43147
1-800-OHIOBWC
Resource center (614) 728-6464
Video library (614) 644-0018

Instructors

William Brutsche, **CIH** graduated from Bowling Green State University in May of 1980 with a Bachelor degree in Environmental Health. After a short stint working for local health departments, he was hired in January 1982 by the Industrial Commission, Division of Safety and Hygiene.

He went on to complete a Master of Science and Education in Public Health at the University of Toledo in 1985. He successfully met the requirements set forth by the American Board of Industrial Hygiene and became a Certified Industrial Hygienist in 1987. He has been involved with OCOSH since its inception way back in 1988. Classes that He has had the pleasure to have been a part of include, Basic Respiratory Protection, Indoor Air Quality, Confined Spaces, Noise and Hearing Conservation, and Fundamentals of Safety and Health.

Michael A. Coates graduated with a B.S. Degree in 1989 from The Ohio State University. For the past seventeen years, Michael has been involved in the safety and health profession, consulting with hundreds of industries. He has been a speaker at national and regional conferences throughout the country and worked with companies such as Pepsi, Lucent Technologies, Coca -Cola, Frito Lay, Kaiser Aluminum and Rockwell International. His work for the last fourteen years has been with The Ohio Division of Safety and Hygiene. He has produced safety and health videos in cooperation with Continental Cable Vision, made numerous presentations in the areas of confined space, code of federal regulations, and the importance of a comprehensive pro-active safety culture in industry.

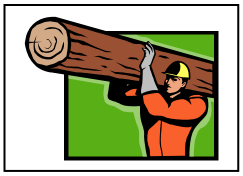
Michael attributes his interest in the safety and health profession to his life experiences, one of them being when he served as a roadie with the Rolling Stones. Currently, Michael is an industrial hygienist who devotes part of his time to conducting training programs.

Don Bentley, PE, CIH is the industrial hygiene technical advisor for the Bureau of Workers' Compensation, Division of Safety and Hygiene. Don has been with the Division since 1982. During that time, Don has worked as an industrial hygienist, an ergonomist, an engineer, and as an industrial hygiene supervisor. His area of specialization is occupational exposure control assessment. Don has a Bachelor of Science Degree in civil engineering from Ohio University. He has worked in private industry and consulting from which he has established a solid foundation of practical experience. He is a Professional Engineer (PE), registered by the Ohio Board of Registration for Professional Engineers and Surveyors in 1986, and a Certified Industrial Hygienist (CIH), certified by the American Board of Industrial Hygienists (ABIH) in 1990.

1

Physics of Sound

Before we get started, we need to take a look at logarithms, which are the basis upon which noise calculations are founded:



A) Logarithmic Calculations

The logarithm (base 10) is the exponent to which 10 is raised, representing the number. Examples include:

a) 100 can be represented as 10^2; thus the log of 100 = 2

b) 0.000001 = 10^{-6} ; thus log of 0.000001 = -6

c) 1,000,000 = 10^6 ; thus log of 1,000,000 = 6

The antilog of a number is 10 raised to the x power or 10^x; x is the logarithm we started with in the previous examples. Examples include:

a) If the logarithm is 2, then the antilogarithm is 10^2 or 100

b) The log of x = -6; so the antilogarithm is 10^{-6} or 0.000001

c) Log x = 6, x = 10^6 = 1,000,000

Examples – logarithmic functions

a) log (20) = ___________

b) log (400) = ____________

On your own calculator:

Exercises – logarithmic functions

Log Key

1) log (0.50) = ________

2) log (2.0) = ________

Examples – antilogarithm functions

a) x = 2 => ____________

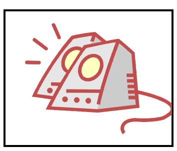
b) x = 4.3 => ____________

Exercises – antilogarithm functions

10^x Key

3) x = 8.5 => __________

4) x = 9.0 => __________



B) "What is sound?"

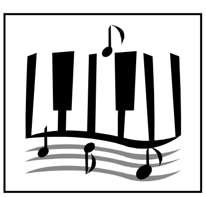
This question has been asked in science/physics classrooms as a discussion of if a tree falls in the forest and no one hears it, did it make a sound? Whether the tree made a sound or not comes down to the definition of sound. We will define sound as any change in **air pressure** that our ears are able to detect and process. For our ears to detect it, a change in pressure has to be strong enough to move the eardrums in our ears. The more the pressure changes, the "louder" we perceive the sound to be.

Sound/noise travels through air as **sound waves**. Standing in a training room, which is 40 feet long, 50 feet wide and 9 feet high may appear to be dead silent, but in fact, a lot of action is taking place. The room contains a huge number of air molecules (about 1.1×10^{28})

that collectively weigh 1,350 pounds. Air is actually fairly substantial stuff, but there is still a lot of empty space between the molecules in the room.

In air, 78% of the molecules are nitrogen, and almost all of the rest are oxygen. Both molecules are shaped like tiny dumbbells. The molecules are moving in random directions at an average speed of over 1000 miles per hour. Each molecule has about 5 billion collisions per second. The little dumbbells are also spinning frantically. The total **kinetic energy** in the air molecules in the room is astounding - more than the kinetic energy of seven 4,800-lb Mercedes hurtling along at 100 mph! This is difficult to comprehend in this dead-quiet room.

The molecules are furiously colliding with my eardrums, exerting a **pressure** of over one ton per square foot. But the collisions on one side of my eardrum are precisely balanced by collisions on the other side; my eardrums don't move, and I hear nothing. (The eustachian tube equalizes the pressure on either side of the eardrum as long as pressure varies slowly, such as for changes in barometric pressure). Sound is typically described as a small rapid variation in pressure. This is one part of the story, but there is another effect, a variation of the average molecular velocity, which is an essential part of the propagation of a sound wave and will be discussed in the next section.



C) Frequency of Sound

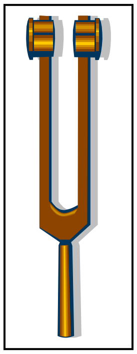
Frequency is the rate at which complete high and low pressure regions are produced by the sound source. The unit of frequency is the **Hertz** (Hz) or cycles per second.

> 1000 cycles per second is 1000 Hz or 1 kiloHz (kHz)
>
> **Speech frequencies**: Those frequencies necessary for understanding speech without facing the speaker are generally regarded as 500 Hz to 3,000 Hz.

For our ears to be able to perceive a sound, the sound has to occur in a certain **frequency range**. For most people, the range of perceivable sounds falls between 20 Hertz (Hz, cycles [oscillations] per second) and 15,000 Hz. We cannot hear sounds below 20 Hz or above 15,000 to 20,000 Hz.

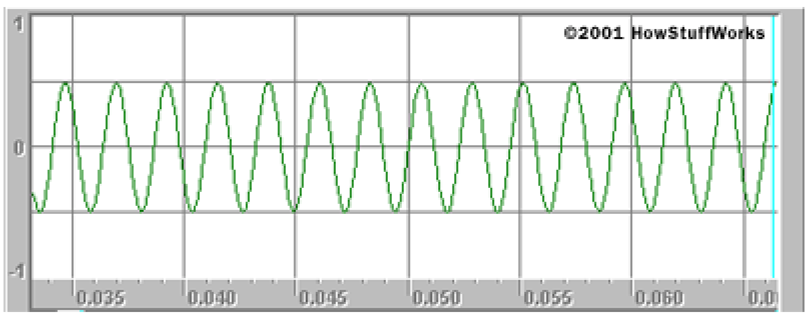
Cool Fact

A **piano** has 88 keys stretching through more than 7 octaves. The lowest note on a piano vibrates at 27.5 Hz and the highest vibrates at 4,186 Hz.

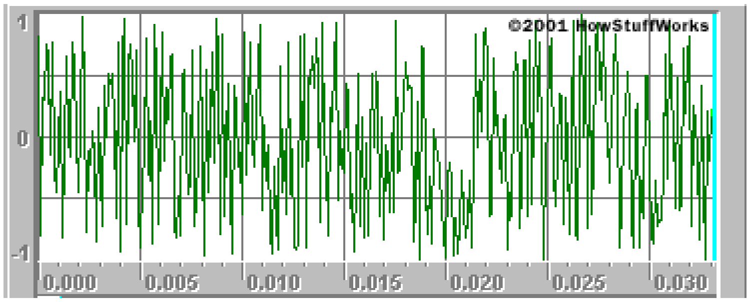


A **tone** is a sound that repeats at a certain specific frequency and an illustration of this would be a tuning fork. We have several here each with a unique tone. That is it vibrates at a given frequency.

Here is what a xxx (close to 440 hz) compression rarefaction wave would look like when shown as a sine wave.



A tone is made up of one frequency or a very small number of related frequencies. The alternative to a tone is a combination of hundreds or thousands of **random frequencies**. We refer to these random-combination sounds as **noise**. When you hear the sound of a river, or the sound of wind rustling through leaves, or the sound of paper tearing or the sound made when you tune your TV to a nonexistent station, you are hearing noise. On a frequency scale the noise would look something like this:

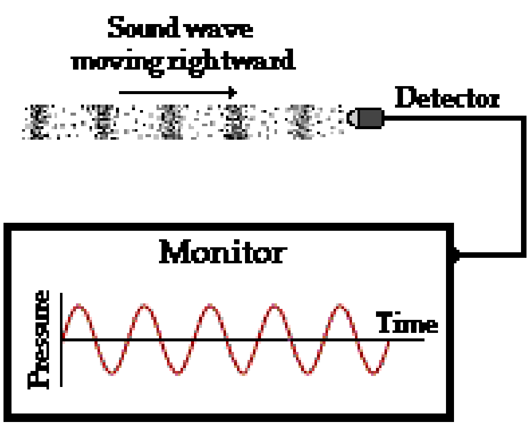


A sound wave, like any other wave, is introduced into a medium by a vibrating object. The vibrating object is the source of the disturbance which moves through the medium. The vibrating object which creates the disturbance could be the vocal chords of a person, the vibrating string and sound board of a guitar or violin, the vibrating tines of a tuning fork, or the vibrating diaphragm of a radio speaker. Regardless of what vibrating object is creating the sound wave, the particles of the **medium** through which the sound moves is vibrating in a back and forth motion at a given **frequency**. The frequency of a wave refers to how often the particles of the medium vibrate when a wave passes through the medium. The frequency of a wave is measured as the number of complete back-and-forth vibrations of a particle of the medium per unit of time. If a particle of air undergoes 1000 longitudinal vibrations in 2 seconds, then the frequency of the wave would be 500 vibrations per second or Hertz.

1 Hertz = 1 vibration/second

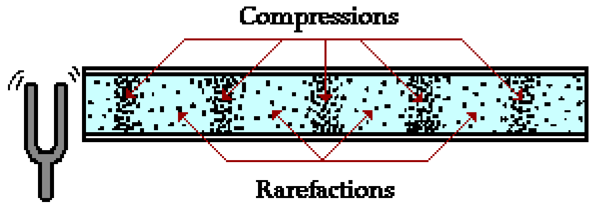
As a sound wave moves through a medium, each particle of the medium vibrates at the same frequency. This is sensible since each particle vibrates due to the motion of its nearest neighbor. The first particle of the medium begins vibrating, at say 500 Hz, and begins to set the second particle into **vibrational motion** at the same frequency of 500 Hz. The second particle begins vibrating at 500 Hz and thus sets the third particle of the medium into vibrational motion at 500 Hz. The process continues throughout the medium; each particle vibrates at the same frequency. And of course, the frequency at which each particle vibrates is the same as the frequency of the original source of the sound wave. Subsequently, a guitar string vibrating at 500 Hz will set the air particles in the room vibrating at the same frequency of 500 Hz, which carries a sound signal to the ear of a listener which is detected as a 500 Hz sound wave.

The back-and-forth vibrational motion of the particles of the medium would not be the only observable phenomenon occurring at a given frequency. Since a sound wave is a pressure wave, a detector could be used to detect **oscillations** in pressure from a high pressure to a low pressure and back to a high pressure. As the compression (high pressure) and rarefaction (low pressure) disturbances move through the medium, they would reach the detector at a given frequency. For example, a compression would reach the detector 500 times per second if the frequency of the wave were 500 Hz. Similarly, a rarefaction would reach the detector 500 times per second if the frequency of the wave were 500 Hz. Thus, the frequency of a sound wave not only refers to the number of back-and-forth vibrations of the particles per unit of time, but also refers to the number of compression or rarefaction disturbances which pass a given point per unit of time. A detector could be used to detect the frequency of these pressure oscillations over a given period of time. The typical output provided by such a detector is a pressure-time plot as shown below.



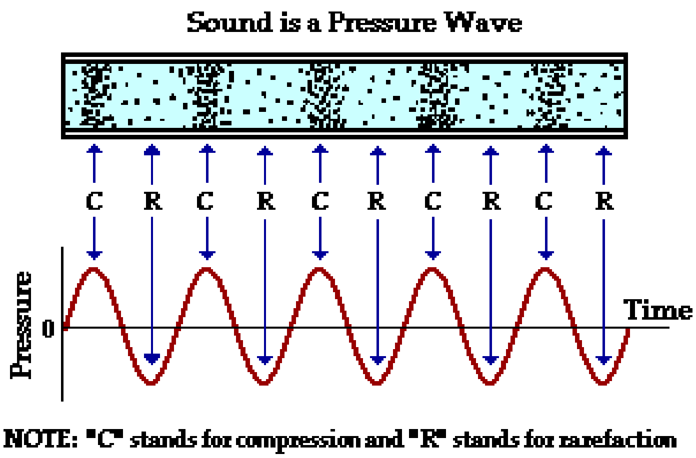
D) Wavelength:

The distance required to complete one complete compression and rarefaction, measured in units of feet or meters.



The **wavelength** of a wave is merely the distance which a disturbance travels along the medium in one complete wave cycle. Since a wave repeats its pattern once every wave cycle, the wavelength is sometimes referred to as the length of the repeating pattern - the length of one complete wave. For a transverse wave, this length is commonly measured from one wave crest to the next adjacent wave crest, or from one wave trough to the next adjacent wave trough. Since a longitudinal wave does not contain crests and troughs, its wavelength must be measured differently. A longitudinal wave consists of a repeating pattern of compressions and rarefactions. Thus, the wavelength is commonly measured as the distance from one compression to the next adjacent compression or the distance from one rarefaction to the next adjacent rarefaction.

Since a sound wave consists of a repeating pattern of high pressure and low pressure regions moving through a medium, it is sometimes referred to as a **pressure wave**. If a detector, whether it be the human ear or a man-made instrument, is used to detect a sound wave, it would detect fluctuations in pressure as the sound wave impinges upon the detecting device. At one instant in time, the detector would detect a high pressure; this would correspond to the arrival of a compression at the detector site. At the next instant in time, the detector might detect normal pressure. And then finally, a low pressure would be detected, corresponding to the arrival of a rarefaction at the detector site. Since the fluctuations in pressure as detected by the detector occur at periodic and regular time intervals, a plot of pressure vs. time would appear as a sine curve. The crests of the sine curve correspond to compressions; the troughs correspond to rarefactions; and the "zero point" corresponds to the pressure which the air would have if there were no disturbance moving through it. The diagram below depicts the correspondence between the longitudinal nature of a sound wave and the pressure-time fluctuations which it creates.



The above diagram can be somewhat misleading if you are not careful. The representation of sound by a sine wave is merely an attempt to illustrate the sinusoidal nature of the pressure-time fluctuations. Do not conclude that sound is a transverse wave which has crests and troughs. Sound is indeed a longitudinal wave with compressions and rarefactions. As sound passes through a medium, the particles of that medium do not vibrate in a transverse manner. Do not be misled - sound is a longitudinal wave.

E) The Speed of Sound

A sound wave is a pressure disturbance which travels through a medium by means of particle interaction. As one particle becomes disturbed, it exerts a force on the next adjacent particle, thus disturbing that particle from rest and transporting the energy through the medium. Like any wave, the speed of a sound wave refers to how fast the **disturbance is passed from particle to particle**. While frequency refers to the number of vibrations which an individual particle makes per unit of time, speed refers to the distance which the disturbance travels per unit of time. Always be cautious to distinguish between the two often confused quantities of speed (*how fast...*) and frequency (*how often...*).

Since the speed of a wave is defined as the distance which a point on a wave (such as a compression or a rarefaction) travels per unit of time, it is often expressed in units of feet/second (abbreviated f/s) or meters/second (abbreviated m/s). In equation form, this is

speed = distance/time

The faster a sound wave travels, the more distance it will cover in the same period of time. If a sound wave is observed to travel a distance of 2300 feet or 700 meters in 2 seconds, then the speed of the wave would be 1150 feet per second (f/s) or 350 meters per second (m/s). A slower wave would cover less distance - perhaps 1975 feet or 600 meters - in the same time period of 2 seconds and thus have a speed of 985 f/s or 300 m/s. Faster waves cover more distance in the same period of time.

The speed of any wave depends upon the properties of the medium through which the wave is traveling. Typically, there are two essential types of properties which affect wave speed - inertial properties and elastic properties. The density of a medium is an example of an **inertial property**. The greater the inertia (i.e., mass density) of individual particles of the medium, the less responsive they will be to the interactions between neighboring particles and the slower the wave. If all other factors are equal (and seldom is it that simple), a sound wave travels faster in a less dense material than a more dense material. Thus, a sound wave will travel nearly three times faster in helium as it will in air; this is mostly due to the lower mass of helium particles as compared to air particles.

Elastic properties are those properties related to the tendency of a material to either maintain its shape or not deform whenever a force or stress is applied to it. A material such as steel will experience a very small deformation of shape (and dimension) when a stress is applied to it. Steel is a rigid material with a high elasticity. On the other hand, a material such as a rubber band is highly flexible; when a force is applied to stretch the rubber band, it deforms or changes its shape readily. A small stress on the rubber band causes a large deformation. Steel is considered to be a stiff or rigid material, whereas a rubber band is considered a flexible material. At the particle level, a stiff or rigid material is characterized by atoms and/or molecules with strong attractions for each other. When a force is applied in an attempt to stretch or deform the material, its strong particle interactions prevent this deformation and help the material maintain its shape. Rigid materials such as steel are considered to have a high elasticity (elastic modulus is the technical term). The phase of matter has a tremendous impact upon the elastic properties of the medium. In general, solids have the strongest interactions between particles, followed by liquids and then gases. For this reason, longitudinal **sound waves travel faster in solids than they do in liquids, than they do in gases**. Even though the inertial factor may favor gases, the elastic factor has a greater influence on the speed (v) of a wave, thus yielding this general pattern:

$$\mathbf{v_{solids} > v_{liquids} > v_{gases}}$$

The speed of a sound wave in air depends upon the properties of the air, namely the temperature and the pressure. The pressure of air (like any gas) will affect the mass density of the air (an inertial property) and the temperature will affect the strength of the particle interactions (an elastic property). At normal atmospheric pressure, the temperature dependence of the speed of a sound wave through air is approximated by the following equation:

$$\mathbf{C = 1054\ f/s + (1.07\ f/s/^{o}F)*T}$$

The T is the temperature of the air in degrees Fahrenheit. This equation is used to determine the speed of a sound wave in air. At a temperature of 72 degrees Fahrenheit this formula yields the following solution.

$$C = 1054\ f/s + (1.07\ f/s/\,^{o}F)*T$$

$$C = 1054\ f/s + (1.07\ f/s/\,^{o}F)*72\,^{o}F$$

$$v = 1054\ f/s + 76\ f/s$$

$$\mathbf{v = 1130\ f/s}$$

At normal atmospheric pressure and a temperature of 72 degrees Fahrenheit, a sound wave will travel at approximately 1130 f/s; this is approximately equal to 750 mph. While this speed may seem fast by human standards (the fastest humans can sprint at approximately 33 f/s and highway speeds are approximately 90 f/s), the speed of a sound wave is slow in comparison to the speed of a light wave. Light travels through air at a speed of approximately 980,000,000 f/s; this is nearly 875,000 times the speed of sound. For this reason, humans can observe a detectable time delay between the thunder and lightning during a storm. The arrival of the light wave from the location of the lightning strike occurs in so little time that it is essentially negligible. Yet the arrival of the sound wave from the location of the lightning strike occurs much later. The time delay between the arrival of the light wave (lightning) and the arrival of the sound wave (thunder) allows a person to approximate his/her distance from the storm location. For instance, if the thunder is heard 3 seconds after the lightning is seen, then sound (whose speed is approximated as 1130 f/s) has traveled a distance of

distance = v * t = 1130 f/s * 3 s = **3390 feet**

If this value is converted to miles, the storm is a distance of 0.65 miles away.

Another phenomenon related to the perception of time delays between two events is the phenomenon of echolocation. A person can often perceive a time delay between the production of a sound and the arrival of a reflection of that sound off a distant barrier. If you have ever made a **holler** within a canyon, perhaps you have heard an echo of your holler off a distant canyon wall. The time delay between the holler and the echo corresponds to the time for the holler to travel the round-trip distance to the canyon wall and back. A measurement of this time would allow a person to estimate the one-way distance to the canyon wall. For instance, if an echo is heard 2.2 seconds after making the holler, then the distance to the canyon wall can be found as follows:

distance = v * t = 1130 f/s * 1.1 s = **1240 feet**

The canyon wall is 1240 feet away. You might have noticed that the time of 1.1 seconds is used in the equation. Since the time delay corresponds to the time for the holler to travel the round-trip distance to the canyon wall and back, the one-way distance to the canyon wall corresponds to one-half the time delay.

While the phenomenon of echolocation is of relatively minimal importance to humans, it is an essential trick of the trade for **bats**. Being merely blind, bats must use sound waves to navigate and hunt. They produce short bursts of ultrasonic sound waves which reflect off their surroundings and return. Their detection of the time delay between the sending and receiving of the pulses allows a bat to approximate the distance to surrounding objects. Some bats, known as Doppler bats, are capable of detecting the speed and direction of any moving objects by monitoring the changes in frequency of the reflected pulses.

Like any wave, a sound wave has a speed which is mathematically related to the frequency and the wavelength of the wave. The mathematical relationship between speed, frequency and wavelength is given by the following equation.

Speed = Wavelength * Frequency

Using the symbols **C**, **λ**, and **f**, the equation can be re-written as

$$C = \lambda * f$$

The above equations are useful for solving mathematical problems related to the speed, frequency and wavelength relationship. However, one important misconception could be conveyed by the equation. Even though wave speed is calculated using the frequency and the wavelength, the wave speed is **not** dependent upon these quantities. An alteration in wavelength does not affect (i.e., change) wave speed. Rather, an alteration in wavelength affects the frequency in an inverse manner. A doubling of the wavelength results in a halving of the frequency; yet the wave speed is not changed. The speed of a sound wave depends on the properties of the medium through which it moves and the only way to change the speed is to change the properties of the medium.

So, sound velocity varies directly with the square root of the density and varies inversely with the compressibility of the medium through which it is traveling.

1) Examples of velocity:

a) In air at 72 ^{o}F the velocity (C) = 1130 f/s

b) In water, 20 ^{o}C = 4,700 f/s

c) In wood, 20 ^{o}C = 13,000 f/s

d) In steel, 20 ^oC = 16,500 f/s

2) Relationship between speed of sound, wavelength and frequency can be expressed as:

$C = f * \lambda$

C = Speed of sound, f/s
f = frequency, Hz
λ = wavelength, feet

Example: If at standard conditions the speed of sound is 1130 f/s, and you have a pure tone 440 Hz frequency sound, what is the wavelength of the pure tone?

$C = f * \lambda \quad \Rightarrow \quad \lambda = C / f \quad = 1130 / 440 = 2.57$ feet

Exercise:

a) For air at 1000 ^oF, as in the exhaust stream of an internal combustion engine;

find C? Once again, C = 1054 f/s + (1.07 f/s/ ^oF)*T

Example:

b) For the 1000 F exhaust stream in the above example, what is the wavelength of the fundamental explosion frequency if the engine is rotating at 3000 rpm and has 4 cylinders?

Therefore, the fundamental frequency in the exhaust stream will be 12000 explosions per minute.

$$\frac{12{,}000}{\text{Minute}} \times \frac{1 \text{ minute}}{60 \text{ seconds}} = \frac{12000}{60} = 200 \text{ Hz}$$

$C_{exhaust}$ = __________ feet/second (previous problem)

λ = C/f = --------------------- = --------------

The range of human hearing is taken to be from 20 Hz to about 15-20 KHz. What wavelengths represent the following frequencies? (Assume standard conditions)

$\lambda_{20\ Hz}$ = ___________

$\lambda_{1000\ Hz}$ = ___________

$\lambda_{16,000\ Hz}$ = ____________

F) Period:

The period is the time for one complete cycle of pressure transition. It is the reciprocal of the frequency:

$T_{(sec)} = 1/f$

a) The period of a 1000 Hz sound wave is:

T = 1/f = 1 / 1000 = 0.001 seconds

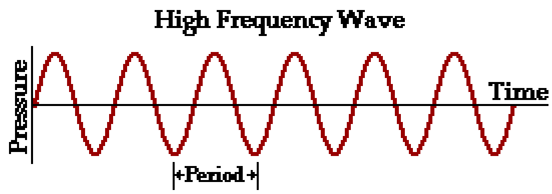
b) What is the period of a 20 Hz sound wave?

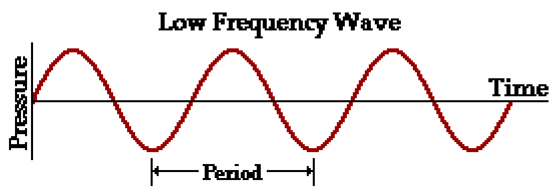
T = ____________

c) What is the period of a 16,000 Hz sound wave?

T = ____________

Since a pressure-time plot shows the fluctuations in pressure over time, the period of the sound wave can be found by measuring the time between successive high pressure points (corresponding to the compressions) or the time between successive low pressure points (corresponding to the rarefactions). So, the frequency is simply the reciprocal of the period. For this reason, a sound wave with a high frequency would correspond to a pressure time plot with a small period - that is, a plot corresponding to a small amount of time between successive high pressure points. Conversely, a sound wave with a low frequency would correspond to a pressure time plot with a large period - that is, a plot corresponding to a large amount of time between successive high pressure points. The diagram below shows two pressure-time plots, one corresponding to a high frequency and the other to a low frequency.





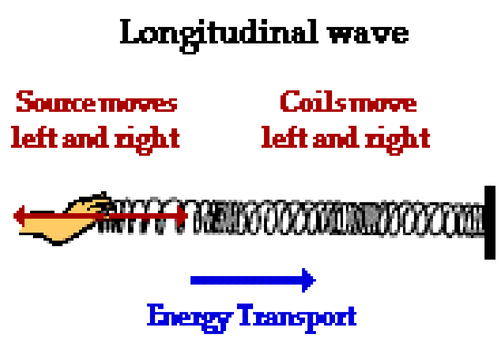
The ears of humans (and other animals) are sensitive detectors capable of detecting the fluctuations in air pressure which impinge upon the eardrum. The mechanics of the ear's detection ability will be discussed later. For now, it is sufficient to say that the human ear is capable of detecting sound waves with a wide range of frequencies, ranging between approximately 20 Hz to 20,000 Hz. Any sound with a frequency below the audible range of hearing (i.e., less than 20 Hz), is known as an **infrasound** and any sound with a frequency above the audible range of hearing (i.e., more than 20 000 Hz) is known as an **ultrasound**. Humans are not alone in their ability to detect a wide range of frequencies. Dogs can detect frequencies as low as approximately 50 Hz and as high as 45,000 Hz. Cats can detect frequencies as low as approximately 45 Hz and as high as 85,000 Hz. Bats, who are essentially blind and must rely on sound echolation for navigation and hunting, can detect frequencies as high as 120,000 Hz. Dolphins can detect frequencies as high as 200,000 Hz. While dogs, cats, bats, and dolphins have an unusual ability to detect ultrasound, an elephant possesses the unusual ability to detect infrasound, having an audible range from approximately 5 Hz to approximately 10,000 Hz.

All of this tells me that the ear evolved primarily for self-defense (or perhaps hunting, as one reader pointed out), and language and enjoyment of music are delightful evolutionary by-products. A defensive purpose also suggests some direct hard-wiring between the ears and primitive parts of the brain, which may account for the powerful emotional impact of music - and its virtual universality among human cultures.

G) Sound Waves

Let's say that a 440 Hz pure tone is playing in the room. The motion of the air molecules is no longer totally random. There are three changes:

- there are bands about 3-feet apart where the molecules are slightly bunched up, separated by bands where the molecules are slightly thinned out.



- the temperature is higher in the bunched up bands (temperature is a measure of the average kinetic energy per molecule). This, plus the first change, represents a pressure variation.
- the average velocity of the molecules in the bunched up bands causes a net drift of molecules in one direction; in the thinned out bands there is a net drift in the other direction. This is the

velocity variation that is usually ignored in the description of a sound wave.

The ensemble of these bands is moving towards me at 1130 feet per second (fps) or 770 miles per hour (mph), the **speed of sound**. This is your basic sound wave.

It is at first hard to understand that the wave traveling towards me at 770 mph does not mean the molecules are traveling towards me at 770 mph. If you stretch out a garden hose straight for about 20 feet and rapidly shake one end back and forth a snaky wave will travel away from you down the hose. The hose isn't going anywhere, but the wave is. All types of waves (hose, sound, water, electromagnetic, football fans, etc.) have a lot in common mathematically. In this sense, the peaks and valleys of the hose are analogous to the bands of molecules that are bunched up and depleted, respectively.

Visualize a 1-foot diameter balloon floating in the middle of the room. The bunching up of molecules, and the temperature increase, that correspond to an increase in pressure, cause the balloon diameter to shrink by 0.0006 inches - roughly 1/5 the thickness of a human hair. It then swells by an equal amount as the thinned out band passes by. The average molecular velocity causes the balloon to sway back and forth by 0.00076 inches. The maximum pressure change due to the sound is small compared to the ton per square foot in the silent room, but is still a very noticeable 0.4 lbs. per square foot for the 117 dB level. The key difference between silence and sound is that the sound pressure outside my ear is not balanced by an equal pressure inside my ear, so my eardrums move back and forth 400 times per second. The same pressure imbalance exists for my chest cavity, where this level of sound can easily be felt (at lower frequencies anyway).

In the tuning fork demonstrations, we know that the tuning fork is vibrating because we hear the sound which is produced by their vibration. Nonetheless, we do not actually visibly detect any vibrations of the tines. This is because the tines are vibrating at a very high frequency. If the tuning fork which is being used corresponds to middle C on the piano keyboard, then the tines are vibrating at a frequency of 256 Hz - 256 vibrations per second. We are unable to detect vibrations of such high frequency.

If the frequency is halved, making the tone one octave lower, the distance between the bands of molecules is doubled and the balloon moves back and forth twice as far. The 0.03 ^{0}F temperature variation, 141 per million variations in molecular density, and 0.1 mph velocity variation remain the same.

The pressure and average molecular velocity are both essential characteristics of a sound wave. The human ear does respond to both pressure and velocity, but for much of the audio spectrum the response to pressure is the dominant factor.

Velocity and speed are used here in describing quite different characteristics, and this certainly can be confusing. To sum up, the contexts are:

1. The random motion of the molecules: molecules going in all directions, at an average speed of over 1000 miles per hour. This chaotic action takes place with or without a sound wave.

2. The average molecular velocity, which causes bands of molecules to drift back and forth, is added on top of the random motion, and causes a systematic movement of the molecules. For a wave traveling from left to right, as viewed from a stationary point, this velocity is at one moment to the left, and then to the right, reversing direction at the frequency of the sound wave. Looking at the entire wave at one instant in time, there are bands where the velocity is to the left, alternating with bands where it is towards the right.

3. The velocity of the wave itself, 770 mph. This is the apparent motion of the wave contour, or any feature, such as the wave crest. For a wave traveling from left to right, this velocity is purely to the right, and it is uniform throughout the entire wave.

Mechanical waves are waves which require a medium in order to transport their energy from one location to another. Because mechanical waves rely on particle interaction in order to transport their energy, they cannot travel through regions of space which are devoid of particles. That is, mechanical waves cannot travel through a vacuum. A ringing bell was placed in a jar and air was evacuated from the jar. Once air was removed from the jar, the sound of the ringing bell could no longer be heard. The clapper could be seen striking the bell, but the sound which it produced could not be heard because there were no particles inside of the jar to transport the disturbance through the vacuum. Sound is a mechanical wave and cannot travel through a vacuum.

What is a Wave?

A wave can be described as a disturbance that travels through a medium from one location to another location. Consider a slinky wave as an example of a wave. When the slinky is stretched from end to end and is held at rest, it assumes a natural position known as the equilibrium or rest position. The coils of the slinky naturally assume this position, spaced equally far apart. To introduce a wave into the slinky, the first particle is displaced or moved from its equilibrium or rest position. The particle might be moved upwards or downwards, forwards or backwards; but once moved, it is returned to its original equilibrium or rest position. The act of moving the first coil of the slinky in a given direction and then returning it to its equilibrium position creates a disturbance in the slinky. We can then observe this disturbance moving through the slinky from one end to the other. If the first coil of the slinky is given a single back-and-forth vibration, then we call the observed motion of the disturbance through the slinky a *slinky pulse*. A **pulse** is a single disturbance moving through a medium from one location to another location. However, if the first coil of the slinky is continuously and periodically vibrated in a back-and-forth manner, we would observe a repeating disturbance moving within the slinky which endures over some prolonged period of time. The repeating and periodic disturbance which moves through a medium from one location to another is referred to as a **wave**.

When a slinky is stretched, the individual coil assume an equilibrium or rest position.

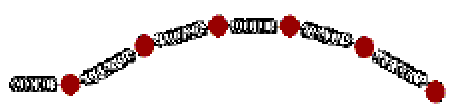
When the first coil of the slinky is repeatedly vibrated back and forth, a disturbance is created which travels through the slinky from one end to the other.

In the case of the slinky wave, the medium through which the wave travels is the slinky coils. In the case of a water wave in the ocean, the medium through which the wave travels is the ocean water. In the case of a sound wave moving from the church choir to the pews, the medium through which the sound wave travels is the air in the room. And in the case of the stadium wave, the medium through which the stadium wave travels is the fans who are in the stadium.

To fully understand the nature of a wave, it is important to consider the medium as a series of interconnected or merely interacting *particles*. In other words, the medium is composed of parts which are capable of interacting with each other. The interactions of one particle of the medium with the next adjacent particle allows the disturbance to travel through the medium. In the case of the slinky wave, the *particles* or interacting parts of the medium are the individual coils of the slinky. In the case of a sound wave in air, the *particles* or interacting parts of the medium are the individual molecules of air. And in the case of a stadium wave, the *particles* or interacting parts of the medium are the fans in the stadium.

Consider the presence of a wave in a slinky. The first coil becomes disturbed and begins to push or pull on the second coil; this push or pull on the second coil will displace the second coil from its equilibrium position. As the second coil becomes displaced, it begins to push or pull on the third coil; the push or pull on the third coil displaces it from its equilibrium position. As the third coil becomes displaced, it begins to push or pull on the fourth coil. This process continues in consecutive fashion, each individual *particle* acting to displace the adjacent particle; subsequently, the disturbance travels through the medium. The medium can be pictured as a series of particles connected by springs. As one particle moves, the spring connecting it to the next particle begins to stretch and apply a force to its adjacent neighbor. As this neighbor begins to move, the spring attaching the neighbor to its neighbor begins to stretch and apply a force on its adjacent neighbor.


A medium can be modeled by a series of particles connected by springs. As one particle is displaced, ...


... the spring attaching it to the next is stretched and begins to exert a force on its neighbor, thus displacing the neighbor from its rest position.

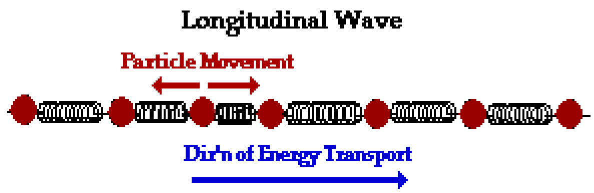
When a wave is present in a medium (that is, when there is a disturbance moving through a medium), the individual particles of the medium are only temporarily displaced from their rest position. There is always a force acting upon the particles which restores them to their original position. In a slinky wave, each coil of the slinky always returns to its original position. In a water wave, each molecule of the water always returns to its original position. And in a stadium wave, each fan in the bleacher always returns to its original position. It is for this reason, that a wave is said to involve the movement of a disturbance without the movement of matter.

Waves are said to be an **energy transport phenomenon**. As a disturbance moves through a medium, from one particle to its adjacent particle, energy is being transported from one end of the medium to the other. In a slinky wave, a person imparts energy to the first coil by doing work upon it. The first coil receives a large amount of energy which it subsequently transfers to the second coil. When the first coil returns to its original position, it possesses the same amount of energy as it had before it was displaced. The first coil transferred its energy to the second coil. The second coil then has a large amount of energy which it subsequently transfers to the third coil. When the third coil returns to its original position, it possesses the same amount of energy as it had before it was displaced. The third coil has received the energy of the second coil. This process of energy transfer continues as each coil interacts with its neighbor. In this manner, energy is transported from one end of the slinky to the other, from its source to another location.

Waves are seen to move through an ocean or lake; yet the water always returns to its rest position. Energy is transported through the medium, yet the water molecules are not transported. Proof of this is the fact that there is still water in the middle of the ocean. The water has not moved from the middle of the ocean to the shore. If we were to observe a gull or duck at rest on the water, it would merely bob up-and-down in a somewhat circular fashion as the disturbance moves through the water; the gull or duck always returning to its original position. The gull or duck is not transported to the shore because the water on which it rests is not transported to the shore. In a water wave, energy is transported without the transport of water.

The same thing can be said about a stadium wave. In a stadium wave, the fans do not get out of their seats and walk around the stadium. We all recognize that it would be ludicrous for any fan to even contemplate such a thought. In a stadium wave, each fan rises up and returns to the original seat. The disturbance moves through the stadium, yet the fans are not transported. Waves involve the transport of energy without the transport of matter.

In conclusion, a wave can be described as a disturbance which travels through a medium, transporting energy from one location (its source) to another location without transporting matter. Each individual particle of the medium is temporarily displaced and then returns to its original equilibrium position.



H) Intensity

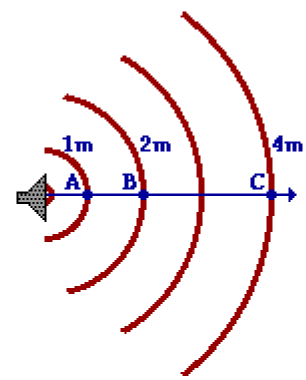
A sound wave is introduced into a medium by the vibration of an object. For example, a vibrating guitar string forces surrounding air molecules to be compressed and expanded, creating a pressure disturbance consisting of an alternating pattern of compressions and rarefactions. The disturbance then travels from particle to particle, through the medium, transporting energy as it moves. The energy which is carried by the disturbance was originally imparted to the medium by the vibrating string. The amount of energy which is transferred to the medium is dependent upon the amplitude of vibrations of the guitar string. If more energy is put into the plucking of the string (that is, more work is done to displace the string a greater amount from its rest position), then the string vibrates with a *wider* amplitude. The greater amplitude of vibration of the guitar string thus imparts more energy to the medium, causing air particles to be displaced a greater distance from their rest position. Subsequently, the amplitude of vibration of the particles of the medium is increased, corresponding to an increased amount of energy being carried by the particles.

The amount of energy which is transported past a given area of the medium per unit of time, is known as the intensity of the sound wave. The greater the amplitude of vibrations of the particles of the medium, the greater the rate at which energy is transported through it, and the more intense the sound wave is. Intensity is the energy/time/area; and since the energy/time ratio is equivalent to the quantity power, intensity is simply the power/area.

$$\text{Intensity} = \frac{\text{Energy}}{\text{Time} * \text{Area}} \quad \text{or} \quad \text{Intensity} = \frac{\text{Power}}{\text{Area}}$$

Typical units for expressing the intensity of a sound wave are Watts/meter^2.

As a sound wave carries its energy through a two-dimensional or three-dimensional medium, the intensity of the sound wave decreases with increasing distance from the source. The decrease in intensity with increasing distance is explained by the fact that the wave is spreading out over a circular (2 dimensions) or spherical (3 dimensions) surface and thus the energy of the sound wave is being distributed over a greater surface area. The diagram at the right shows that the sound wave in a 2-dimensional medium is spreading out in space over a circular pattern. Since energy is conserved and the area through which this energy is transported is increasing, the power (being a quantity which is measured on a *per area* basis) must decrease. The mathematical relationship between intensity and distance is sometimes referred to as an inverse square relationship. The intensity varies inversely with the square of the distance from the source. So, if the distance from the source is doubled (increased by a factor of 2), then the intensity is quartered (decreased by a factor of 4). Similarly, if the distance from the source is quadrupled, then the intensity is decreased by a factor of 16. Applied to the diagram at the right, the intensity at point B is one-fourth the intensity as point A and the intensity at point C is one-sixteenth the intensity at point A. Since the intensity distance relationship is an inverse relationship, an increase in one quantity



corresponds to a decrease in the other quantity. And since the intensity distance relationship is an inverse square relationship, whatever factor by which the distance is increased, the intensity is decreased by a factor equal to the square of the "distance change factor." The sample data in the table below illustrates the inverse square relationship between power and distance.

Distance	Intensity
1 m	160 units
2 m	40 units
3 m	17.8 units
4 m	10 units

Humans are equipped with very sensitive ears capable of detecting sound waves of extremely low intensity. The faintest sound which the typical human ear can detect has an intensity of $1*10^{-12}$ W/m^2. This intensity corresponds to a pressure wave in which a compression of the particles of the medium increases the air pressure in that compressional region by a mere 0.3 billionths of an atmosphere. A sound with an intensity of $1*10^{-12}$ W/m^2 corresponds to a sound which will displace particles of air by a mere one-billionth of a centimeter. The human ear can detect such a sound. This faintest sound which the human ear can detect is known as the threshold of hearing. The most intense sound which the ear can safely detect without suffering any physical damage is more than one billion times more intense than the threshold of hearing.

Loudness

While the intensity of a sound is a very objective quantity which can be measured with sensitive instrumentation, the **loudness** of a sound is more of a subjective response which will vary with a number of factors. The same sound will not be perceived to have the same loudness to all individuals. Age is one factor which affects the human ear's response to a sound. Quite obviously, your grandparents do not hear like they used to. The same intensity of a sound would not be perceived to have the same loudness to them as it would to you.

Furthermore, two sounds with the same intensity but different frequencies will not be perceived to have the same loudness. Because of the human ear's tendency to amplify sounds having frequencies in the range from 1000 Hz to 5000 Hz, sounds with these intensities seem louder to the human ear. Despite the distinction between intensity and loudness, it is safe to state that the more intense sounds will be perceived to be the loudest sounds.

The amount of sound at a location away from the source is generally described by the sound pressure or sound intensity; while the ability of the source to produce sound is described by the sound power of the source.

I) Sound Intensity

The sound intensity at a specific location away from the source is the average rate at which sound energy is flowing through a unit area normal to the direction of sound propagation. The units of I are joules per square meter per second (which is equivalent to power per unit area in watts/m^2). Thus, sound intensity is a vector quantity, possessing both a magnitude and a direction.

a) Intensity, I, is expressed as:

$I = p^2 / (\rho*(C))$ where p^2 = (acoustic pressure)^2
ρ = density of air
C = speed of sound

b) Intensity can be measured by means of a twin microphone probe, with signal processing by a microprocessor controlled cross correlation spectrum analyzer.

c) Measurement of intensity is very useful in industrial noise situations where it is not possible to turn individual sound sources on or off in a reverberant (diffuse) sound field.

J) Intensity level in decibels:

It is also possible to describe acoustic intensity as a level above or below a reference intensity.

a) $L_I = 10 \log I / I_o$

where L_I = Sound intensity level, dB
I = Sound intensity in watts/m^2
I_o = Reference intensity, 10^{-12} watts/m^2

b) Example: For an intensity of I = 1 watt/m^2, what is the intensity level, L_I, in decibels?

$$L_I = 10 \log I / I_o$$

$$= 10 \log ((1 \text{ watt/m}^2)/(10^{-12} \text{ watt/m}^2))$$

$$= 10 * \log (10^{12}) = 10 * 12 * 1 = 120 \text{ dB}$$

c) Example: For an intensity of I = 0.5 watt/m^2, what is the intensity level, L_I, in decibels?

Since the range of intensities which the human ear can detect is so large, the scale which is frequently used by physicists to measure intensity is a scale based on multiples of 10. This type of scale is sometimes referred to as a logarithmic scale. The scale for measuring intensity is the decibel scale. The threshold of hearing is assigned a sound level of 0 decibels (abbreviated 0 dB); this sound corresponds to an intensity of $1*10^{-12}$ W/m^2. A sound which is 10 times more intense ($1*10^{-11}$ W/m^2) is assigned a sound level of 10 dB. A sound which is 10*10 or 100 times more intense ($1*10^{-10}$ W/m^2) is assigned a sound level of 20 dB. A sound which is 10*10*10 or 1000 times more intense ($1*10^{-9}$ W/m^2) is assigned a sound level of 30 dB. A sound which is 10*10*10*10 or 10000 times more intense ($1*10^{-8}$ W/m^2) is assigned a sound level of 40 dB. Observe that this scale is based on powers or multiples of 10. If one sound is 10^x times more intense than another sound, then it has a sound level which is 10*x more decibels than the less intense sound. The table below lists some common sounds with an estimate of their intensity and decibel level.

Source	Intensity	Intensity Level	# Times Greater Than TOH
Threshold of Hearing (TOH)	$1*10^{-12}$ W/m^2	0 dB	10^0
Rustling Leaves	$1*10^{-11}$ W/m^2	10 dB	10^1
Whisper	$1*10^{-10}$ W/m^2	20 dB	10^2
Normal Conversation	$1*10^{-6}$ W/m^2	60 dB	10^6
Busy Street Traffic	$1*10^{-5}$ W/m^2	70 dB	10^7
Vacuum Cleaner	$1*10^{-4}$ W/m^2	80 dB	10^8
Large Orchestra	$6.3*10^{-3}$ W/m^2	98 dB	$10^{9.8}$
Walkman at Maximum Level	$1*10^{-2}$ W/m^2	100 dB	10^{10}
Front Rows of Rock Concert	$1*10^{-1}$ W/m^2	110 dB	10^{11}
Threshold of Pain	$1*10^{1}$ W/m^2	130 dB	10^{13}
Military Jet Takeoff	$1*10^{2}$ W/m^2	140 dB	10^{14}
Instant Perforation of Eardrum	$1*10^{4}$ W/m^2	160 dB	10^{16}

K) Sound Power (W)

For a given sound source, there will be a characteristic sound power associated with it that does not change unless some attribute of the source is changed; i.e., if a machine produces 1 watt of acoustic power, the power remains 1 watt regardless of where an observer is located. The acoustic power represents the ability of the source to emit sound. This is in contrast to sound intensity and sound pressure, which vary with the square of the distance from the source to the measurement point.

$$W = 4\pi r^2 I$$

where W = the acoustic power in watts
r = the distance from the source in meters
I = the acoustic intensity in watts/m^2

L) Sound Power Level in Decibels

As with acoustic intensity, the acoustic power of a source can also be expressed as a level above a reference power, expressed in dB.

$$L_W = 10 \log (W / W_o)$$

where W = sound power in watts

Wo = reference power, 10^{-12} watts

M) Sound Pressure (p)

Sound pressure refers to the rms (root mean square) value of the pressure changes above and below atmospheric when used to measure steady state noise. The units of sound pressure are newtons per square meter (N/m^2), dynes per square centimeter (d/cm^2), microbars (ubar), or Pascals (Pa).

a) 1 N/m2 = 1 Pascal = 1 Pa

b) "RMS" pressure means "root mean square" pressure.

$$P_{rms} = \sqrt{\overline{x^2}} = \left[1/T \int_0^T p^2 dt \right]^{1/2}$$

Sound power and sound pressure

Sound pressure level (SPL) is given in dB SPL. This is a scale that is defined such that the threshold of hearing is 0 dB. The threshold of pain is about 135 dB. This is a logarithmic scale where power doubles for each 3 dB increase; the 135 dB difference between the thresholds of hearing and pain means the power doubles about 45 times - an increase of 32 trillion ($32x10^{12}$) in the power level. This is an incredible dynamic range, and totally blows away anything human engineers are capable of creating. (Actually in a Dec 99 Newsgroup post Dick Pierce states that B&K 4138 microphones have a dynamic range of 140 dB, so I was underrating human engineers). At the low end of the range, the ears lose function due to background noise. At 0 dB SPL noise created by blood flow in the ear is the most predominant background source. It is shown elsewhere that the noise of molecules colliding with the eardrum is not far below this level. At the threshold sound level of 0 dB SPL, Everest states that the eardrum moves a distance smaller than the diameter of a hydrogen molecule! At first I was incredulous when I read this, but it is consistent with the change in diameter of the balloon example used in the previously. For a 0 dB SPL the change in balloon diameter is $6x10^{-10}$ inches, which is about 1/10 of the diameter of a hydrogen atom. The sensitivity of the ear is truly mind-boggling.

N) Sound Pressure Level in Decibels

The ratio expressed in decibels (dB) of the root mean square pressure to a reference root mean square pressure. The reference pressure is equal to the assumed threshold of hearing at 1000 Hz for young people without prior industrial noise exposure.

$$L_p = 10 \log (P/P_o)^2$$

$$= 20 \log (P/P_o)$$

Where L_p = sound pressure level in dB
P = rms sound pressure in N/m^2, $dynes/cm^2$, uN/m^2, or Pa
P = the reference sound pressure 2×10^{-5} N/m^2 or 20 uN/m^2, or 20 uPa

Example: For a sound source having a sound pressure of 1 N/m^2, what is the sound pressure level in dB?

$$L_p = 20 \log (P/P_o) = 20 \log (1\ N/m^2 / 2 \times 10^{-5}\ N/m^2)$$

$$20 \log (0.5 \times 10^5) = 20 (-0.301 + 5) = 94 \text{ dB}$$

Exercise: If $p = 2 \times 10^{-3}$ N/m^2 , what is L_p ?

Exercise: For a sound source of 0.4 Pa, what is the sound pressure level in dB?

Sound pressure level

Weighted sound levels

Subjective vs. Objective Sound Levels

SPL is an objective measurement of sound pressure, or power in watts, and is independent of frequency. In 1933, Fletcher and Munson of Bell Labs, did a study that showed that subjective sound levels varied significantly from the SPL level. That is, when two tones were played at the exactly the same SPL level, one sounded louder than the other. The results were very dependent on how loud the tones were to begin with. This is illustrated by the set of Fletcher-Munson curves. The vertical axis is the objective SPL sound level. Each of the curves in the graph represents a constant subjective sound level, which are in units called "phones." The lowest curve is the minimum audible level of sound. As noted above, the ear is most sensitive around 2-5 kHz. To be audible at this minimum level, a sound at 20Hz must be 80 dB (100 million times!) more powerful than a sound at 3 kHz.

Near the top, the curve at 100 phones is a fairly loud level. To sound equally loud at this level, the sound at 20 Hz must be about 40 dB more powerful. This change in subjective level for different loudness levels means that music played softly will seem to be lacking in bass. For years, pre-amps have come equipped with "loudness" controls to compensate for this.

O) Decibel Addition: For any number of logarithmically related quantities -

$$L_T = 10 \log (10^{L_1/10} + 10^{L_2/10} + 10^{L_3/10} + \ldots + 10^{L_n/10})$$

Where $L_T = L_{total}$ or $L_{overall}$

L_1, L_2, L_3 etc. = the individual sound levels

1. Example: Two machines, each have the same sound pressure level at the measuring location, 93 dB. What is the sound pressure level if both machines are turned on?

$$L_T = 10 \log (10^{L_1/10} + 10^{L_2/10})$$

$$10 \log (10^{93/10} + 10^{93/10})$$

$$10 \log (2 \times 10^{9.3}) = 96 \text{ dB}$$

2. Exercise: Three machines have the following sound pressure levels at a given measurement location:

L_1 = 95 dB
L_2 = 96 dB
L_3 = 100 dB

What is the resulting sound pressure level if all three machines are turned on at the same time?

Rule-of-Thumb for dB addition: (when a limited number of sources are added together)

0 dB difference	add 3 dB to higher value
1 or 1.5 dB difference	add 2.5 dB
2 to 3 dB difference	add 2 dB
3.5 to 4.5 dB difference	add 1.5 dB
5 to 7 dB difference	add 1 dB
7.5 to 13 dB difference	add 0.5 dB
>13 dB difference	0 dB

3. Exercise – Using the data from Exercise 2 above, and the approximation method given, find the total sound pressure level:

P) Relationship Between Sound Power Level (LW) and Sound Pressure Level (LP).

For free field, omnidirectional conditions,

a) $L_w = L_p + 10*\log r^2 + 0.5 - T$

where: r = distance from source in feet

T = temperature and altitude correction factor, which can be ignored in most cases.

b) Exercise: A sound pressure level of 100 dB is measured 3 feet from a source. What is the L_p at 12 feet from the source?

Note: Important rule-of-thumb – each doubling of distance from source results in 6 dB loss

Q) Inverse Square Law

1) Under far field/free field conditions, sound intensity varies inversely with the square of the distance from the source.

$L_{p2} = L_{p1} - 20*\log(r_2/r_1)$

Where: L_{p1}, L_{p2} = sound pressure level in dB at locations 1 and 2

r_2, r_1 = Distance from noise source to points 1 and 2 in feet

a) Exercise: Use data from the previous example. A sound pressure level of 100 dB is measured at 3 feet from a source. What is L_p at 12 feet from the source?

R) Relationship Between Sound Power Level (Lw) and Sound Pressure Level (LP) in Free but Directional Fields.

1. $L_w = L_p + 10*\log(r^2/Q) + 0.5 - T$

Where Q = Directivity factor

Q = 1 for a spherical radiation
Q = 2 for ½ sphere
Q = 4 for ¼ sphere
Q = 8 for 1/8 sphere

Note: This treatment assumes noise source is bounded by one or more reflecting surfaces.

S) Octave Band Principles

Bandwidth

Octave band

One thing to notice is that the two C notes are separated by exactly a factor of two -- 264 is one half of 528. This is the basis of **octaves**. Any note's frequency can be doubled to "go up an octave," and any note's frequency can be halved to "go down an octave."

What is White Noise?

Because white noise contains all frequencies, it is frequently used to **mask** other sounds. If you are in a hotel and voices from the room next door are leaking into your room, you might turn on a fan to drown out the voices. The fan produces a good approximation of white noise. Why does that work? Why does white noise drown out voices?

Here is one way to think about it. Let's say two people are talking at the same time. Your brain can normally "pick out" one of the two voices and actually listen to it and understand it. If three people are talking simultaneously, your brain can probably still pick out one voice. However, if 1,000 people are talking simultaneously, there is no way that your brain can pick out one voice. It turns out that 1,000 people talking together sounds a lot like white noise. So when you turn on a fan to create white noise, you are essentially creating a source of 1,000 voices. The voice nextdoor makes it 1,001 voices, and your brain can't pick it out any more.

Decibels

Points of Reference *measured in dBA or decibels

- 0 The softest sound a person can hear with normal hearing
- 10 normal breathing
- 20 whispering at 5 feet
- 30 soft whisper
- 50 rainfall
- 60 normal conversation
- 110 shouting in ear
- 120 thunder

Home

- 50 refrigerator
- 50 - 60 electric toothbrush
- 50 - 75 washing machine
- 50 - 75 air conditioner
- 50 - 80 electric shaver
- 55 coffee percolator
- 55 - 70 dishwasher
- 60 sewing machine
- 60 - 85 vacuum cleaner
- 60 - 95 hair dryer
- 65 - 80 alarm clock
- 70 TV audio
- 70 - 80 coffee grinder
- 70 - 95 garbage disposal
- 75 - 85 flush toilet
- 80 pop-up toaster
- 80 doorbell
- 80 ringing telephone
- 80 whistling kettle

Work

- 40 quiet office, library
- 50 large office
- 65 - 95 power lawn mower
- 80 manual machine, tools
- 85 handsaw
- 90 tractor
- 90 - 115 subway
- 95 electric drill
- 100 factory machinery
- 100 oodworking class
- 105 snow blower
- 110 power saw
- 110 leafblower
- 120 hain saw, hammer on nail
- 120 pneumatic drills, heavy machine
- 120 jet plane (at ramp)

Recreation

- 40 quiet residential area
- 70 freeway traffic
- 85 heavy traffic, noisy restaurant
- 90 truck, shouted conversation
- 95 - 110 motorcycle
- 100 snowmobile
- 100 school dance, boom box
- 110 disco
- 110 busy video arcade
- 110 symphony concert
- 110 car horn
- 110 -120 rock concert
- 112 personal cassette player on high
- 117 football game (stadium)
- 120 band concert

- 80 - 90 food mixer or processor
- 80 - 90 blender
- 80 - 95 garbage disposal
- 110 baby crying
- 110 squeaky toy held close to the ear
- 135 noisy squeeze toys

- 120 ambulance siren
- 125 chain saw
- 130 jackhammer, power drill
- 130 air raid
- 130 percussion section at symphony
- 140 airplane taking off
- 150 jet engine taking off
- 150 artillery fire at 500 feet
- 180 rocket launching from pad

- 125 auto stereo (factory installed)
- 130 stock car races
- 143 bicycle horn
- 150 firecracker
- 156 capgun
- 157 balloon pop
- 162 fireworks (at 3 feet)
- 163 rifle
- 166 handgun
- 170 shotgun

Most construction noise comes from equipment. These decibel levels have been measured:

Equip.	dBA	Equip.	dBA
Pneu. chip hammer	103-113	Earth Tamper	90-96
Jack hammer	102-111	Crane	90-96
Concrete joint cutter	99-102	Hammer	87-95
Skilsaw	88-102	Gradeall	87-94
Stud welder	101	Front-end loader	86-94
Bulldozer	93-96	Backhoe	84-93

The noise levels change. The noise from a gradeall earthmover is 94 decibels from 10 feet away. The noise is only 82 decibels if you are 70 feet away. A crane lifting a load can make 96 decibels of noise; at rest, it may make less than 80 decibels.

This information is taken in part from The Physics Classroom – Sound Waves and Music by Tom Henderson, science teacher at Glenbrook South High School in Glenview, Illinois. A very extensive study on sound waves can be found at the following website: http://www.glenbrook.k12.il.us/gbssci/phys/Class/sound/u11l1a.html

2

HEARING CONSERVATION PROGRAM EVALUATION CHECKLIST

NIOSH

Training and Education

Failures or deficiencies in hearing conservation programs (hearing loss prevention programs) can often be traced to inadequacies in the training and education of noise-exposed employees and those who conduct elements of the program.

1. Has training been conducted at least once a year?

2. Was the training provided by a qualified instructor?

3. Was the success of each training program evaluated?

4. Is the content revised periodically?

5. Are managers and supervisors directly involved?

6. Are posters, regulations, handouts, and employee newsletters used as supplements?

7. Are personal counseling sessions conducted for employees having problems with hearing protection devices or showing hearing threshold shifts?

Supervisor Involvement

Data indicates that employees who refuse to wear hearing protectors or who fail to show up for hearing tests frequently work for supervisors who are not totally committed to the hearing loss prevention programs.

1. Have supervisors been provided with the knowledge required to supervise the use and care of hearing protectors by subordinates?

2. Do supervisors wear hearing protectors in appropriate areas?

3. Have supervisors been counseled when employees resist wearing protectors or fail to show up for hearing tests?

4. Are disciplinary actions enforced when employees repeatedly refuse to wear hearing protectors?

Noise Measurement

For noise measurements to be useful, they need to be related to noise exposure risks or the prioritization of noise control efforts, rather than merely filed away. In addition, the results need to be communicated to the appropriate personnel, especially when follow-up actions are required.

1. Were the essential/critical noise studies performed?

2. Was the purpose of each noise study clearly stated? Have noise-exposed employees been notified of their exposures and appraised of auditory risks?

3. Are the results routinely transmitted to supervisors and other key individuals?

4. Are results entered into health/medical records of noise exposed employees?

5. Are results entered into shop folders?

6. If noise maps exist, are they used by the proper staff?

7. Are noise measurement results considered when contemplating procurement of new equipment? Modifying the facility? Relocating employees?

8. Have there been changes in areas, equipment, or processes that have altered noise exposure? Have follow-up noise measurements been conducted?

9. Are appropriate steps taken to include (or exclude) employees in the hearing loss prevention programs whose exposures have changed significantly?

Engineering and Administrative Controls

Controlling noise by engineering and administrative methods is often the most effective means of reducing or eliminating the hazard. In some cases, engineering controls will remove requirements for other components of the program, such as audiometric testing and the use of hearing protectors.

1. Have noise control needs been prioritized?

2. Has the cost-effectiveness of various options been addressed?

3. Are employees and supervisors appraised of plans for noise control measures? Are they consulted on various approaches?

4. Will in-house resources or outside consultants perform the work?

5. Have employees and supervisors been counseled on the operation and maintenance of noise control devices?

6. Are noise control projects monitored to ensure timely completion?

7. Has the full potential for administrative controls been evaluated? Are noisy processes conducted during shifts with fewer employees? Do employees have sound-treated lunch or break areas?

Monitoring Audiometry and Record Keeping

The skills of audiometric technicians, the status of the audiometer, and the quality of audiometric test records are crucial to hearing loss prevention program success. Useful information may be ascertained from the audiometric records as well as from those who actually administer the tests.

1. Has the audiometric technician been adequately trained, certified, and recertified as necessary?

2. Do on-the-job observations of the technicians indicate that they perform a thorough and valid audiometric test, instruct and consult the employee effectively, and keep appropriate records?

3. Are records complete?

4. Are follow-up actions documented?

5. Are hearing threshold levels reasonably consistent from test to test? If not, are the reasons for inconsistencies investigated promptly?

6. Are the annual test results compared to baseline to identify the presence of an OSHA standard threshold shift?

7. Is the annual incidence of standard threshold shift greater than a few percent? If so, are problem areas pinpointed and remedial steps taken?

8. Are audiometric trends (deteriorations) being identified, both in individuals and in groups of employees? (NIOSH recommends no more than 5% of workers showing 15 dB Significant Threshold Shift, same ear, same frequency.)

9. Do records show that appropriate audiometer calibration procedures have been followed?

10. Is there documentation showing that the background sound levels in the audiometer room were low enough to permit valid testing?

11. Are the results of audiometric tests being communicated to supervisors and managers as well as to employees?

12. Has corrective action been taken if the rate of no-shows for audiometric test appointments is more than about 5%?

13. Are employees incurring STS notified in writing within at least 21 days? (NIOSH recommends immediate notification if retest shows 15 dB Significant Threshold Shift, same ear, same frequency.)

Referrals

Referrals to outside sources for consultation or treatment are sometimes in order, but they can be an expensive element of the hearing loss prevention program, and should not be undertaken unnecessarily.

1. Are referral procedures clearly specified?
2. Have letters of agreement between the company and consulting physicians or audiologists been executed?
3. Have mechanisms been established to ensure that employees needing evaluation or treatment actually receive the service (i.e., transportation, scheduling, reminders)?
4. Are records properly transmitted to the physician or audiologist, and back to the company?
5. If medical treatment is recommended, does the employee understand the condition requiring treatment, the recommendation, and methods of obtaining such treatment?
6. Are employees being referred unnecessarily?

Hearing Protection Devices

When noise control measures are infeasible, or until such time as they are installed, hearing protection devices are the only way to prevent hazardous levels of noise from damaging the inner ear. Making sure that these devices are worn effectively requires continuous attention on the part of supervisors and program implementors as well as noise-exposed employees.

1. Have hearing protectors been made available to all employees whose daily average noise exposures are 85 dBA or above? (NIOSH recommends requiring HPD use if noises equal or exceed 85 dBA regardless of exposure time.)

2. Are employees given the opportunity to select from a variety of appropriate protectors?

3. Are employees fitted carefully with special attention to comfort?

4. Are employees thoroughly trained, not only initially, but at least once a year?

5. Are the protectors checked regularly for wear or defects, and replaced immediately if necessary?

6. If employees use disposable hearing protectors, are replacements readily available?

7. Do employees understand the appropriate hygiene requirements?

8. Have any employees developed ear infections or irritations associated with the use of hearing protectors? Are there any employees who are unable to wear these devices because of medical conditions? Have these conditions been treated promptly and successfully?

9. Have alternative types of hearing protectors been considered when problems with current devices are experienced?

10. Do employees who incur noise-induced hearing loss receive intensive counseling?

11. Are those who fit and supervise the wearing of hearing protectors competent to deal with the many problems that can occur?

12. Do workers complain that protectors interfere with their ability to do their jobs? Do they interfere with spoken instructions or warning signals? Are these complaints followed promptly with counseling, noise control, or other measures?

13. Are employees encouraged to take their hearing protectors home if they engage in noisy non-occupational activities?

14. Are new types of hearing protectors or potentially more effective hearing protectors considered as they become available?

15. Is the effectiveness of the hearing protector program evaluated regularly?

16. Have the-ear protection levels been evaluated to ensure that either over or under protection has been adequately balanced according to the anticipated ambient noise levels?

17. Is each hearing protector user required to demonstrate that he or she understands how to use and care for the protector? Are the results documented?

Administrative

Keeping organized and current on administrative matters will help the program run smoothly.

1. Have there been any changes in federal or state regulations? Have hearing loss prevention program policies been modified to reflect these changes?

2. Are copies of company policies and guidelines regarding the hearing loss prevention program available in the offices that support the various program elements? Are those who implement the program elements aware of these policies? Do they comply?

3. Are necessary materials and supplies being ordered with a minimum of delay?

4. Are procurement officers overriding the hearing loss prevention program implementor's requests for specific hearing protectors or other hearing loss prevention equipment? If so, have corrective steps been taken?

5. Is the performance of key personnel evaluated periodically? If such performance is found to be less than acceptable, are steps taken to correct the situation?

6. Safety: Has the failure to hear warning shouts or alarms been tied to any accidents or injuries? If so, have remedial steps been taken?

Other points to consider

Be proactive

Effective programs go beyond OSHA's minimum requirements.

Management should put a high priority on employee training sessions and make attendance mandatory. Management should also commit to supplying the program's staff with the training and education they need.

In addition to setting a good example, supervisors should frequently remind their employees about the importance of hearing protection and be responsive to the employees' questions and concerns.

The safety staff should provide more than basic training. Presentations by experts or respected co-workers can help trainees relate to the real-life consequences of not being able to hear voices, music, the sounds of nature, or warning signals. An expert can explain audiometric test results at a level that makes sense to the group. Workers who understand their test results are more receptive to using hearing protection. Training should include hands-on exercises in selecting and fitting hearing protection.

Employees should be encouraged to ask questions and comment on the program, and they should be involved in brainstorming sessions to find engineering solutions to noise problems.

Hearing loss prevention needs the commitment and cooperation of management, supervisors, safety staff, and employees.

COMPANY: Bil and Don IH High Dollar Consultation
NOISE SAMPLING RESULTS TABLE A

WORKER NAME	JOB/OPERATION	DATE	MINUTES SAMPLED	LOW THRESHOLD RESULT (1)		OSHA ACTION LEVEL	HIGH THRESHOLD RESULT (2)		OSHA PEL
Tom Morris	Vinyl Grinder	9/16/02	432	13%	76 dBA	85 dBA	7%	72 dBA	90 dBA
James Clark	Back-up Foreman	9/16/02	436	25%	81 dBA	85 dBA	5%	69 dBA	90 dBA
Don Mullins	Foreman	9/16/02	428	15%	77 dBA	85 dBA	4%	68 dBA	90 dBA
Chris Hamrick	#14 Extruder	9/16/01	442	52%	86 dBA	85 dBA	22%	80 dBA	90 dBA
Ryan Rob	Labor	9/16/02	327	34%	85 dBA	85 dBA	19%	81 dBA	90 dBA
Mike Ely	#19 Extruder	9/16/02	425	34%	83 dBA	85 dBA	8%	73 dBA	90 dBA
Ed Violet	Machine Shop	9/16/02	420	109%	92 dBA	85 dBA	90%	90 dBA	90 dBA
James Taylor	Mold Cleaning	9/16/02	425	149%	94 dBA	85 dBA	109%	92 dBA	90 dBA
Tom Kelly	Milling	9/17/02	403	44%	85 dBA	85 dBA	11%	75 dBA	90 dBA
Jim Scholl	Press 302	9/17/02	429	78%	89 dBA	85 dBA	44%	85 dBA	90 dBA
Rickey Stoner	Press 93	9/17/02	435	117%	92 dBA	85 dBA	77%	89 dBA	90 dBA
Ken Foxxy	Press 82	9/17/02	430	198%	96 dBA	85 dBA	177%	95 dBA	90 dBA
Marty Grant	Press 69 & 70	9/17/02	431	99%	91 dBA	85 dBA	82%	89 dBA	90 dBA

(1) The low threshold results were collected using dosimeters that measure and integrate all noise equal to 80 dBA or higher. Sound levels below 80 dBA are measured but not integrated into these results. The low threshold level is used to determine the need for a Hearing Conservation Program at the OSHA Action Level of 85 dBA.

(2) The high threshold results were collected using dosimeters that measure and integrate all noise equal to 90 dBA or higher. Sound levels below 90 dBA are measured but not integrated into these results. The high threshold level is used to determine the need for engineering/administrative controls and mandatory wearing of hearing protection above the OSHA PEL of 90 dBA.

All employees in the similar exposure group (SEG) requires…..
1910.95 (m)(4) exposure monitoring records must be kept for at least 2 years.

OSHA PEL – Occupational Safety and Health Administration Permissible Exposure Level
dBA – decibels "A" weighted

The hearing mechanism

The hearing mechanism is a delicate structure suspended in the middle of your head. It is divided into three separate areas. The first area is the outer ear. This contains the familiar parts of the ear. The outer ear includes the ear canal and this ends at the ear drum. The ear drum is technically referred to as the tympanic membrane. Embedded in the tympanic membrane is the first bone of the hearing chain from the middle ear. This is the maleus bone.

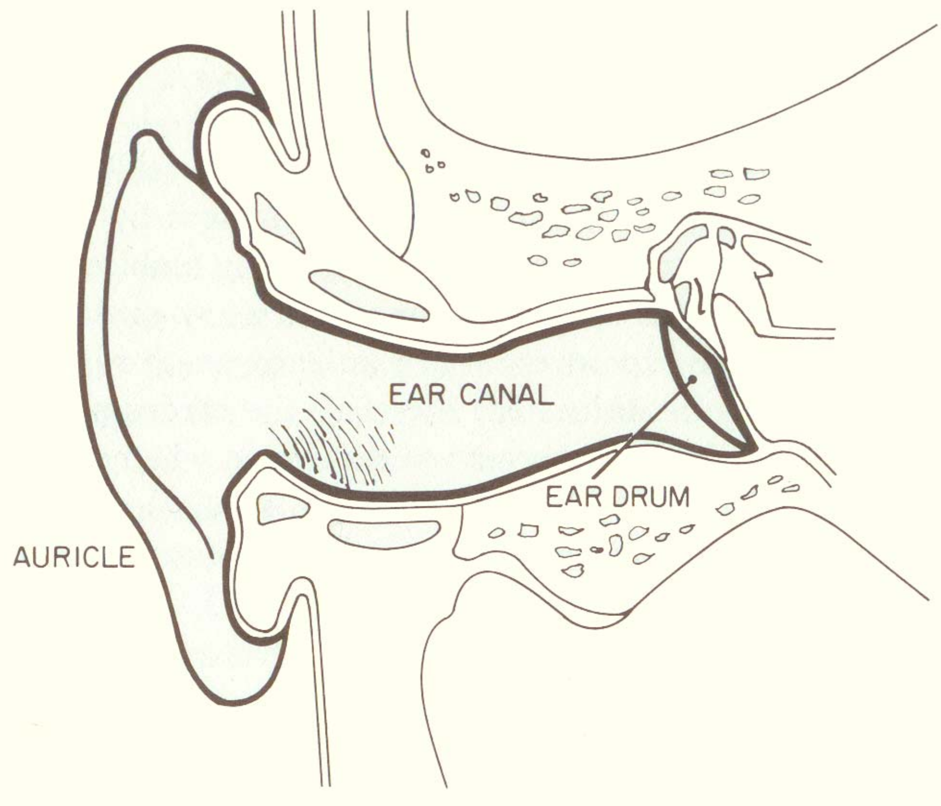


Figure 10.5 The external ear.

The middle ear is an air filled space between the outer ear and the inner ear. The air for this space comes from the eustachian tube. The eustachian tube connects the middle ear space with the back of the throat in the area directly behind the nose. This tube opens and closes many times during the day. Some activities that will open the tube include swallowing, yawning and chewing. In the middle ear space, there are three bones connecting the ear drum to the inner ear. The maleus connects to the incus which in turn connects to the stapes. The stapes is often referred to as a stirrup. The stapes moves in an opening to the inner ear. Associated with the middle ear air tracts enter the surrounding bone. These air cells are largest directly behind the ear and make up the mastoid.

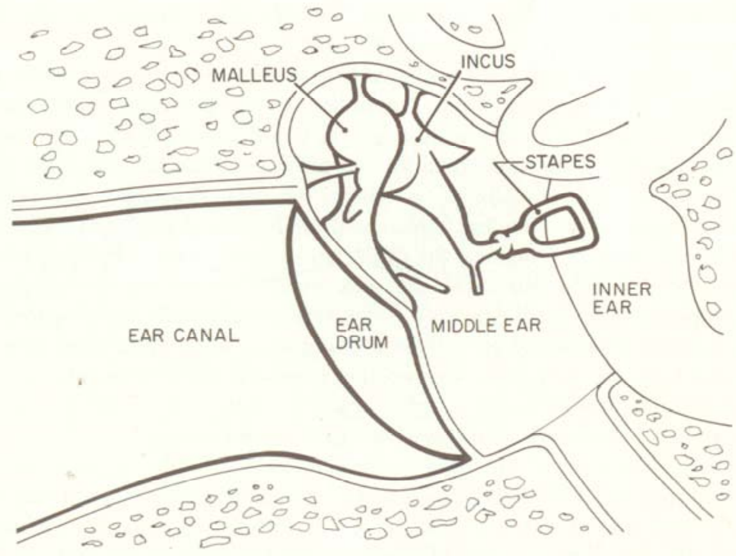


Figure 10.6 The middle ear.

The inner ear is an extremely small structure that is totally encased in bone. The bone is very dense and develops early in life. The inner ear, if removed from the head and placed on a dime, would still show silver around the edges. The inner ear is composed mostly of fluid. This fluid is divided into several compartments. There are two main divisions to the inner ear. One division controls the sense of balance. Another division controls and provides hearing. The fluid filling these compartments includes perilymph and endolymph. Perilymph and endolymph are composed of differing salt solutions. The salt solutions

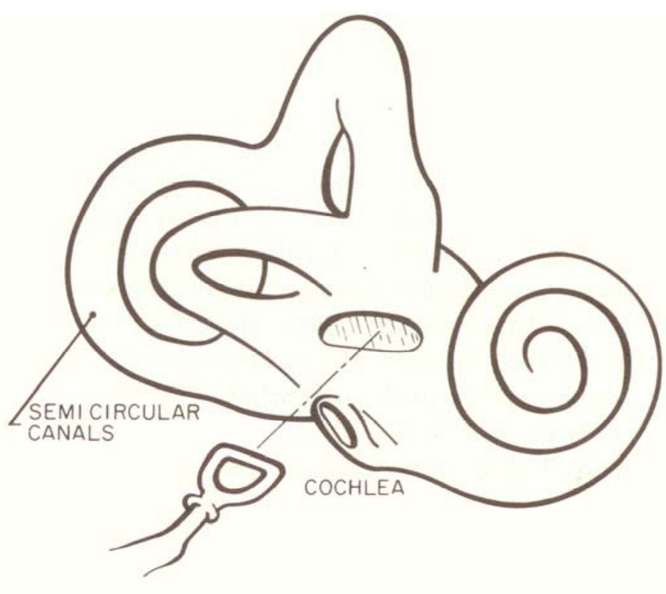


Figure 10.7 The inner ear.

must be properly balanced so that the electrical potentials of the inner ear are normal. Suspended in the fluid are tiny hair cells. The motion of these hair cells creates a signal sent back to the brain along the hearing nerve. The hair cells in the balance part of the inner ear, called the labyrinth, send their signal to the brain's balance center.

The hair cells and nerve cells of the inner ear are permanent structures. This means that when you are born, you get one set of cells. If the cells die because of infection or trauma they are gone forever. At this time, we have no way to replace or regrow the cells. Numerous diseases can affect different areas of the ear. Frequently, your doctor will ask for a hearing test in order to better understand what might be causing a problem with the ear.

Hearing tests measure two important things. An audiologist will fit you with special ear phones that will enable you to hear very quiet sounds. You will be placed in a special quiet room. The audiologist will present sounds in each earphone. They will vary the pitch and loudness. By performing this and other tests, the audiologist will be able to tell whether you have a hearing loss from the outer and middle ear (a conductive hearing loss) or an inner ear type of hearing loss (a sensorineural hearing loss).

http://www.ahc.umn.edu/ahc_content/colleges/med_school/departments/Otolaryngology/index2.cfm/nav/52667/parent/52638/type/D/content_path/colleges@med_school@departments@Otolaryngology@Oto_ENT_Clinics@Otology-Neurotology@Physiology_and_Function_of_the_Ear/content_name/Physiology_and_Function_of_the_Ear/pic/none/bold/

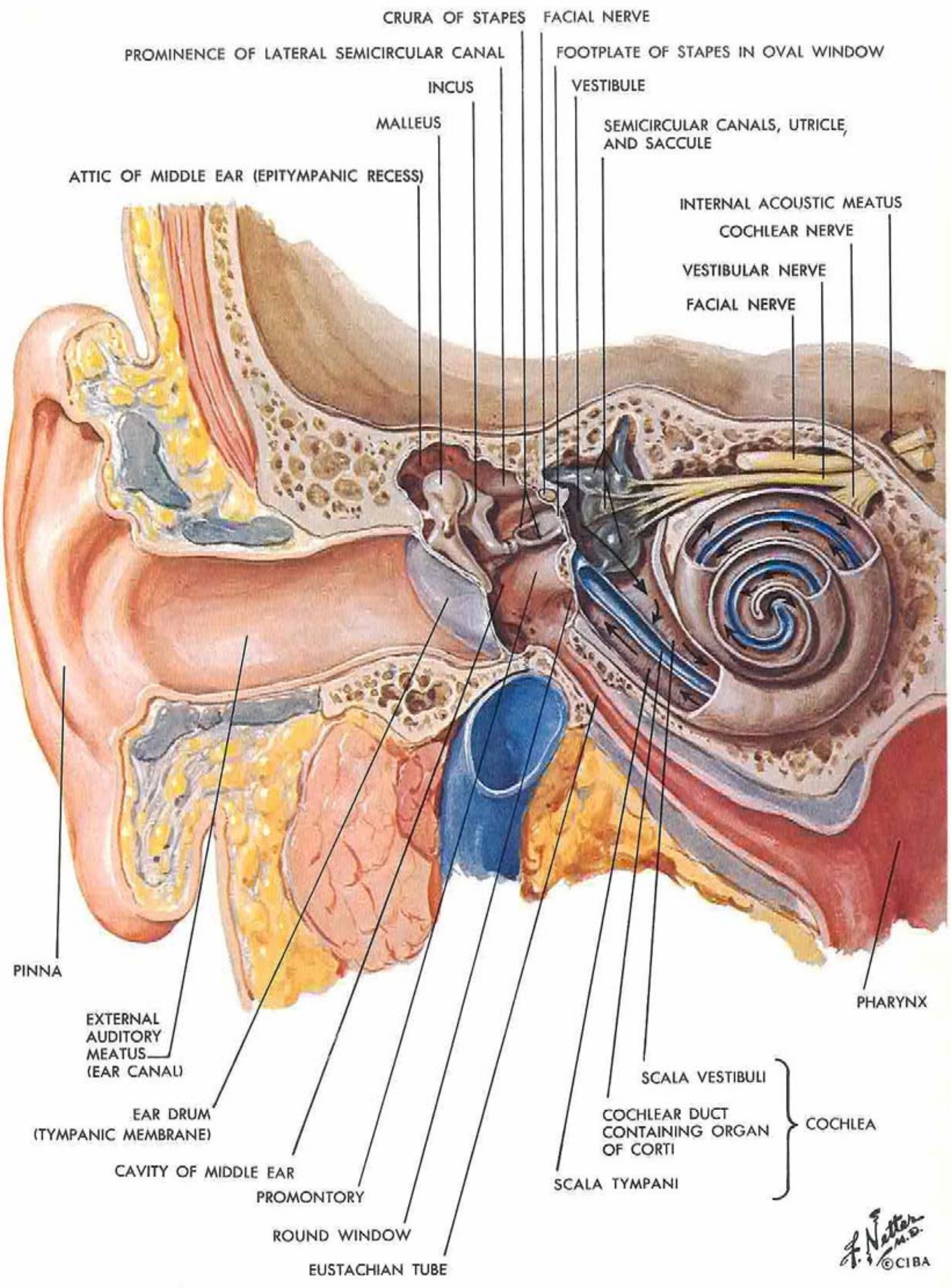
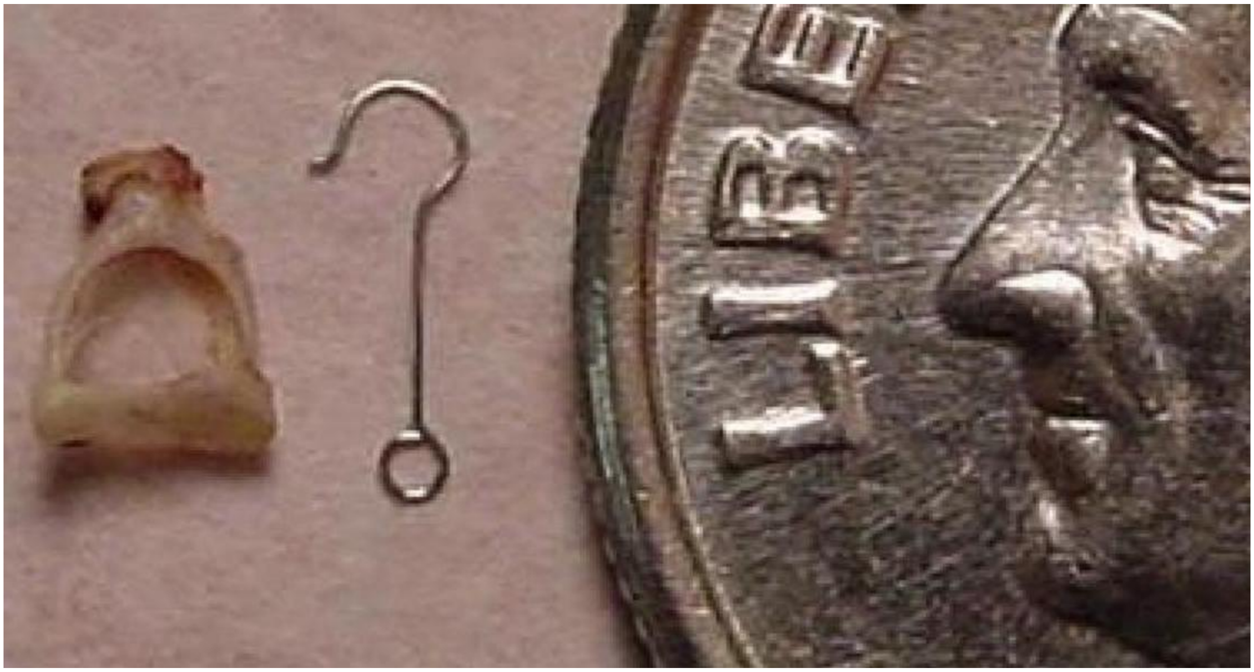
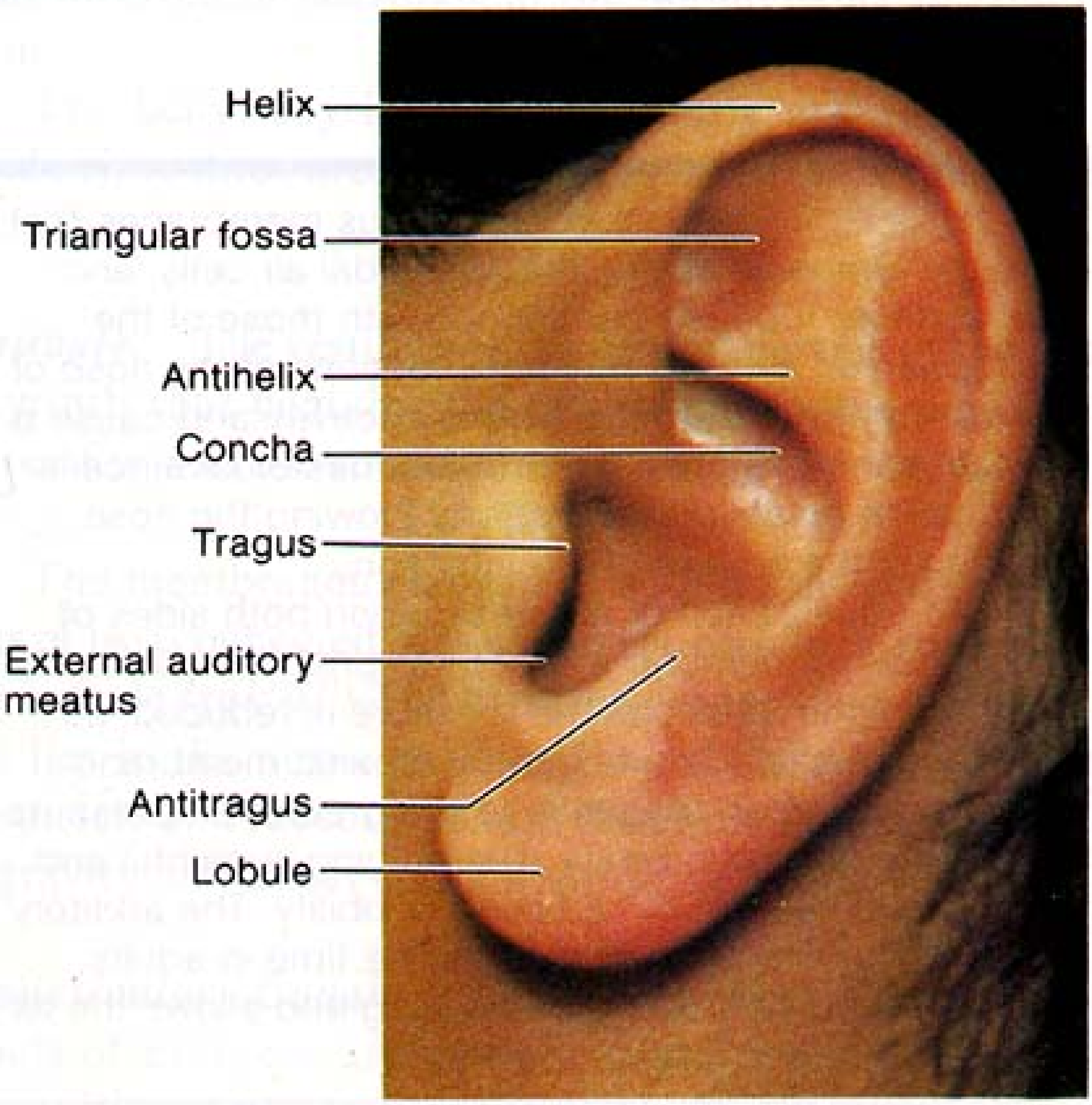


Figure 24-1. Pathway of Sound Conduction Showing Anatomic Relationships.


LIBE


LIBERTY
IN GOD WE TRUST
1986

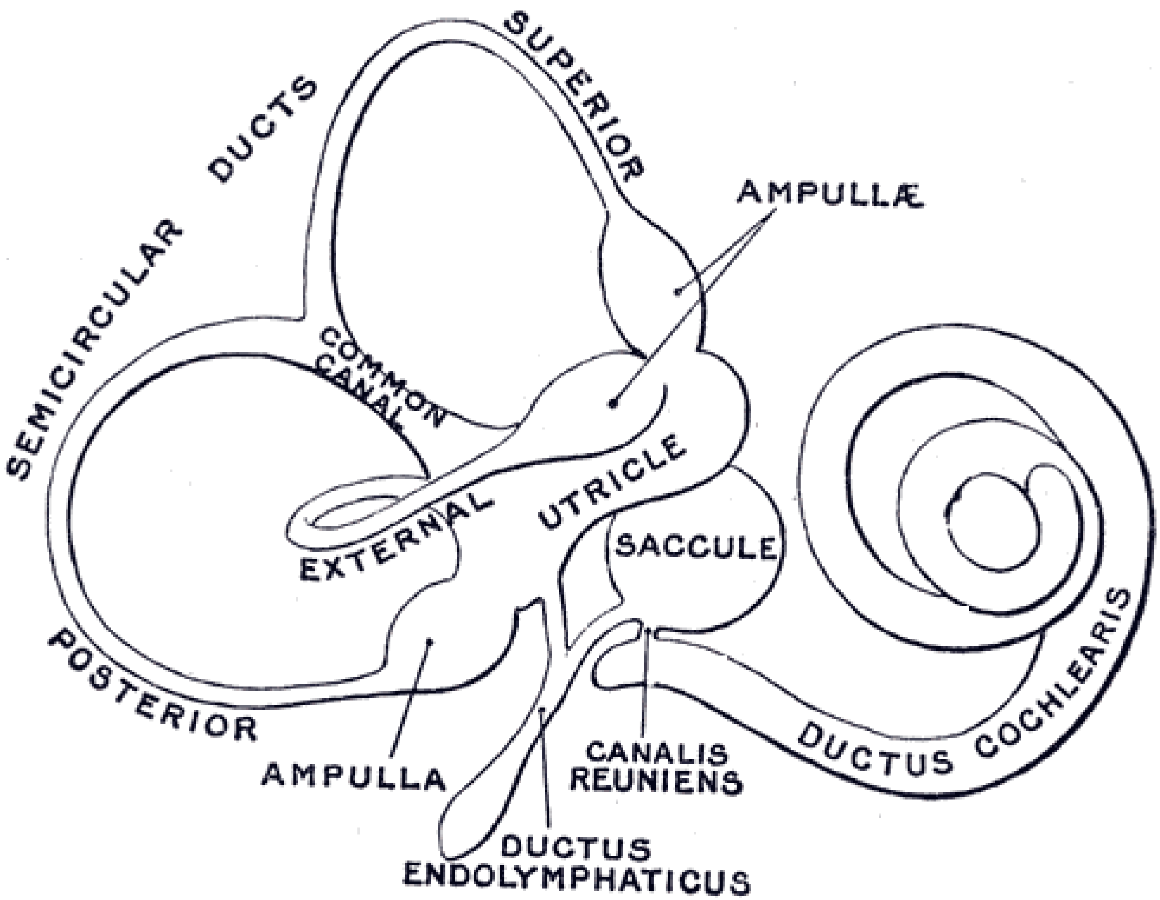
The surface anatomy of the auricle of the ear.



How an Ear Works - Balance

Balance function and the inner ear

The human inner ear can be divided into several compartments. Inside the skull, there are several bones that merge into one solid structure. The temporal bone houses the ear. Inside the bone is a fluid filled space referred to as the inner ear. It forms early in life well before birth. The inner ear is smaller than a dime and contains less than three drops of fluid. The fluids are composed of differing salt solutions that create an electrical current. Two major divisions of the inner ear are the cochlea for hearing and the vestibule that provides balance information.



http://www.ahc.umn.edu/ahc_content/colleges/med_school/departments/Otolaryngology/Oto_ENT_Clinics/Otology-Neurotology/Physiology_and_Function_of_the_Ear/line%20draw%20labyrinth.gif

The balance half of the inner ear is subdivided into three semicircular canals and in the largest opening (called the vestibule) there are two more segments called the utricle and saccule. The utricle and saccule determine your orientation to gravity. They detect linear accelerations in any direction. When a car starts and stops or when an elevator goes up and down, this is the part of the ear that detects that motion and tells the brain how fast you went. The semicircular canals give information about turning. Getting out of bed or bending and twisting are signaled from this part of the inner ear.

Normally both inner ears are always sending signals back to the brain, even when we are not moving. The brain expects to get equal and accurate information from the inner ear. Information from the inner ear is faster and more direct than any other type of signal. If a disease causes the signal to become greater or less than the other side we experience a conflict in sensory perceptions. The brain will verify information with the eyesight and sensation from all of the joints and the muscles attached to those joints. Conflicts in sensory perceptions may be created by amusement park rides where it is done for fun. Amusement park operators understand how to create brief conflicts. They will flash lights in the wrong direction and wrong speed to create a conflict between eyesight perceptions of position and speed and the inner ear. They also make flat turns quickly. These kinds of turns move one ear more than the other ear and therefore briefly create a difference between the inner ears. In disease, this can result in incapacitation and disabling vertigo (vertigo - a perception of abnormal rotation that does not correspond to the physical world) and nausea.

The brain cannot adapt to bad information, but it will adapt over a long period of time to no signal. If there is no signal, the brain will come to rely on only the good side. This is called central adaptation. It is not as well understood as the inner ear itself.

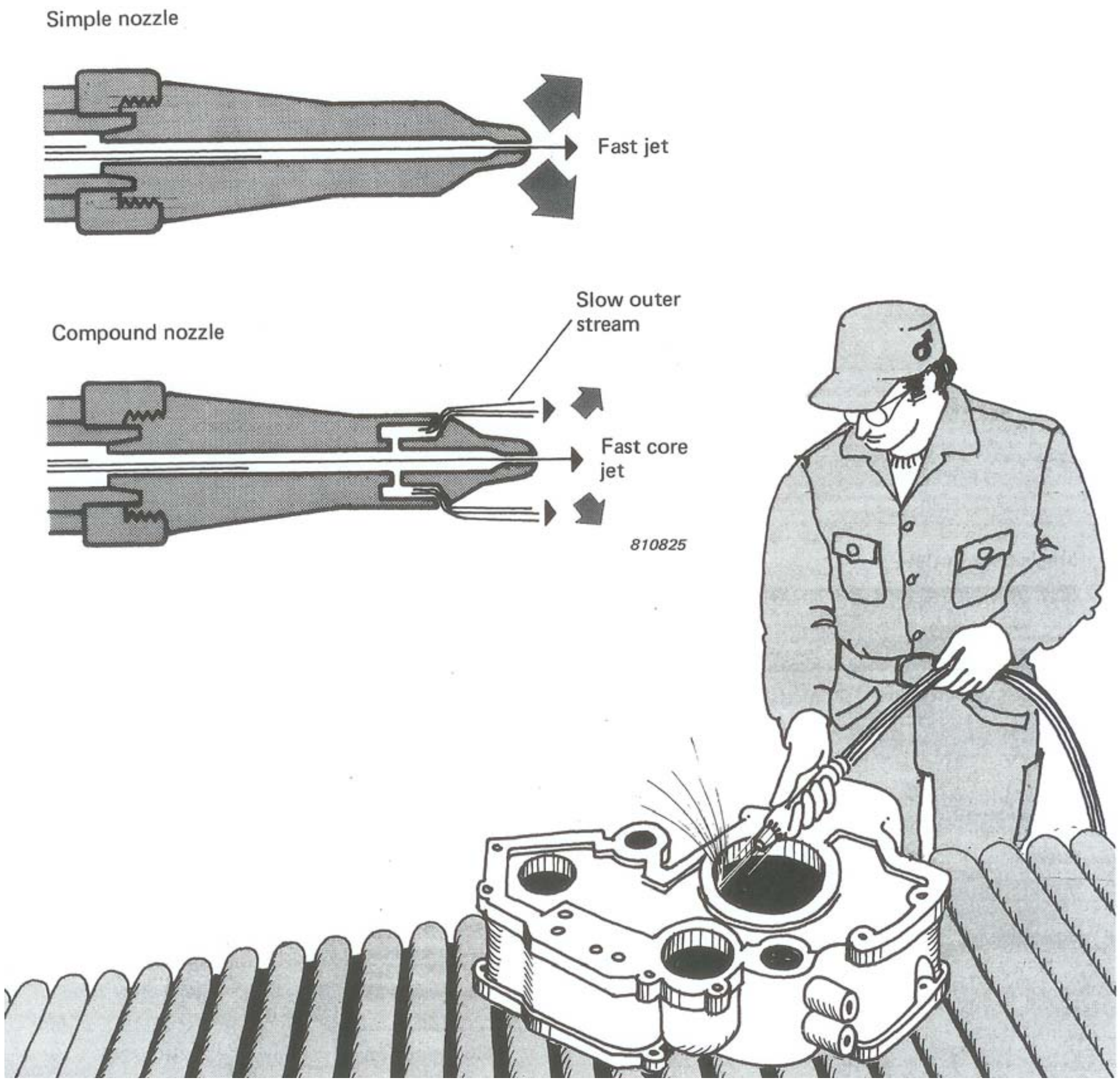
Eye movement is in part used to control the movement and focus control of the eye. When you turn quickly, the inner ear signals eye muscle controls where you turned and how far. This enables those centers to recenter the eye and focus on the target more rapidly. People who have dizziness may not focus clearly or quickly.

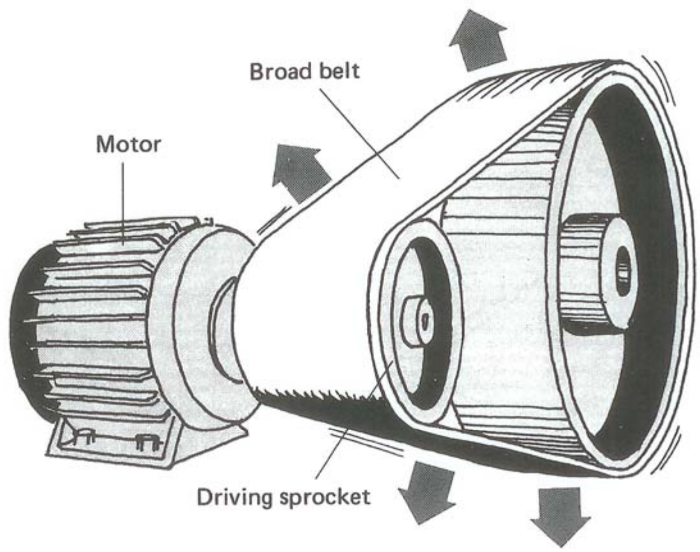
This page is located at: www.ent.umn.edu/clinics/Otology-Neurotology/Physiology_and_Function/balance/

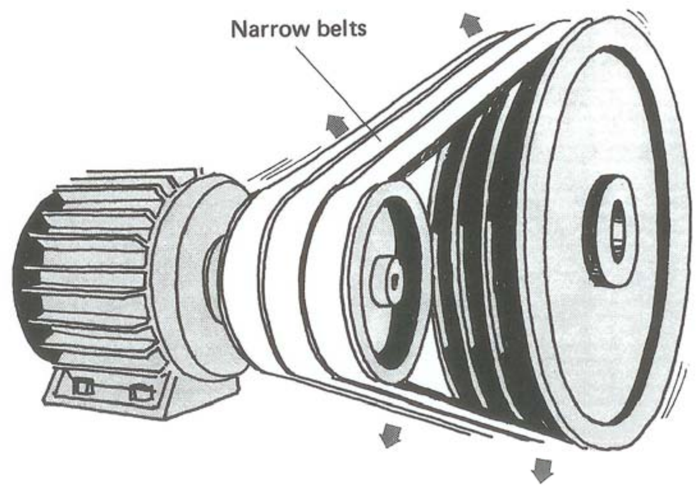
NOISE CONTROL

A guide for
workers and employers

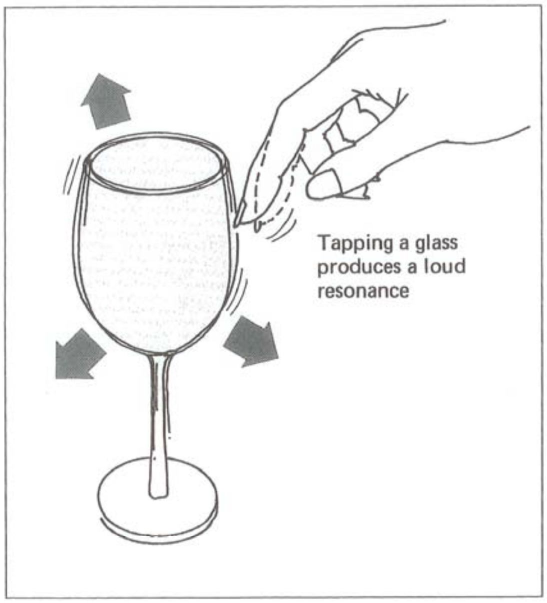
U.S. Department of Labor
Occupational Safety and
Health Administration


Simple nozzle
Fast jet
Compound nozzle
Slow outer stream
Fast core jet
810825

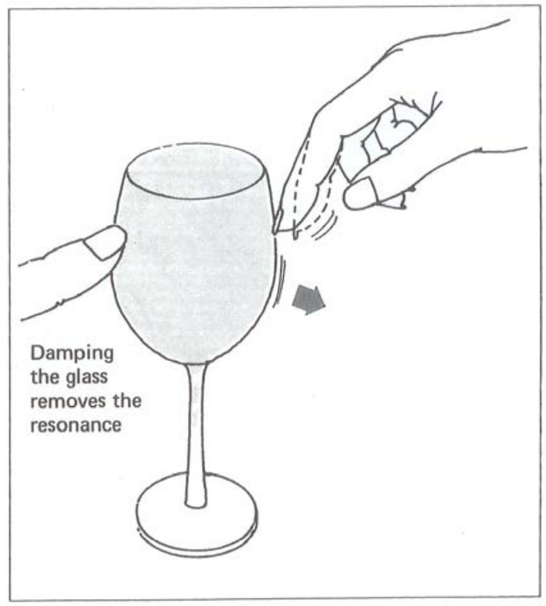

Broad belt
Motor
Driving sprocket


Narrow belts

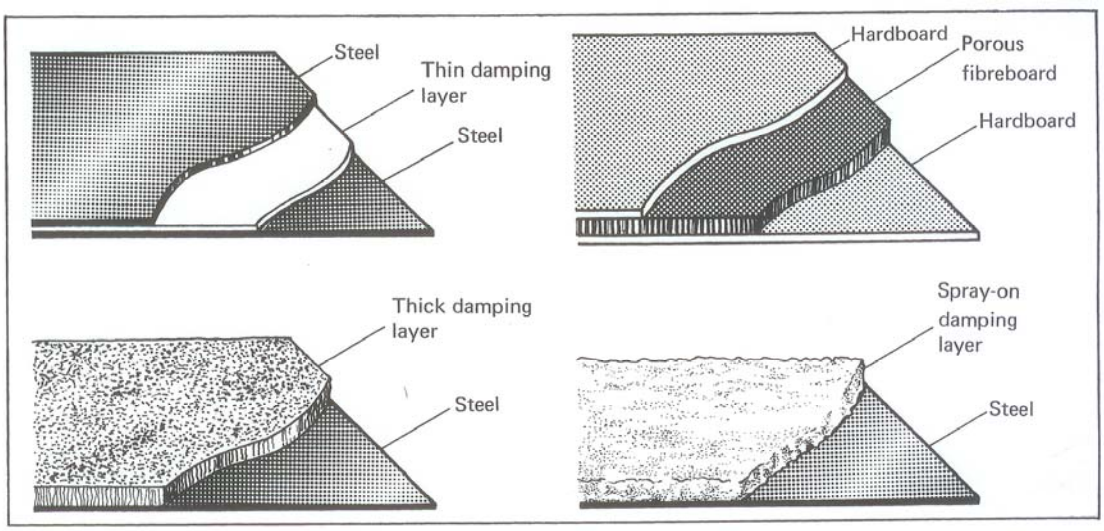
Principle



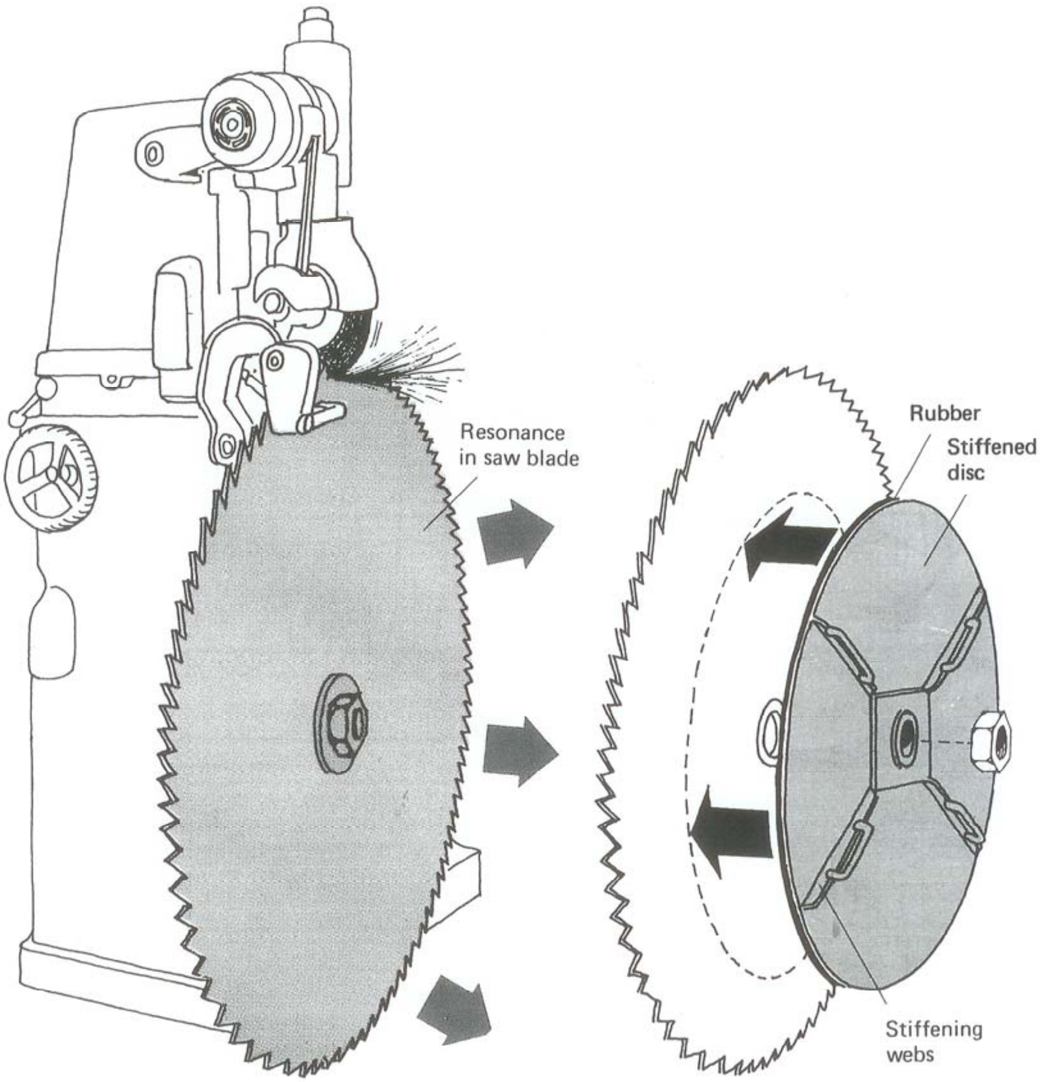
Tapping a glass produces a loud resonance

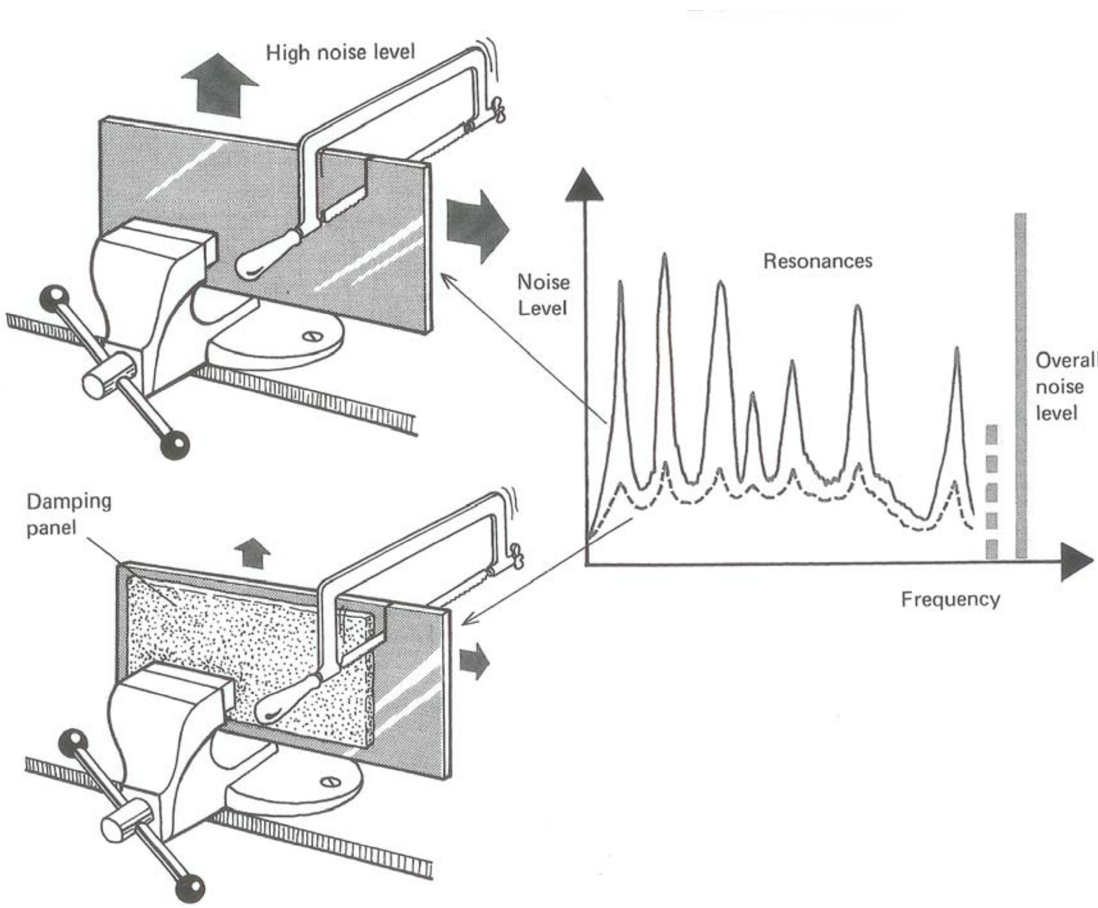


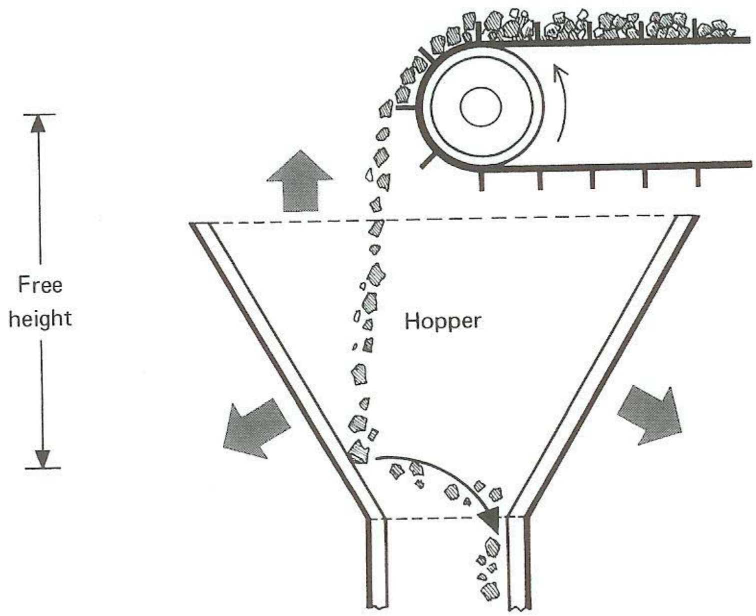
Damping the glass removes the resonance

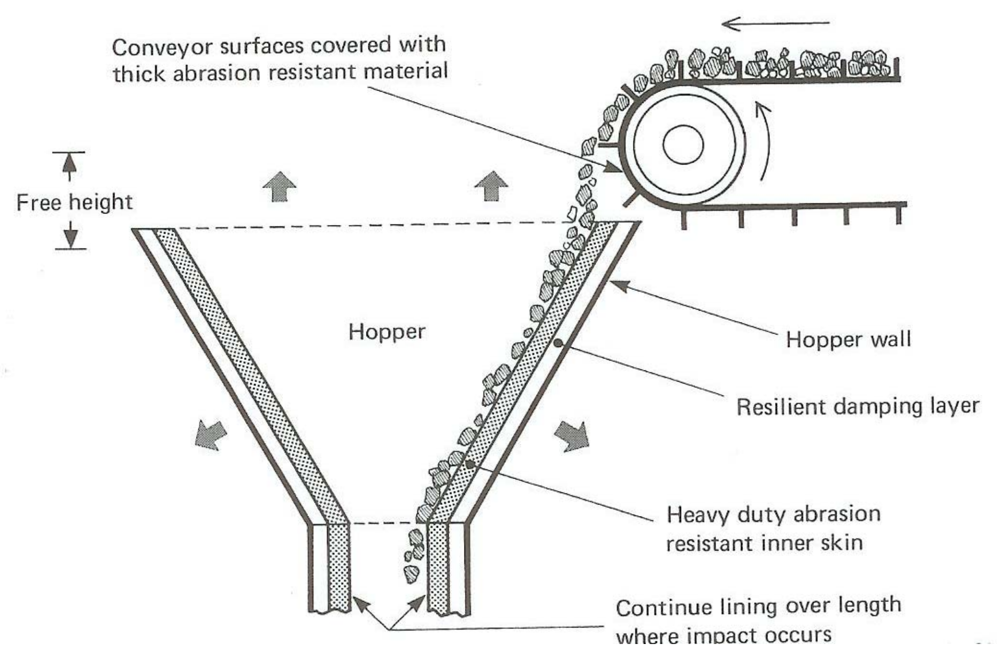


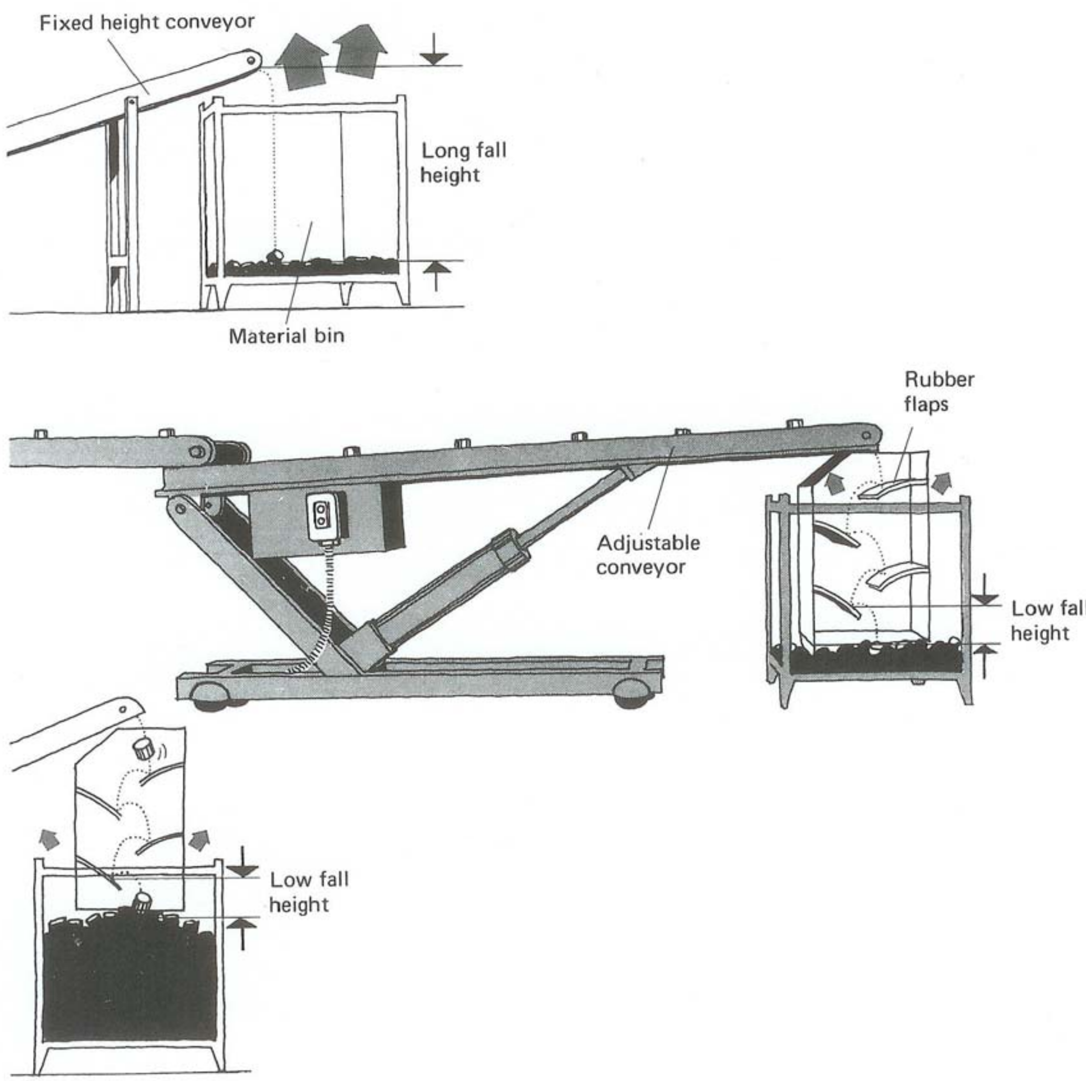
Steel
Thin damping layer
Steel
Hardboard
Porous fibreboard
Hardboard
Thick damping layer
Steel
Spray-on damping layer
Steel

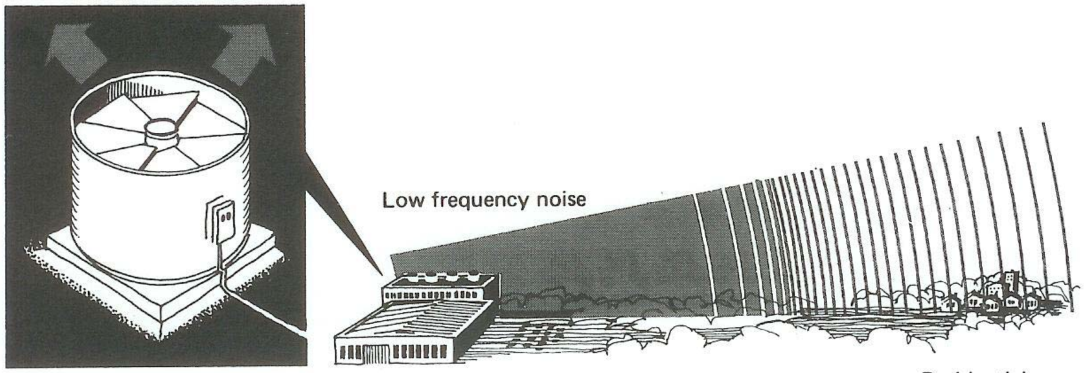

Resonance
in saw blade
Rubber
Stiffened
disc
Stiffening
webs


High noise level
Damping panel
Noise Level
Resonances
Overall noise level
Frequency


Free
height
Hopper

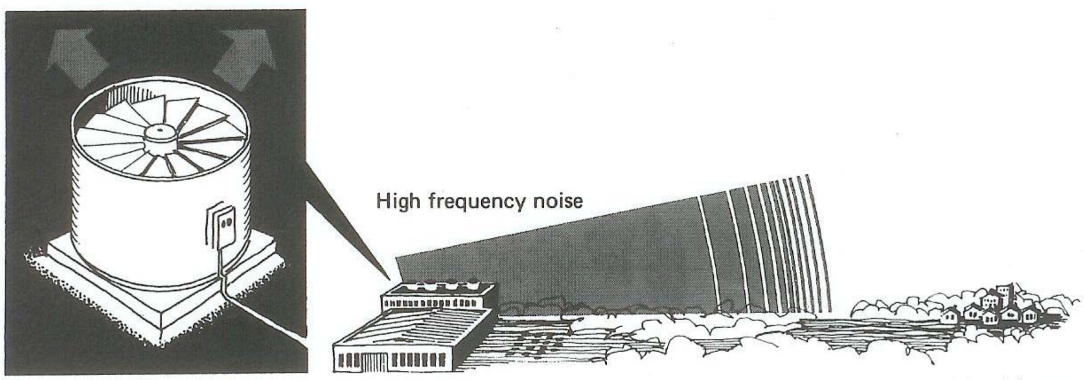

Conveyor surfaces covered with
thick abrasion resistant material
Free height
Hopper
Hopper wall
Resilient damping layer
Heavy duty abrasion
resistant inner skin
Continue lining over length
where impact occurs


Fixed height conveyor
Long fall
height
Material bin
Rubber
flaps
Adjustable
conveyor
Low fall
height
Low fall
height



Fan with few blades

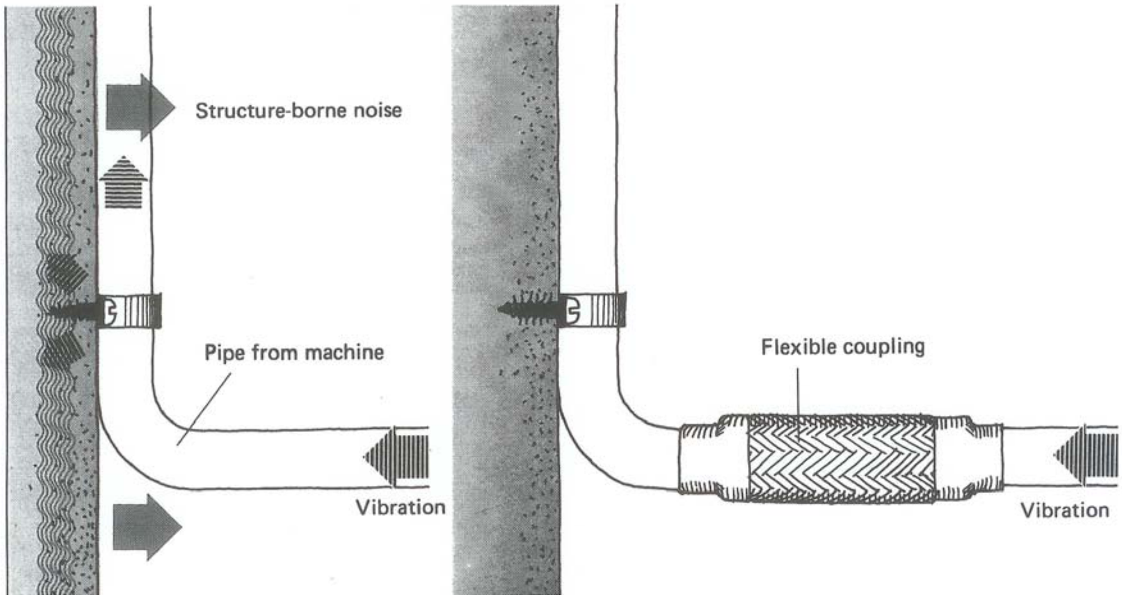
Residential area

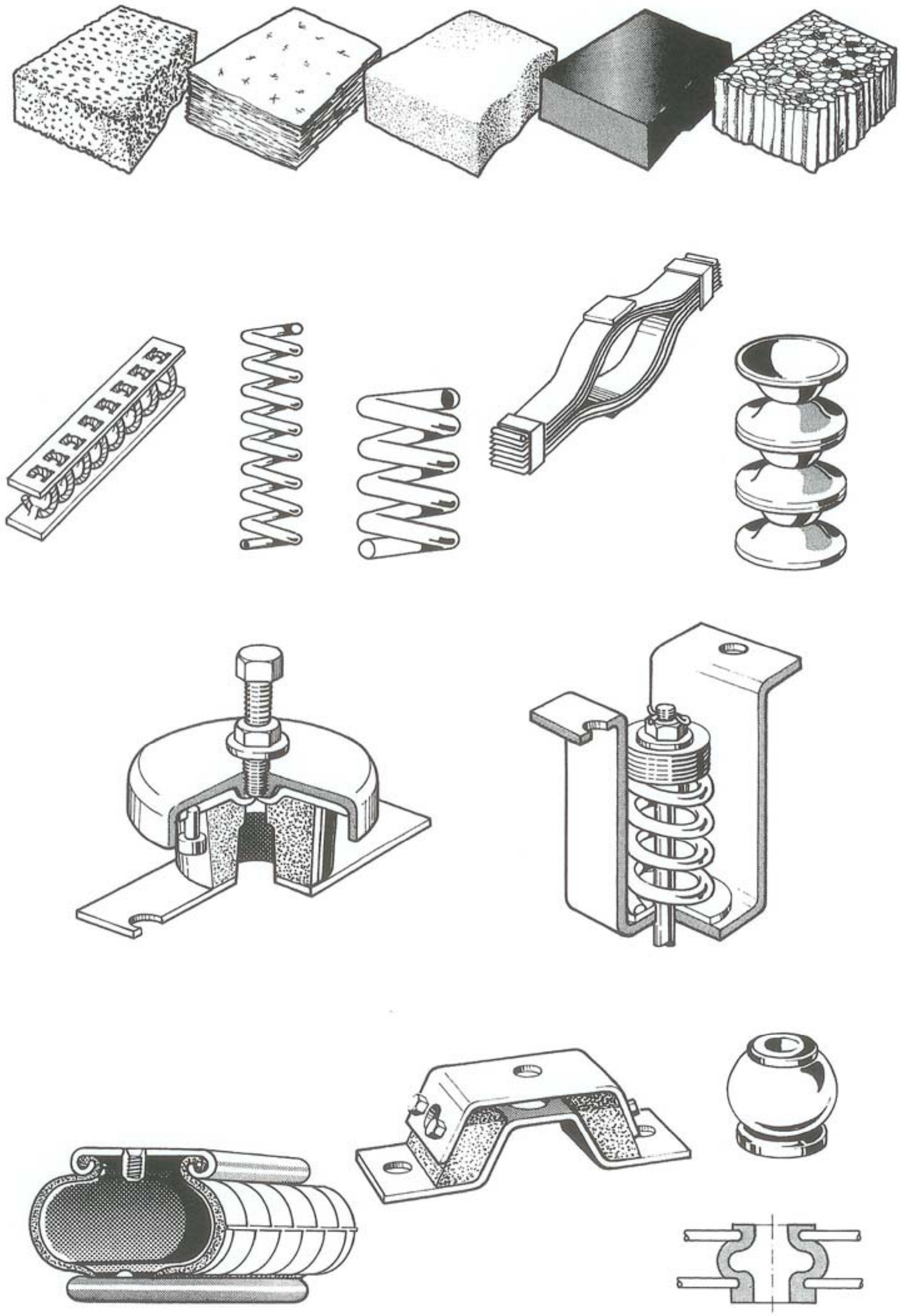


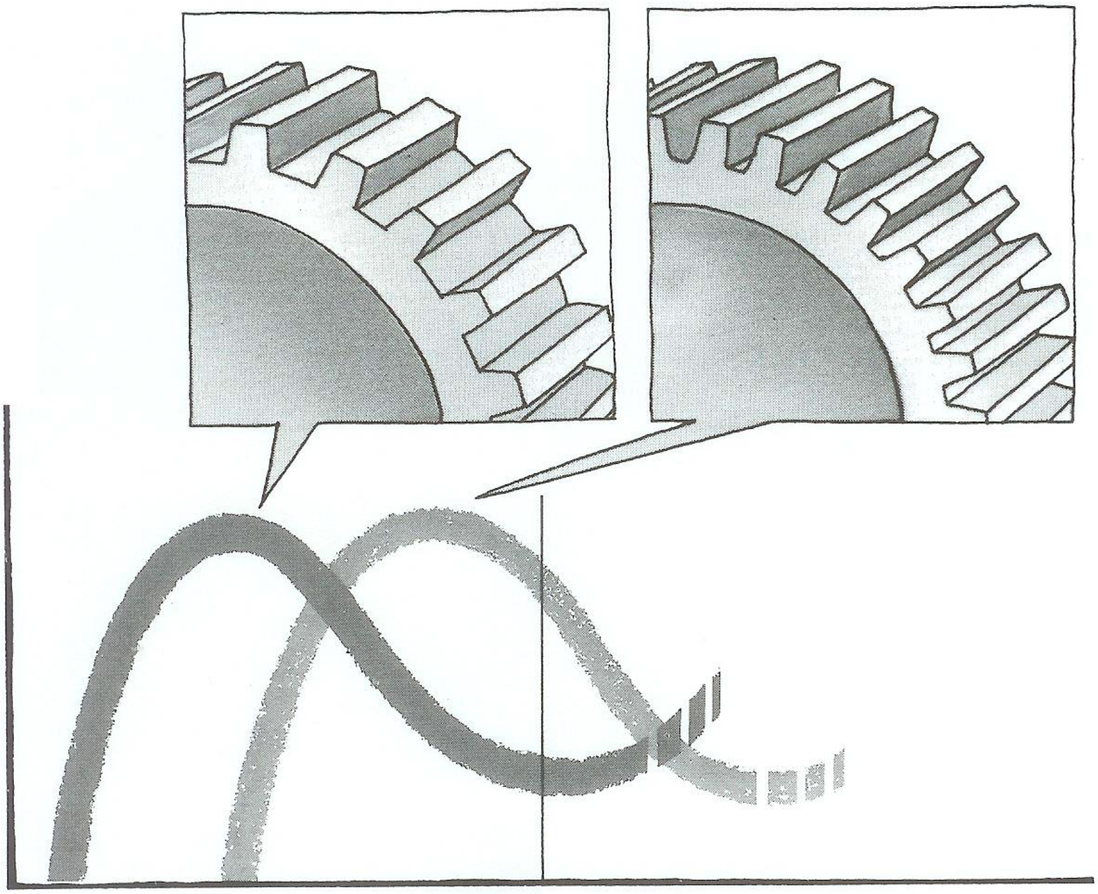
Fan with many blades

Residential area

Principle

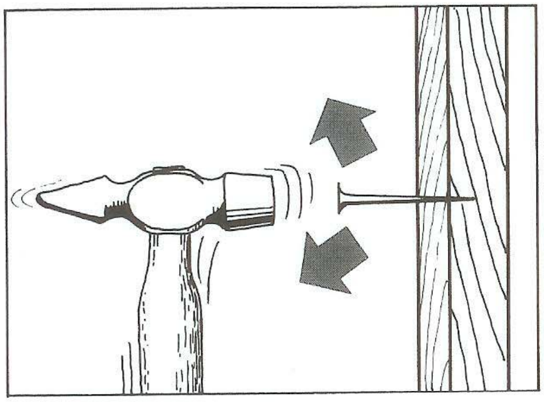

Structure-borne noise
Pipe from machine
Vibration
Flexible coupling
Vibration



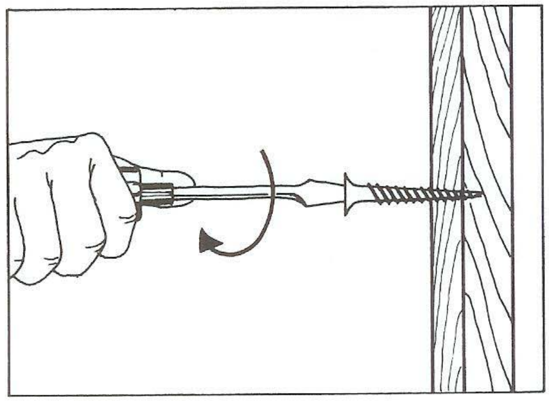


Two panels can be fixed together

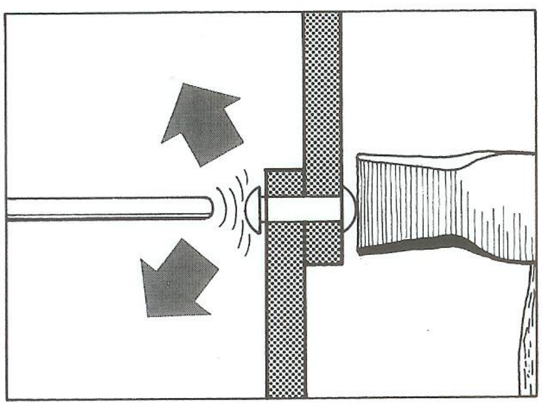
using nails — **noisy**



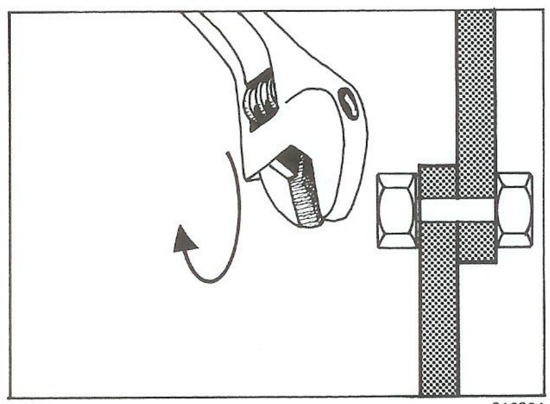
or screws — **quiet**

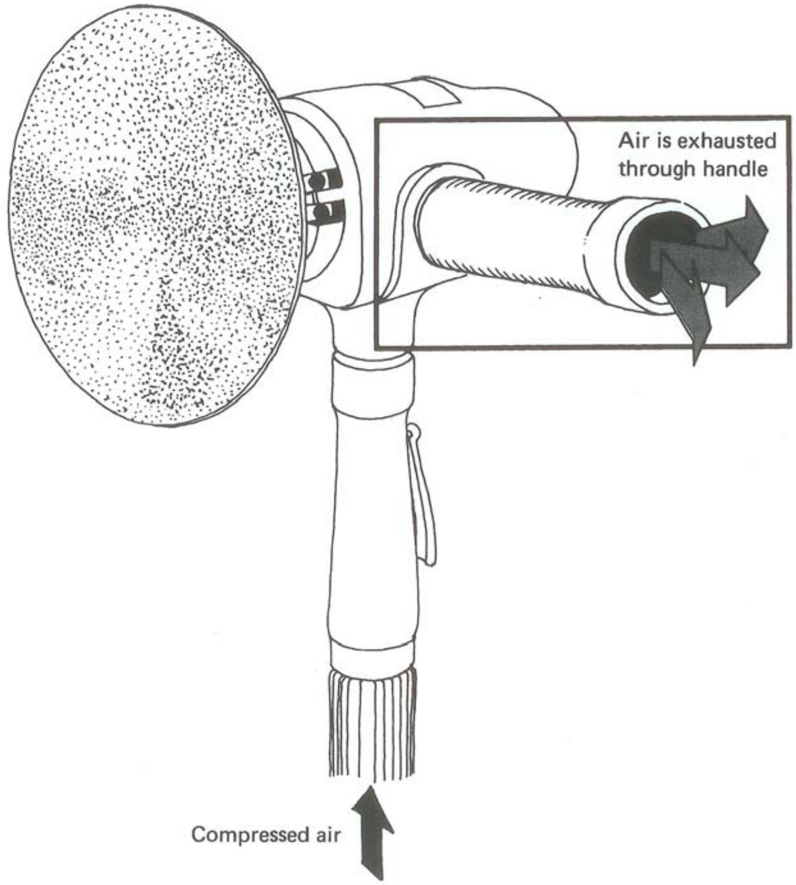


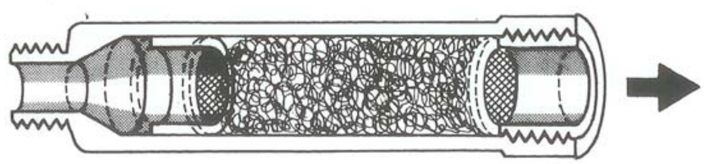
Steel sheet may be rivetted
Very noisy

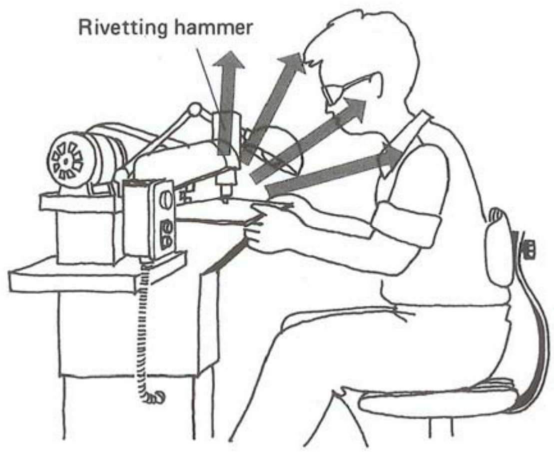


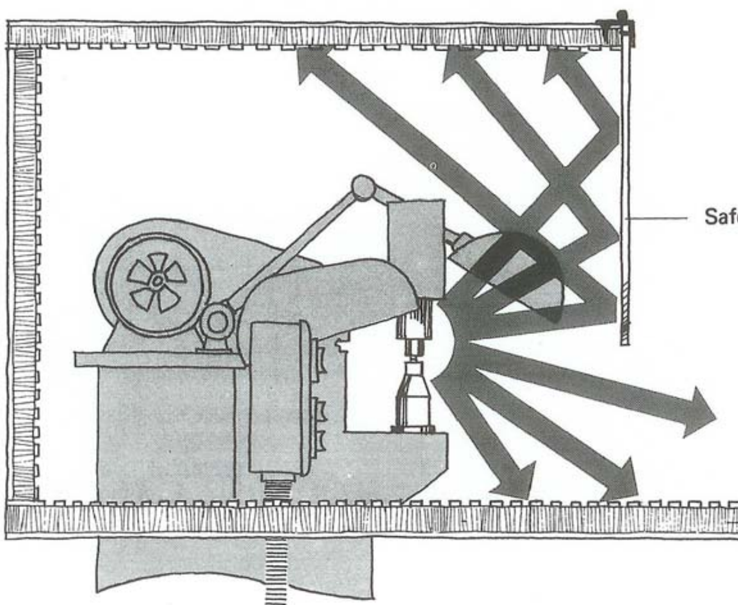
or bolted — **very quiet**




Air is exhausted through handle
Compressed air




Rivetting hammer


Safety glass
Enclosure with sound absorbent lining

Workshop: Fundamental concepts of noise control

Workshop A: Noise control demonstration

OBJECTIVE: To use the noise control demonstration kit to reinforce basic ideas of noise control.

SETUP: Use the noise control demonstration kit to observe:

a. The effect of barrier material
b. The effect of partial and total enclosures
c. The effect of sound absorption material on noise control
d. The effect of short-circuiting on noise control

Absorber only partial	__________	
Absorber only total	__________	
Barrier only partial	__________	__________
Barrier only total	__________	__________
Barrier/absorber total	__________	
Rubber band on bell	__________	
Rubber mount on barrier/absorber		__________

Audiograms

What is an audiogram?
An audiogram is a chart or graph that shows the softest sounds your ear can hear at different frequencies or pitches. These sounds are called **thresholds**. The audiologist marks on a graph your threshold at different pitches.

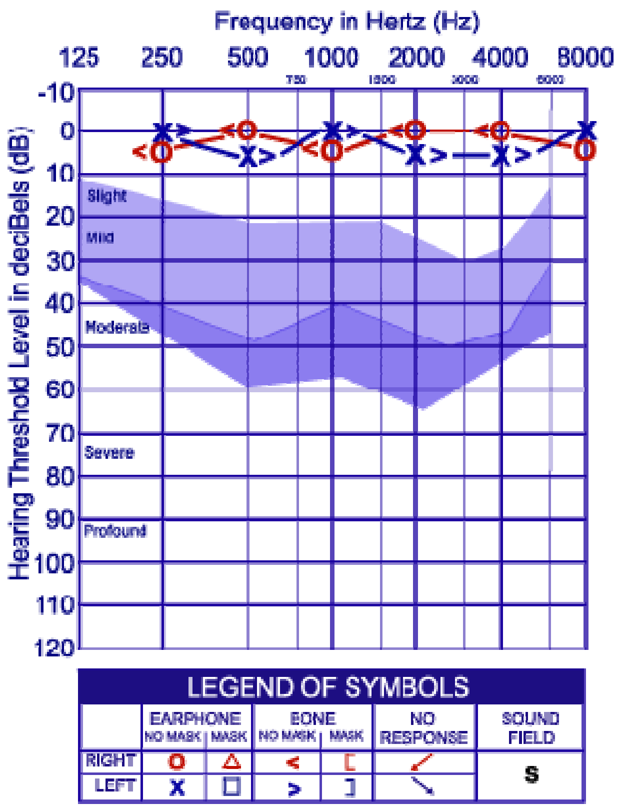


Image courtesy of EDEN - The Electronic Deaf Education Network

This is an audiogram of normal hearing. The red and blue marks show the softest sounds this person could hear in her right (red) and left (blue) ears. The shaded areas show the range of speech sounds. This is called the "speech banana."

This person can hear sounds even softer than the speech sounds. But if a person can't hear sounds in the area of the speech banana, they will have trouble understanding what people say.

How to read an audiogram

<u>From left to right – frequency</u>

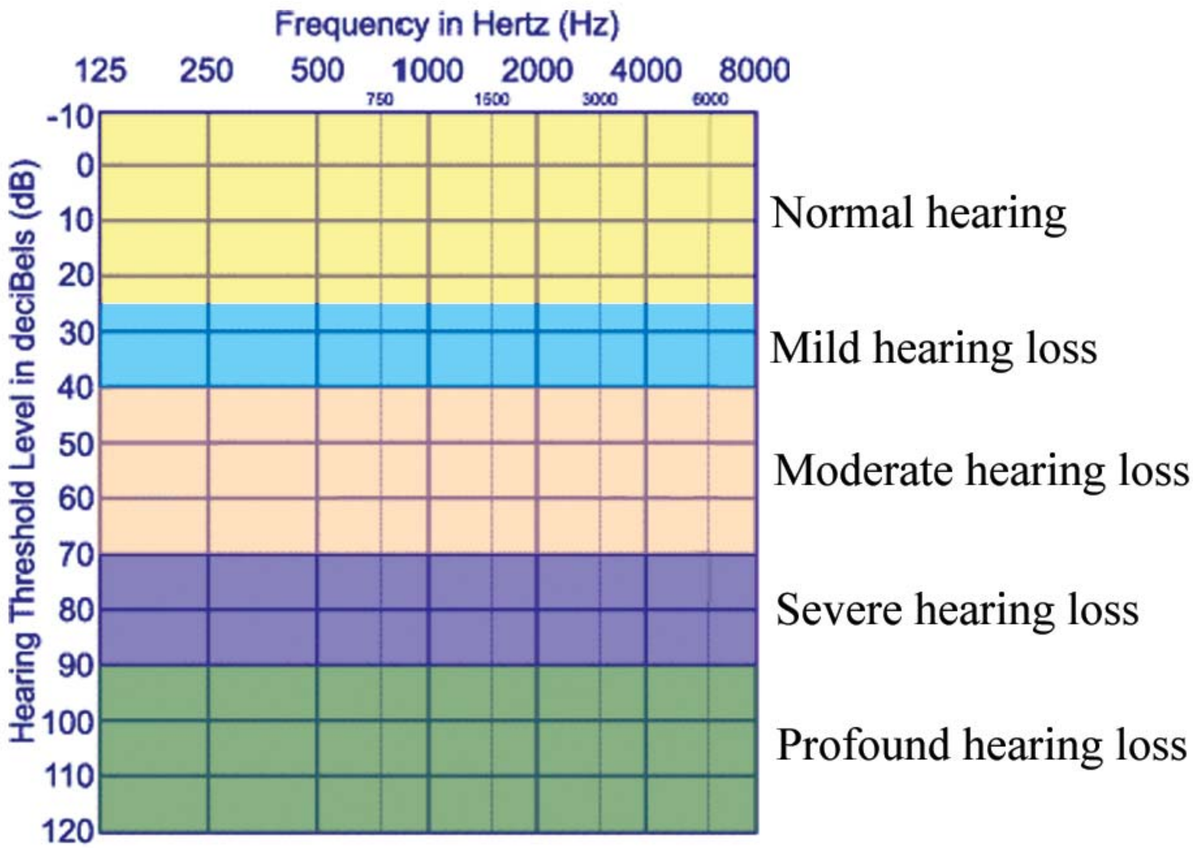
- **Frequency** refers to how high or low-pitched a sound is.
- Frequency is measured in **Hertz (Hz)**.
- Low-pitched sounds are towards the left of the audiogram.
  Vowels like "a," e" and "i" are examples of low-pitched sounds.

- High-pitched sounds are towards the right of the audiogram.
  Sounds like "th," "f" and "s" are examples of high-pitched sounds.

<u>From top to bottom – hearing threshold (loudness)</u>

- The loudness of a sound is measured in **decibels (dB)**.
- Loud sounds are towards the bottom of the audiogram.
- Quiet sounds are towards the top of the audiogram.
- The range of speech sounds are shown in the shaded area.
- About half of spoken sounds are above the darker area.

When you have a hearing loss, you may not hear some sounds because they are too soft, or the pitch is too high or low. Read more about this on our page about the sounds we hear.



Audiograms of different kinds of hearing loss

- Mild to moderate conductive hearing loss in the right ear
- Bilateral mild to moderate sensorineural hearing loss
- Bilateral mild sloping to profound sensorineural hearing loss
- Bilateral mild precipitously sloping to profound hearing loss
- Bilateral profound sensorineural hearing loss

Mild to Moderate Conductive Hearing Loss in the Right Ear

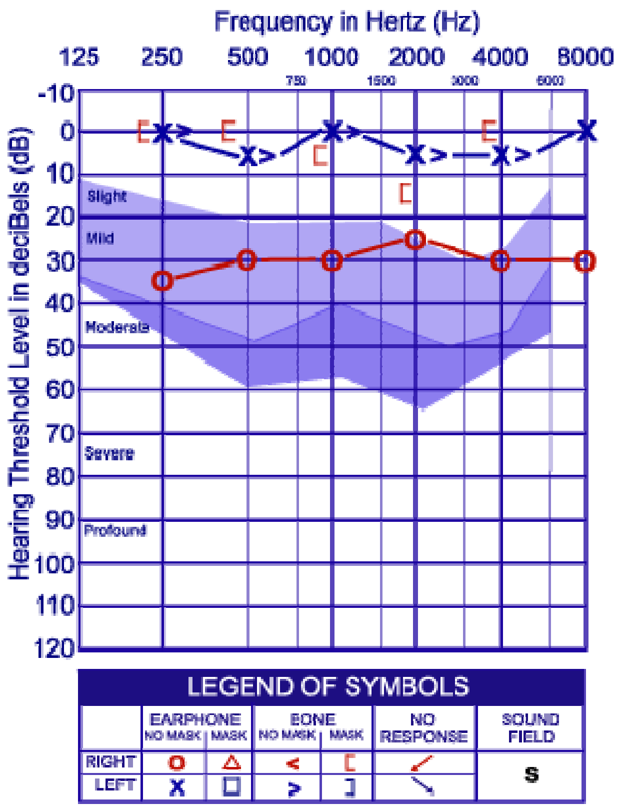


Image courtesy of EDEN - The Electronic Deaf Education Network

This audiogram shows a **mild to moderate conductive hearing loss**.

- **Mild to moderate** means that the hearing loss can range from 25dB to 70dB. This means that the quietest sounds the child can hear range between 25 and 70 dB.
- **Conductive hearing** loss is when sound can't reach the inner ear. If bone conduction thresholds are higher than air conduction thresholds, this could mean that something is not working right in the middle or outer ear.
- One of the most common causes for conductive hearing loss is liquid behind the eardrum. This is often caused by ear infections.

Bilateral Mild to Moderate Sensorineural Hearing Loss

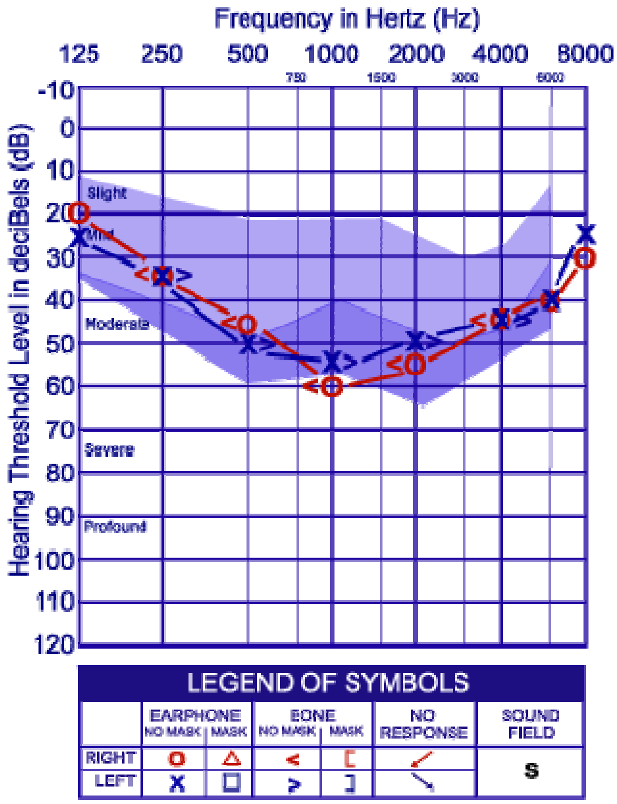


Image courtesy of EDEN - The Electronic Deaf Education Network

This audiogram shows a **bilateral mild to moderate sensorineural hearing loss**.

- **Bilateral** means that both ears have a hearing loss.
- **Mild to moderate** means that the hearing loss can range from 25dB to 70dB. This means that the quietest sounds a person can hear range between 25 and 70 dB.
- **Sensorineural hearing loss** is when the cochlea or auditory nerve isn't working correctly. If the air and bone conduction thresholds are about the same, then you could have a sensorineural hearing loss.

The hearing loss in the picture is also called a "Cookie-Bite" hearing loss. This kind of hearing loss has the worst hearing loss in the middle frequencies. Many children with hearing loss from birth (or congenital hearing loss) have this kind of hearing loss.

A person with this much hearing loss will need to use hearing aids as well as listening assistance devices to hear what people are saying.

Bilateral Mild Sloping to Profound Sensorineural Hearing Loss

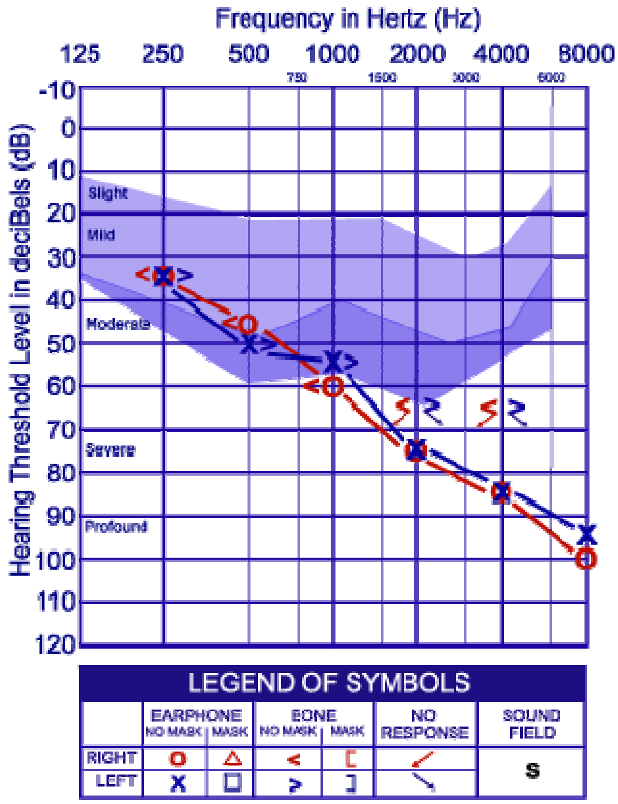


Image courtesy of EDEN - The Electronic Deaf Education Network

This audiogram shows a **bilateral mild sloping to profound sensorineural hearing loss**.

- **Bilateral** means that both ears have a hearing loss.
- **Mild sloping to profound** means the hearing loss is mild for the lower frequencies, but profound for the higher frequencies.
- **Sensorineural** means that the cochlea or auditory nerve isn't working correctly.

This kind of hearing is most often seen in older adults, but is also seen in children.

Because of the very severe hearing loss at the highest frequencies, this person may not be able to hear some speech sounds at all.

A person with this amount of hearing loss will need to use hearing aids as well as other listening assistance devices to hear what people are saying.

Bilateral Mild Precipitously Sloping to Profound Hearing Loss

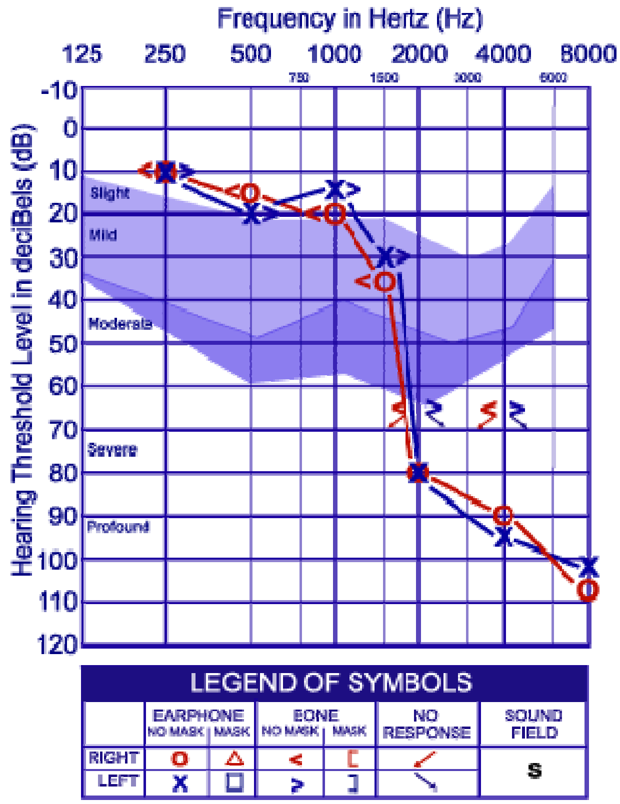


Image courtesy of EDEN - The Electronic Deaf Education Network

This audiogram shows a **bilateral mild precipitously sloping to profound hearing loss**.

- **Bilateral** means that both ears have a hearing loss.
- **Mild precipitously sloping to profound** means that hearing loss is mild for the lower frequencies, but it suddenly gets a lot worse for the higher frequencies.
- **Sensorineural** means that the cochlea or auditory nerve isn't working correctly.

This kind of hearing loss is also called "Ski Slope Loss." Individuals with this kind of hearing loss can work just fine in quiet rooms. But they may have a lot more trouble working in big or noisy rooms.

A person with this amount of hearing loss will need to use hearing aids as well as other listening assistance devices to hear what people are saying. They may also need special ear mold add-ons or changes, like the Libby Horn or the Continuous Flow Adapter (CFA) to make these sounds accessible to them.

Bilateral Profound Sensorineural Hearing Loss

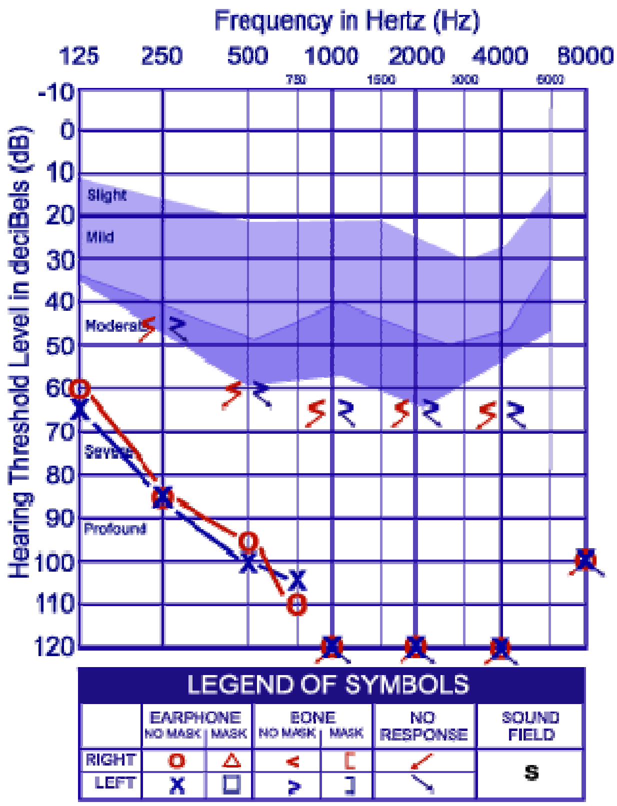


Image courtesy of [EDEN - The Electronic Deaf Education Network]

This audiogram shows a **bilateral profound sensorineural hearing loss**.

- **Bilateral** means that both ears have a hearing loss.
- **Profound** means that the hearing loss is 90dB or greater. This means that the affected individual may not be able to hear anything softer than 90dB.
- **Sensorineural** means that the cochlea or auditory nerve isn't working correctly.

This kind of hearing loss is sometimes called a "Left Corner" audiogram.

A person with this much hearing loss may not be able to hear much, even with hearing aids. Therefore, they may not be able to learn to speak through hearing alone. They may benefit from using sign language and by reading lips. They may also be a candidate for a cochlear implant.

6

HEARING CONSERVATION

Purpose: To protect employees from effects of hazardous noise.

OSHA Standards
- 29 CFR 1910.95 (General Industry)
- 29 CFR 1926.52 (Construction)

Workplace Monitoring

- **85 decibels A-weighting (dBA) or greater**
    - Time Weighted Average (TWA) for work shift
    - Implement a hearing conservation program (General industry only. Construction action level is 90 dBA)
    - Conduct baseline and annual audiometric tests

- **Above 90 dBA**
    - Time Weighted Average (TWA) for work shift
    - Hearing protection is mandatory

Recordkeeping
- Workplace noise measurements: 2 years
- Audiometric records: duration of employment

Employee Training
- Conducted annually
- Effects of hazardous noise
- Purpose of hearing protectors, advantages and disadvantages of various types
- Instructions of selection, fitting, use and care

Source of Additional Help

"Hearing Conservation" booklet (OSHA Publication)

http://www.osha.gov/Publications/osha3074.pdf

Regulations (Standards - 29 CFR)

Occupational noise exposure. - 1910.95

Regulations (Standards - 29 CFR) - Table of Contents

- **Part Number:** 1910
- **Part Title:** Occupational Safety and Health Standards
- **Subpart:** G
- **Subpart Title:** Occupational Health and Environment Control
- **Standard Number:** 1910.95
- **Title:** Occupational noise exposure.

- **Appendix:** A , B , C , D , E , F , G , H , I

1910.95(a)

Protection against the effects of noise exposure shall be provided when the sound levels exceed those shown in Table G-16 when measured on the A scale of a standard sound level meter at slow response. When noise levels are determined by octave band analysis, the equivalent A-weighted sound level may be determined as follows:

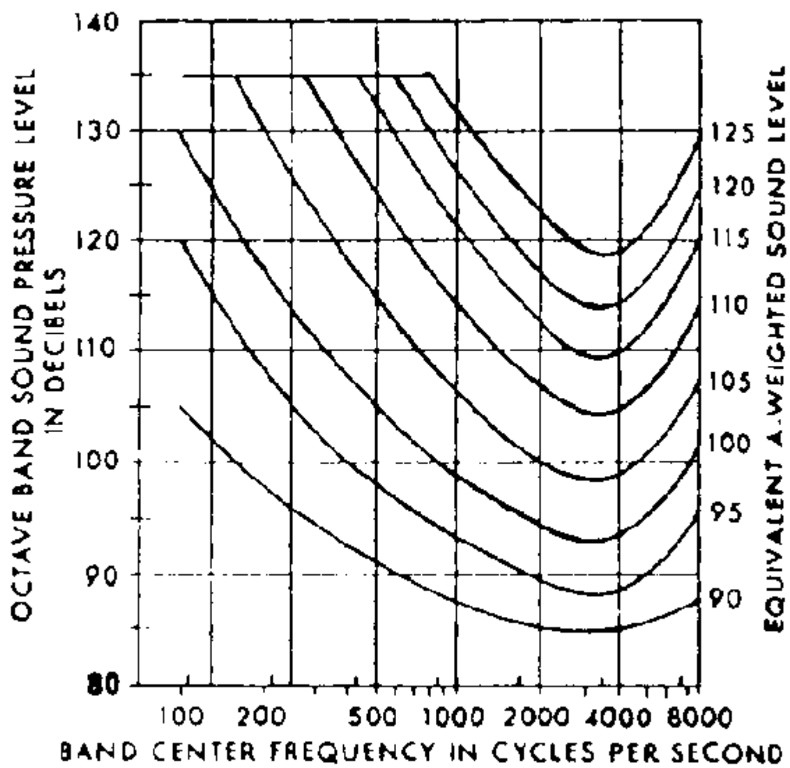


FIGURE G-9

FIGURE G-9 - Equivalent A-Weighted Sound Level

Equivalent sound level contours. Octave band sound pressure levels may be converted to the equivalent A-weighted sound level by plotting them on this graph and noting the A-weighted sound level corresponding to the point of highest penetration into the sound level contours. This equivalent A-weighted sound level, which may differ from the actual A-weighted sound level of the noise, is used to determine exposure limits from Table 1.G-16.

1910.95(b)

1910.95(b)(1)

When employees are subjected to sound exceeding those listed in Table G-16, feasible administrative or engineering controls shall be utilized. If such controls fail to reduce sound levels within the levels of Table G-16, personal protective equipment shall be provided and used to reduce sound levels within the levels of the table.

1910.95(b)(2)

If the variations in noise level involve maxima at intervals of one second or less, it is to be considered continuous.

TABLE G-16 - PERMISSIBLE NOISE EXPOSURES (1)

Duration per day, hours	Sound level dBA slow response
8	90
6	92
4	95
3	97
2	100
1 1/2	102
1	105
1/2	110
1/4 or less	115

Footnote(1) When the daily noise exposure is composed of two or more periods of noise exposure of different levels, their combined effect should be considered, rather than the individual effect of each. If the sum of the following fractions: C(1)/T(1) + C(2)/T(2) C(n)/T(n) exceeds unity, then, the mixed exposure should be considered to exceed the limit value. Cn indicates the total time of exposure at a specified noise level, and Tn indicates the total time of exposure permitted at that level. Exposure to impulsive or impact noise should not exceed 140 dB peak sound pressure level.

1910.95(c)

"Hearing conservation program."

1910.95(c)(1)

The employer shall administer a continuing, effective hearing conservation program, as described in paragraphs (c) through (o) of this section, whenever employee noise exposures equal or exceed an 8-hour time-weighted average sound level (TWA) of 85 decibels measured on the A scale (slow response) or, equivalently, a dose of fifty percent. For purposes of the hearing conservation program, employee noise exposures shall be computed in accordance with appendix A and Table G-16a, and without regard to any attenuation provided by the use of personal protective equipment.

1910.95(c)(2)

For purposes of paragraphs (c) through (n) of this section, an 8-hour time-weighted average of 85 decibels or a dose of fifty percent shall also be referred to as the action level.

1910.95(d)

"Monitoring."

1910.95(d)(1)

When information indicates that any employee's exposure may equal or exceed an 8-hour time-weighted average of 85 decibels, the employer shall develop and implement a monitoring program.

1910.95(d)(1)(i)

The sampling strategy shall be designed to identify employees for inclusion in the hearing conservation program and to enable the proper selection of hearing protectors.

1910.95(d)(1)(ii)

Where circumstances such as high worker mobility, significant variations in sound level, or a significant component of impulse noise make area monitoring generally inappropriate, the employer shall use representative personal sampling to comply with the monitoring requirements of this paragraph unless the employer can show that area sampling produces equivalent results.

1910.95(d)(2)

1910.95(d)(2)(i)

All continuous, intermittent and impulsive sound levels from 80 decibels to 130 decibels shall be integrated into the noise measurements.

1910.95(d)(2)(ii)

Instruments used to measure employee noise exposure shall be calibrated to ensure measurement accuracy.

1910.95(d)(3)

Monitoring shall be repeated whenever a change in production, process, equipment or controls increases noise exposures to the extent that:

1910.95(d)(3)(i)

Additional employees may be exposed at or above the action level; or

1910.95(d)(3)(ii)

The attenuation provided by hearing protectors being used by employees may be rendered inadequate to meet the requirements of paragraph (j) of this section.

1910.95(e)

"Employee notification." The employer shall notify each employee exposed at or above an 8-hour time-weighted average of 85 decibels of the results of the monitoring.

1910.95(f)

"Observation of monitoring." The employer shall provide affected employees or their representatives with an opportunity to observe any noise measurements conducted pursuant to this section.

1910.95(g)

"Audiometric testing program."

1910.95(g)(1)

The employer shall establish and maintain an audiometric testing program as provided in this paragraph by making audiometric testing available to all employees whose exposures equal or exceed an 8-hour time-weighted average of 85 decibels.

1910.95(g)(2)

The program shall be provided at no cost to employees.

1910.95(g)(3)

Audiometric tests shall be performed by a licensed or certified audiologist, otolaryngologist, or other physician, or by a technician who is certified by the Council of Accreditation in Occupational Hearing Conservation, or who has satisfactorily demonstrated competence in administering audiometric examinations, obtaining valid audiograms, and properly using, maintaining and checking calibration and proper functioning of the audiometers being used. A technician who operates microprocessor audiometers does not need to be certified. A technician who performs audiometric tests must be responsible to an audiologist, otolaryngologist or physician.

1910.95(g)(4)

All audiograms obtained pursuant to this section shall meet the requirements of Appendix C: "Audiometric Measuring Instruments."

1910.95(g)(5)

"Baseline audiogram."

1910.95(g)(5)(i)

Within 6 months of an employee's first exposure at or above the action level, the employer shall establish a valid baseline audiogram against which subsequent audiograms can be compared.

1910.95(g)(5)(ii)

"Mobile test van exception." Where mobile test vans are used to meet the audiometric testing obligation, the employer shall obtain a valid baseline audiogram within one year of an employee's first exposure at or above the action level. Where baseline audiograms are obtained more than six months after the employee's first exposure at or above the action level, employees shall wear hearing protectors for any period exceeding six months after first exposure until the baseline audiogram is obtained.

1910.95(g)(5)(iii)

Testing to establish a baseline audiogram shall be preceded by at least 14 hours without exposure to workplace noise. Hearing protectors may be used as a substitute for the requirement that baseline audiograms be preceded by 14 hours without exposure to workplace noise.

1910.95(g)(5)(iv)

The employer shall notify employees of the need to avoid high levels of non-occupational noise exposure during the 14-hour period immediately preceding the audiometric examination.

1910.95(g)(6)

"Annual audiogram." At least annually after obtaining the baseline audiogram, the employer shall obtain a new audiogram for each employee exposed at or above an 8-hour time-weighted average of 85 decibels.

1910.95(g)(7)

"Evaluation of audiogram."

1910.95(g)(7)(i)

Each employee's annual audiogram shall be compared to that employee's baseline audiogram to determine if the audiogram is valid and if a standard threshold shift as defined in paragraph (g)(10) of this section, has occurred. This comparison may be done by a technician.

1910.95(g)(7)(ii)

If the annual audiogram shows that an employee has suffered a standard threshold shift, the employer may obtain a retest within thirty days and consider the results of the retest as the annual audiogram.

1910.95(g)(7)(iii)

The audiologist, otolaryngologist, or physician shall review problem audiograms and shall determine whether there is a need for further evaluation. The employer shall provide to the person performing this evaluation the following information:

1910.95(g)(7)(iii)(A)

A copy of the requirements for hearing conservation as set forth in paragraphs (c) through (n) of this section;

1910.95(g)(7)(iii)(B)

The baseline audiogram and most recent audiogram of the employee to be evaluated;

1910.95(g)(7)(iii)(C)

Measurements of background sound pressure levels in the audiometric test room as required in Appendix D: Audiometric Test Rooms.

1910.95(g)(7)(iii)(D)

Records of audiometer calibrations required by paragraph (h)(5) of this section.

1910.95(g)(8)

"Follow-up procedures."

1910.95(g)(8)(i)

If a comparison of the annual audiogram to the baseline audiogram indicates a standard threshold shift as defined in paragraph (g)(10) of this section has occurred, the employee shall be informed of this fact in writing, within 21 days of the determination.

1910.95(g)(8)(ii)

Unless a physician determines that the standard threshold shift is not work related or aggravated by occupational noise exposure, the employer shall ensure that the following steps are taken when a standard threshold shift occurs:

1910.95(g)(8)(ii)(A)

Employees not using hearing protectors shall be fitted with hearing protectors, trained in their use and care, and required to use them.

1910.95(g)(8)(ii)(B)

Employees already using hearing protectors shall be refitted and retrained in the use of hearing protectors and provided with hearing protectors offering greater attenuation if necessary.

1910.95(g)(8)(ii)(C)

The employee shall be referred for a clinical audiological evaluation or an otological examination, as appropriate, if additional testing is necessary or if the employer suspects that a medical pathology of the ear is caused or aggravated by the wearing of hearing protectors.

1910.95(g)(8)(ii)(D)

The employee is informed of the need for an otological examination if a medical pathology of the ear that is unrelated to the use of hearing protectors is suspected.

1910.95(g)(8)(iii)

If subsequent audiometric testing of an employee whose exposure to noise is less than an 8-hour TWA of 90 decibels indicates that a standard threshold shift is not persistent, the employer:

1910.95(g)(8)(iii)(A)

Shall inform the employee of the new audiometric interpretation; and

1910.95(g)(8)(iii)(B)

May discontinue the required use of hearing protectors for that employee.

1910.95(g)(9)

"Revised baseline." An annual audiogram may be substituted for the baseline audiogram when, in the judgment of the audiologist, otolaryngologist or physician who is evaluating the audiogram:

1910.95(g)(9)(i)

The standard threshold shift revealed by the audiogram is persistent; or

1910.95(g)(9)(ii)

The hearing threshold shown in the annual audiogram indicates significant improvement over the baseline audiogram.

1910.95(g)(10)

"Standard threshold shift."

1910.95(g)(10)(i)

As used in this section, a standard threshold shift is a change in hearing threshold relative to the baseline audiogram of an average of 10 dB or more at 2000, 3000, and 4000 Hz in either ear.

1910.95(g)(10)(ii)

In determining whether a standard threshold shift has occurred, allowance may be made for the contribution of aging (presbycusis) to the change in hearing level by correcting the annual audiogram according to the procedure described in Appendix F: "Calculation and Application of Age Correction to Audiograms."

1910.95(h)

"Audiometric test requirements."

1910.95(h)(1)

Audiometric tests shall be pure tone, air conduction, hearing threshold examinations, with test frequencies including as a minimum 500, 1000, 2000, 3000, 4000, and 6000 Hz. Tests at each frequency shall be taken separately for each ear.

1910.95(h)(2)

Audiometric tests shall be conducted with audiometers (including microprocessor audiometers) that meet the specifications of, and are maintained and used in accordance with, American National Standard Specification for Audiometers, S3.6-1969, which is incorporated by reference as specified in Sec. 1910.6.

1910.95(h)(3)

Pulsed-tone and self-recording audiometers, if used, shall meet the requirements specified in Appendix C: "Audiometric Measuring Instruments."

1910.95(h)(4)

Audiometric examinations shall be administered in a room meeting the requirements listed in Appendix D: "Audiometric Test Rooms."

1910.95(h)(5)

"Audiometer calibration."

1910.95(h)(5)(i)

The functional operation of the audiometer shall be checked before each day's use by testing a person with known, stable hearing thresholds, and by listening to the audiometer's output to make sure that the output is free from distorted or unwanted sounds. Deviations of 10 decibels or greater require an acoustic calibration.

1910.95(h)(5)(ii)

Audiometer calibration shall be checked acoustically at least annually in accordance with Appendix E: "Acoustic Calibration of Audiometers." Test frequencies below 500 Hz and above 6000 Hz may be omitted from this check. Deviations of 15 decibels or greater require an exhaustive calibration.

1910.95(h)(5)(iii)

An exhaustive calibration shall be performed at least every two years in accordance with sections 4.1.2; 4.1.3.; 4.1.4.3; 4.2; 4.4.1; 4.4.2; 4.4.3; and 4.5 of the American National Standard Specification for Audiometers, S3.6-1969. Test frequencies below 500 Hz and above 6000 Hz may be omitted from this calibration.

1910.95(i)

"Hearing protectors."

1910.95(i)(1)

Employers shall make hearing protectors available to all employees exposed to an 8-hour time-weighted average of 85 decibels or greater at no cost to the employees. Hearing protectors shall be replaced as necessary.

1910.95(i)(2)

Employers shall ensure that hearing protectors are worn:

1910.95(i)(2)(i)

By an employee who is required by paragraph (b)(1) of this section to wear personal protective equipment; and

1910.95(i)(2)(ii)

By any employee who is exposed to an 8-hour time-weighted average of 85 decibels or greater, and who:

1910.95(i)(2)(ii)(A)

Has not yet had a baseline audiogram established pursuant to paragraph (g)(5)(ii); or

1910.95(i)(2)(ii)(B)

Has experienced a standard threshold shift.

1910.95(i)(3)

Employees shall be given the opportunity to select their hearing protectors from a variety of suitable hearing protectors provided by the employer.

1910.95(i)(4)

The employer shall provide training in the use and care of all hearing protectors provided to employees.

1910.95(i)(5)

The employer shall ensure proper initial fitting and supervise the correct use of all hearing protectors.

1910.95(j)

"Hearing protector attenuation."

1910.95(j)(1)

The employer shall evaluate hearing protector attenuation for the specific noise environments in which the protector will be used. The employer shall use one of the evaluation methods described in Appendix B: "Methods for Estimating the Adequacy of Hearing Protection Attenuation."

1910.95(j)(2)

Hearing protectors must attenuate employee exposure at least to an 8-hour time-weighted average of 90 decibels as required by paragraph (b) of this section.

1910.95(j)(3)

For employees who have experienced a standard threshold shift, hearing protectors must attenuate employee exposure to an 8-hour time-weighted average of 85 decibels or below.

1910.95(j)(4)

The adequacy of hearing protector attenuation shall be re-evaluated whenever employee noise exposures increase to the extent that the hearing protectors provided may no longer provide adequate attenuation. The employer shall provide more effective hearing protectors where necessary.

1910.95(k)

"Training program."

1910.95(k)(1)

The employer shall institute a training program for all employees who are exposed to noise at or above an 8-hour time-weighted average of 85 decibels, and shall ensure employee participation in such program.

1910.95(k)(2)

The training program shall be repeated annually for each employee included in the hearing conservation program. Information provided in the training program shall be updated to be consistent with changes in protective equipment and work processes.

1910.95(k)(3)

The employer shall ensure that each employee is informed of the following:

1910.95(k)(3)(i)

The effects of noise on hearing;

1910.95(k)(3)(ii)

The purpose of hearing protectors, the advantages, disadvantages, and attenuation of various types, and instructions on selection, fitting, use, and care; and

1910.95(k)(3)(iii)

The purpose of audiometric testing, and an explanation of the test procedures.

1910.95(l)

"Access to information and training materials."

1910.95(l)(1)

The employer shall make available to affected employees or their representatives, copies of this standard and shall also post a copy in the workplace.

1910.95(l)(2)

The employer shall provide to affected employees any informational materials pertaining to the standard that are supplied to the employer by the Assistant Secretary.

1910.95(l)(3)

The employer shall provide, upon request, all materials related to the employer's training and education program pertaining to this standard to the Assistant Secretary and the Director.

1910.95(m)

"Recordkeeping" -

1910.95(m)(1)

"Exposure measurements." The employer shall maintain an accurate record of all employee exposure measurements required by paragraph (d) of this section.

1910.95(m)(2)

"Audiometric tests."

1910.95(m)(2)(i)

The employer shall retain all employee audiometric test records obtained pursuant to paragraph (g) of this section:

1910.95(m)(2)(ii)

This record shall include:

1910.95(m)(2)(ii)(A)

Name and job classification of the employee;

1910.95(m)(2)(ii)(B)

Date of the audiogram;

1910.95(m)(2)(ii)(C)

The examiner's name;

1910.95(m)(2)(ii)(D)

Date of the last acoustic or exhaustive calibration of the audiometer; and

1910.95(m)(2)(ii)(E)

Employee's most recent noise exposure assessment.

1910.95(m)(2)(ii)(F)

The employer shall maintain accurate records of the measurements of the background sound pressure levels in audiometric test rooms.

1910.95(m)(3)

"Record retention." The employer shall retain records required in this paragraph (m) for at least the following periods.

1910.95(m)(3)(i)

Noise exposure measurement records shall be retained for two years.

1910.95(m)(3)(ii)

Audiometric test records shall be retained for the duration of the affected employee's employment.

1910.95(m)(4)

"Access to records." All records required by this section shall be provided upon request to employees, former employees, representatives designated by the individual employee, and the Assistant Secretary. The provisions of 29 CFR 1910.20 (a)-(e) and (g)-(i) apply to access to records under this section.

1910.95(m)(5)

"Transfer of records." If the employer ceases to do business, the employer shall transfer to the successor employer, all records required to be maintained by this section, and the successor employer shall retain them for the remainder of the period prescribed in paragraph (m)(3) of this section.

1910.95(n)

"Appendices."

1910.95(n)(1)

Appendices A, B, C, D, and E to this section are incorporated as part of this section and the contents of these appendices are mandatory.

1910.95(n)(2)

Appendices F and G to this section are informational and are not intended to create any additional obligations not otherwise imposed or to detract from any existing obligations.

1910.95(o)

"Exemptions." Paragraphs (c) through (n) of this section shall not apply to employers engaged in oil and gas well drilling and servicing operations.

1910.95(p)

"Startup date." Baseline audiograms required by paragraph (g) of this section shall be completed by March 1, 1984.

[39 FR 23502, June 27, 1974, as amended at 46 FR 4161, Jan. 16, 1981; 46 FR 62845, Dec. 29, 1981; 48 FR 9776, Mar. 8, 1983; 48 FR 29687, June 28, 1983; 54 FR 24333, June 7, 1989; 61 FR 5507, Feb. 13, 1996; 61 FR 9227, March 7, 1996]

Next Standard (1910.95 App A)

Regulations (Standards - 29 CFR)

Noise exposure computation - 1910.95 App A

Regulations (Standards - 29 CFR) - Table of Contents

- **Part Number:** 1910
- **Part Title:** Occupational Safety and Health Standards
- **Subpart:** G
- **Subpart Title:** Occupational Health and Environment Control
- **Standard Number:** 1910.95 App A
- **Title:** Noise exposure computation

This Appendix is Mandatory

I. Computation of Employee Noise Exposure

(1) Noise dose is computed using Table G-16a as follows:

(i) When the sound level, L, is constant over the entire work shift, the noise dose, D, in percent, is given by: D=100 C/T where C is the total length of the work day, in hours, and T is the reference duration corresponding to the measured sound level, L, as given in Table G-16a or by the formula shown as a footnote to that table.

(ii) When the workshift noise exposure is composed of two or more periods of noise at different levels, the total noise dose over the work day is given by:

$$D = 100\ (C(1)/T(1) + C(2)/T(2) + \ldots + C(n)/T(n)),$$

where C(n) indicates the total time of exposure at a specific noise level, and T(n) indicates the reference duration for that level as given by Table G-16a.

(2) The 8-hour time-weighted average sound level (TWA), in decibels, may be computed from the dose, in percent, by means of the formula: TWA = 16.61 log(10) (D/100) + 90. For an 8-hour workshift with the noise level constant over the entire shift, the TWA is equal to the measured sound level.

(3) A table relating dose and TWA is given in Section II.

TABLE G-16A

A-weighted sound level, L (decibel)	Reference duration, T (hour)
80	32
81	27.9
82	24.3
83	21.1
84	18.4
85	16
86	13.9
87	12.1
88	10.6
89	9.2
90	8

91	7.0
92	6.1
93	5.3
94	4.6
95	4
96	3.5
97	3.0
98	2.6
99	2.3
100	2
101	1.7
102	1.5
103	1.3
104	1.1
105	1
106	0.87
107	0.76
108	0.66
109	0.57
110	0.5
111	0.44
112	0.38
113	0.33
114	0.29
115	0.25
116	0.22
117	0.19
118	0.16
119	0.14
120	0.125
121	0.11
122	0.095
123	0.082
124	0.072
125	0.063
126	0.054
127	0.047
128	0.041
129	0.036
130	0.031

In the above table, the reference duration, T, is computed by

$$T = \frac{8}{2^{(L-90)/5}}$$

where L is the measured A-weighted sound level.

II. Conversion Between "Dose" and "8-Hour Time-Weighted Average" Sound Level

Compliance with paragraphs (c)-(r) of this regulation is determined by the amount of exposure to noise in the workplace. The amount of such exposure is usually measured with an audiodosimeter which gives a readout in terms of "dose." In order to better understand the requirements of the amendment, dosimeter readings can be converted to an "8-hour time-weighted average sound level." (TWA).

In order to convert the reading of a dosimeter into TWA, see Table A-1, below. This table applies to dosimeters that are set by the manufacturer to calculate dose or percent exposure according to the relationships in Table G-16a. So, for example, a dose of 91 percent over an eight hour day results in a TWA of 89.3 dB, and, a dose of 50 percent corresponds to a TWA of 85 dB.

If the dose as read on the dosimeter is less than or greater than the values found in Table A-1, the TWA may be calculated by using the formula: TWA = 16.61 log(10) (D/100) + 90 where TWA=8-hour time-weighted average sound level and D = accumulated dose in percent exposure.

TABLE A-1 - CONVERSION FROM "PERCENT NOISE EXPOSURE" OR "DOSE" TO "8-HOUR TIME-WEIGHTED AVERAGE SOUND LEVEL" (TWA)

Dose or percent noise exposure	TWA
10	73.4
15	76.3
20	78.4
25	80.0
30	81.3
35	82.4
40	83.4
45	84.2
50	85.0
55	85.7
60	86.3
65	86.9
70	87.4
75	87.9
80	88.4
81	88.5
82	88.6
83	88.7
84	88.7
85	88.8
86	88.9
87	89.0
88	89.1
89	89.2
90	89.2
91	89.3
92	89.4
93	89.5
94	89.6
95	89.6
96	89.7
97	89.8
98	89.9
99	89.9

100	90.0
101	90.1
102	90.1
103	90.2
104	90.3
105	90.4
106	90.4
107	90.5
108	90.6
109	90.6
110	90.7
111	90.8
112	90.8
113	90.9
114	90.9
115	91.1
116	91.1
117	91.1
118	91.2
119	91.3
120	91.3
125	91.6
130	91.9
135	92.2
140	92.4
145	92.7
150	92.9
155	93.2
160	93.4
165	93.6
170	93.8
175	94.0
180	94.2
185	94.4
190	94.6
195	94.8
200	95.0
210	95.4
220	95.7
230	96.0
240	96.3
250	96.6
260	96.9
270	97.2
280	97.4
290	97.7
300	97.9
310	98.2
320	98.4
330	98.6
340	98.8
350	99.0
360	99.2
370	99.4
380	99.6
390	99.8
400	100.0
410	100.2
420	100.4
430	100.5

440	100.7
450	100.8
460	101.0
470	101.2
480	101.3
490	101.5
500	101.6
510	101.8
520	101.9
530	102.0
540	102.2
550	102.3
560	102.4
570	102.6
580	102.7
590	102.8
600	102.9
610	103.0
620	103.2
630	103.3
640	103.4
650	103.5
660	103.6
670	103.7
680	103.8
690	103.9
700	104.0
710	104.1
720	104.2
730	104.3
740	104.4
750	104.5
760	104.6
770	104.7
780	104.8
790	104.9
800	105.0
810	105.1
820	105.2
830	105.3
840	105.4
850	105.4
860	105.5
870	105.6
880	105.7
890	105.8
900	105.8
910	105.9
920	106.0
930	106.1
940	106.2
950	106.2
960	106.3
970	106.4
980	106.5
990	106.5
999	106.6

Regulations (Standards - 29 CFR)

Methods for estimating the adequacy of hearing protector attenuation - 1910.95 App B

Regulations (Standards - 29 CFR) - Table of Contents

- **Part Number:** 1910
- **Part Title:** Occupational Safety and Health Standards
- **Subpart:** G
- **Subpart Title:** Occupational Health and Environment Control
- **Standard Number:** 1910.95 App B
- **Title:** Methods for estimating the adequacy of hearing protector attenuation

This Appendix is Mandatory

For employees who have experienced a significant threshold shift, hearing protector attenuation must be sufficient to reduce employee exposure to a TWA of 85 dB. Employers must select one of the following methods by which to estimate the adequacy of hearing protector attenuation.

The most convenient method is the Noise Reduction Rating (NRR) developed by the Environmental Protection Agency (EPA). According to EPA regulation, the NRR must be shown on the hearing protector package. The NRR is then related to an individual worker's noise environment in order to assess the adequacy of the attenuation of a given hearing protector. This appendix describes four methods of using the NRR to determine whether a particular hearing protector provides adequate protection within a given exposure environment. Selection among the four procedures is dependent upon the employer's noise measuring instruments.

Instead of using the NRR, employers may evaluate the adequacy of hearing protector attenuation by using one of the three methods developed by the National Institute for Occupational Safety and Health (NIOSH), which are described in the "List of Personal Hearing Protectors and Attenuation Data," HEW Publication No. 76-120, 1975, pages 21-37. These methods are known as NIOSH methods No. 1, No. 2 and No. 3. The NRR described below is a simplification of NIOSH method No. 2. The most complex method is NIOSH method No. 1, which is probably the most accurate method since it uses the largest amount of spectral information from the individual employee's noise environment. As in the case of the NRR method described below, if one of the NIOSH methods is used, the selected method must be applied to an individual's noise environment to assess the adequacy of the attenuation. Employers should be careful to take a sufficient number of measurements in order to achieve a representative sample for each time segment.

NOTE: The employer must remember that calculated attenuation values reflect realistic values only to the extent that the protectors are properly fitted and worn.

When using the NRR to assess hearing protector adequacy, one of the following methods must be used:

(i) When using a dosimeter that is capable of C-weighted measurements:

(A) Obtain the employee's C-weighted dose for the entire workshift, and convert to TWA (see appendix A, II).

(B) Subtract the NRR from the C-weighted TWA to obtain the estimated A-weighted TWA under the ear protector.

(ii) When using a dosimeter that is not capable of C-weighted measurements, the following method may be used:

(A) Convert the A-weighted dose to TWA (see appendix A).

(B) Subtract 7 dB from the NRR.

(C) Subtract the remainder from the A-weighted TWA to obtain the estimated A-weighted TWA under the ear protector.

(iii) When using a sound level meter set to the A-weighting network:

(A) Obtain the employee's A-weighted TWA.

(B) Subtract 7 dB from the NRR, and subtract the remainder from the A-weighted TWA to obtain the estimated A-weighted TWA under the ear protector.

(iv) When using a sound level meter set on the C-weighting network:

(A) Obtain a representative sample of the C-weighted sound levels in the employee's environment.

(B) Subtract the NRR from the C-weighted average sound level to obtain the estimated A-weighted TWA under the ear protector.

(v) When using area monitoring procedures and a sound level meter set to the A-weighing network.

(A) Obtain a representative sound level for the area in question.

(B) Subtract 7 dB from the NRR and subtract the remainder from the A-weighted sound level for that area.

(vi) When using area monitoring procedures and a sound level meter set to the C-weighting network:

(A) Obtain a representative sound level for the area in question.

(B) Subtract the NRR from the C-weighted sound level for that area.

Audiometric measuring instruments - 1910.95 App C

Regulations (Standards - 29 CFR) - Table of Contents

- **Part Number:** 1910
- **Part Title:** Occupational Safety and Health Standards
- **Subpart:** G
- **Subpart Title:** Occupational Health and Environment Control
- **Standard Number:** 1910.95 App C
- **Title:** Audiometric measuring instruments

This Appendix is Mandatory

1. In the event that pulsed-tone audiometers are used, they shall have a tone on-time of at least 200 milliseconds.

2. Self-recording audiometers shall comply with the following requirements:

(A) The chart upon which the audiogram is traced shall have lines at positions corresponding to all multiples of 10 dB hearing level within the intensity range spanned by the audiometer. The lines shall be equally spaced and shall be separated by at least 1/4 inch. Additional increments are optional. The audiogram pen tracings shall not exceed 2 dB in width.

(B) It shall be possible to set the stylus manually at the 10-dB increment lines for calibration purposes.

(C) The slewing rate for the audiometer attenuator shall not be more than 6 dB/sec except that an initial slewing rate greater than 6 dB/sec is permitted at the beginning of each new test frequency, but only until the second subject response.

(D) The audiometer shall remain at each required test frequency for 30 seconds (+ or - 3 seconds). The audiogram shall be clearly marked at each change of frequency and the actual frequency change of the audiometer shall not deviate from the frequency boundaries marked on the audiogram by more than + or - 3 seconds.

(E) It must be possible at each test frequency to place a horizontal line segment parallel to the time axis on the audiogram, such that the audiometric tracing crosses the line segment at least six times at that test frequency. At each test frequency the threshold shall be the average of the midpoints of the tracing excursions.

Audiometric test rooms - 1910.95 App D

Regulations (Standards - 29 CFR) - Table of Contents

- **Part Number:** 1910
- **Part Title:** Occupational Safety and Health Standards
- **Subpart:** G
- **Subpart Title:** Occupational Health and Environment Control
- **Standard Number:** 1910.95 App D
- **Title:** Audiometric test rooms

This Appendix is Mandatory

Rooms used for audiometric testing shall not have background sound pressure levels exceeding those in Table D-1 when measured by equipment conforming at least to the Type 2 requirements of American National Standard Specification for Sound Level Meters, S1.4-1971 (R1976), and to the Class II requirements of American National Standard Specification for Octave, Half-Octave, and Third-Octave Band Filter Sets, S1.11-1971 (R1976).

TABLE D-1 - MAXIMUM ALLOWABLE OCTAVE-BAND SOUND PRESSURE LEVELS FOR AUDIOMETRIC TEST ROOMS

Octave-band center frequency (Hz)...............	500	1000	2000	4000	8000
Sound pressure level (dB) ...	40	40	47	57	62

Acoustic calibration of audiometers - 1910.95 App E

Regulations (Standards - 29 CFR) - Table of Contents

- **Part Number:** 1910
- **Part Title:** Occupational Safety and Health Standards
- **Subpart:** G
- **Subpart Title:** Occupational Health and Environment Control
- **Standard Number:** 1910.95 App E
- **Title:** Acoustic calibration of audiometers

This Appendix is Mandatory

Audiometer calibration shall be checked acoustically, at least annually, according to the procedures described in this appendix. The equipment necessary to perform these measurements is a sound level meter, octave-band filter set, and a National Bureau of Standards 9A coupler. In making these measurements, the accuracy of the calibrating equipment shall be sufficient to determine that the audiometer is within the tolerances permitted by American Standard Specification for Audiometers, S3.6-1969.

(1) "Sound Pressure Output Check"

A. Place the earphone coupler over the microphone of the sound level meter and place the earphone on the coupler.

B. Set the audiometer's hearing threshold level (HTL) dial to 70 dB.

C. Measure the sound pressure level of the tones at each test frequency from 500 Hz through 6000 Hz for each earphone.

D. At each frequency the readout on the sound level meter should correspond to the levels in Table E-1 or Table E-2, as appropriate, for the type of earphone, in the column entitled "sound level meter reading."

(2) "Linearity Check"

A. With the earphone in place, set the frequency to 1000 Hz and the HTL dial on the audiometer to 70 dB.

B. Measure the sound levels in the coupler at each 10-dB decrement from 70 dB to 10 dB, noting the sound level meter reading at each setting.

C. For each 10-dB decrement on the audiometer the sound level meter should indicate a corresponding 10 dB decrease.

D. This measurement may be made electrically with a voltmeter connected to the earphone terminals.

(3) "Tolerances"

When any of the measured sound levels deviate from the levels in Table E-1 or Table E-2 by + or - 3 dB at any test frequency between 500 and 3000 Hz, 4 dB at 4000 Hz, or 5 dB at 6000 Hz, an exhaustive calibration is advised. An exhaustive calibration is required if the deviations are greater than 15 dB or greater at any test frequency.

TABLE E-1 - REFERENCE THRESHOLD LEVELS FOR TELEPHONICS - TDH-39 EARPHONES

Frequency, Hz	Reference threshold level for TDH-39 earphones, dB	Sound level meter reading, dB
500	11.5	81.5
1000	7	77
2000	9	79
3000	10	80
4000	9.5	79.5
6000	15.5	85.5

TABLE E-2 - REFERENCE THRESHOLD LEVELS FOR TELEPHONICS - TDH-49 EARPHONES

Frequency, Hz	Reference threshold level for TDH-49 earphones, dB	Sound level meter reading, dB
500	13.5	83.5
1000	7.5	77.5
2000	11	81.0
3000	9.5	79.5
4000	10.5	80.5
6000	13.5	83.5

Calculations and application of age corrections to audiograms - 1910.95 App F

Regulations (Standards - 29 CFR) - Table of Contents

- **Part Number:** 1910
- **Part Title:** Occupational Safety and Health Standards
- **Subpart:** G
- **Subpart Title:** Occupational Health and Environment Control
- **Standard Number:** 1910.95 App F
- **Title:** Calculations and application of age corrections to audiograms

This Appendix Is Non-Mandatory

In determining whether a standard threshold shift has occurred, allowance may be made for the contribution of aging to the change in hearing level by adjusting the most recent audiogram. If the employer chooses to adjust the audiogram, the employer shall follow the procedure described below. This procedure and the age correction tables were developed by the National Institute for Occupational Safety and Health in the criteria document entitled "Criteria for a Recommended Standard . . . Occupational Exposure to Noise," ((HSM)-11001).

For each audiometric test frequency;

(i) Determine from Tables F-1 or F-2 the age correction values for the employee by:

(A) Finding the age at which the most recent audiogram was taken and recording the corresponding values of age corrections at 1000 Hz through 6000 Hz;

(B) Finding the age at which the baseline audiogram was taken and recording the corresponding values of age corrections at 1000 Hz through 6000 Hz.

(ii) Subtract the values found in step (i)(B) from the value found in step (i)(A).

(iii) The differences calculated in step (ii) represented that portion of the change in hearing that may be due to aging.

EXAMPLE: Employee is a 32-year-old male. The audiometric history for his right ear is shown in decibels below.

Employee's age	Audiometric test frequency (Hz)				
	1000	2000	3000	4000	6000
26......................	10	5	5	10	5
*27.....................	0	0	0	5	5
28......................	0	0	0	10	5
29......................	5	0	5	15	5
30......................	0	5	10	20	10
31......................	5	10	20	15	15
*32.....................	5	10	10	25	20

The audiogram at age 27 is considered the baseline since it shows the best hearing threshold levels. Asterisks have been used to identify the baseline and most recent audiogram. A threshold shift of 20 dB exists at 4000 Hz between the audiograms taken at ages 27 and 32.

(The threshold shift is computed by subtracting the hearing threshold at age 27, which was 5, from the hearing threshold at age 32, which is 25). A retest audiogram has confirmed this shift. The contribution of aging to this change in hearing may be estimated in the following manner:

Go to Table F-1 and find the age correction values (in dB) for 4000 Hz at age 27 and age 32.

	Frequency (Hz)				
	1000	2000	3000	4000	6000
Age 32...................	6	5	7	10	14
Age 27...................	5	4	6	7	11
Difference	1	1	1	3	3

The difference represents the amount of hearing loss that may be attributed to aging in the time period between the baseline audiogram and the most recent audiogram. In this example, the difference at 4000 Hz is 3 dB. This value is subtracted from the hearing level at 4000 Hz, which in the most recent audiogram is 25, yielding 22 after adjustment. Then the hearing threshold in the baseline audiogram at 4000 Hz (5) is subtracted from the adjusted annual audiogram hearing threshold at 4000 Hz (22). Thus the age-corrected threshold shift would be 17 dB (as opposed to a threshold shift of 20 dB without age correction).

TABLE F-1 - AGE CORRECTION VALUES IN DECIBELS FOR MALES

Years	Audiometric Test Frequency (Hz)				
	1000	2000	3000	4000	6000
20 or younger...........	5	3	4	5	8
21	5	3	4	5	8
22	5	3	4	5	8
23	5	3	4	6	9
24	5	3	5	6	9
25	5	3	5	7	10
26	5	4	5	7	10
27	5	4	6	7	11
28	6	4	6	8	11
29	6	4	6	8	12
30	6	4	6	9	12
31	6	4	7	9	13
32	6	5	7	10	14
33	6	5	7	10	14
34	6	5	8	11	15
35	7	5	8	11	15
36	7	5	9	12	16
37	7	6	9	12	17
38	7	6	9	13	17
39	7	6	10	14	18
40	7	6	10	14	19
41	7	6	10	14	20
42	8	7	11	16	20
43	8	7	12	16	21
44	8	7	12	17	22
45	8	7	13	18	23
46	8	8	13	19	24
47	8	8	14	19	24
48	9	8	14	20	25
49	9	9	15	21	26
50	9	9	16	22	27
51	9	9	16	23	28
52	9	10	17	24	29
53	9	10	18	25	30
54	10	10	18	26	31
55	10	11	19	27	32
56	10	11	20	28	34
57	10	11	21	29	35
58	10	12	22	31	36
59	11	12	22	32	37
60 or older	11	13	23	33	38

TABLE F-2 - AGE CORRECTION VALUES IN DECIBELS FOR FEMALES

Years	Audiometric Test Frequency (Hz)				
	1000	2000	3000	4000	6000
20 or younger...........	7	4	3	3	6
21	7	4	4	3	6
22	7	4	4	4	6
23	7	5	4	4	7
24	7	5	4	4	7
25	8	5	4	4	7
26	8	5	5	4	8
27	8	5	5	5	8
28	8	5	5	5	8
29	8	5	5	5	9
30	8	6	5	5	9
31	8	6	6	5	9
32	9	6	6	6	10
33	9	6	6	6	10
34	9	6	6	6	10
35	9	6	7	7	11
36	9	7	7	7	11
37	9	7	7	7	12
38	10	7	7	7	12
39	10	7	8	8	12
40	10	7	8	8	13
41	10	8	8	8	13
42	10	8	9	9	13
43	11	8	9	9	14
44	11	8	9	9	14
45	11	8	10	10	15
46	11	9	10	10	15
47	11	9	10	11	16
48	12	9	11	11	16
49	12	9	11	11	16
50	12	10	11	12	17
51	12	10	12	12	17
52	12	10	12	13	18
53	13	10	13	13	18
54	13	11	13	14	19
55	13	11	14	14	19
56	13	11	14	15	20
57	13	11	15	15	20
58	14	12	15	16	21
59	14	12	16	16	21
60 or older	14	12	16	17	22

Regulations (Standards - 29 CFR)

Monitoring noise levels non-mandatory informational appendix - 1910.95 App G

Regulations (Standards - 29 CFR) - Table of Contents

- **Part Number:** 1910
- **Part Title:** Occupational Safety and Health Standards
- **Subpart:** G
- **Subpart Title:** Occupational Health and Environment Control
- **Standard Number:** 1910.95 App G
- **Title:** Monitoring noise levels non-mandatory informational appendix

This appendix provides information to help employers comply with the noise monitoring obligations that are part of the hearing conservation amendment.

WHAT IS THE PURPOSE OF NOISE MONITORING?

This revised amendment requires that employees be placed in a hearing conservation program if they are exposed to average noise levels of 85 dB or greater during an 8 hour workday. In order to determine if exposures are at or above this level, it may be necessary to measure or monitor the actual noise levels in the workplace and to estimate the noise exposure or "dose" received by employees during the workday.

WHEN IS IT NECESSARY TO IMPLEMENT A NOISE MONITORING PROGRAM?

It is not necessary for every employer to measure workplace noise. Noise monitoring or measuring must be conducted only when exposures are at or above 85 dB. Factors which suggest that noise exposures in the workplace may be at this level include employee complaints about the loudness of noise, indications that employees are losing their hearing, or noisy conditions which make normal conversation difficult. The employer should also consider any information available regarding noise emitted from specific machines. In addition, actual workplace noise measurements can suggest whether or not a monitoring program should be initiated.

HOW IS NOISE MEASURED?

Basically, there are two different instruments to measure noise exposures: the sound level meter and the dosimeter. A sound level meter is a device that measures the intensity of sound at a given moment. Since sound level meters provide a measure of sound intensity at only one point in time, it is generally necessary to take a number of measurements at different times during the day to estimate noise exposure over a workday. If noise levels fluctuate, the amount of time noise remains at each of the various measured levels must be determined.

To estimate employee noise exposures with a sound level meter, it is also generally necessary to take several measurements at different locations within the workplace. After appropriate sound level meter readings are obtained, people sometimes draw "maps" of the sound levels within different areas of the workplace. By using a sound level "map" and information on employee locations throughout the day, estimates of individual exposure levels can be developed. This measurement method is generally referred to as "area" noise monitoring.

A dosimeter is like a sound level meter except that it stores sound level measurements and integrates these measurements over time, providing an average noise exposure reading for a given period of time, such as an 8-hour workday. With a dosimeter, a microphone is attached to the employee's clothing and the exposure measurement is simply read at the end of the desired time period. A reader may be used to read-out the dosimeter's measurements. Since the dosimeter is worn by the employee, it measures noise levels in those locations in which the employee travels. A sound level meter can also be positioned within the immediate vicinity of the exposed worker to obtain an individual exposure estimate. Such procedures are generally referred to as "personal" noise monitoring.

Area monitoring can be used to estimate noise exposure when the noise levels are relatively constant and employees are not mobile. In workplaces where employees move about in different areas or where the noise intensity tends to fluctuate over time, noise exposure is generally more accurately estimated by the personal monitoring approach.

In situations where personal monitoring is appropriate, proper positioning of the microphone is necessary to obtain accurate measurements. With a dosimeter, the microphone is generally located on the shoulder and remains in that position for the entire workday. With a sound level meter, the microphone is stationed near the employee's head, and the instrument is usually held by an individual who follows the employee as he or she moves about.

Manufacturer's instructions, contained in dosimeter and sound level meter operating manuals, should be followed for calibration and maintenance. To ensure accurate results, it is considered good professional practice to calibrate instruments before and after each use.

HOW OFTEN IS IT NECESSARY TO MONITOR NOISE LEVELS?

The amendment requires that when there are significant changes in machinery or production processes that may result in increased noise levels, remonitoring must be conducted to determine whether additional employees need to be included in the hearing conservation program. Many companies choose to remonitor periodically (once every year or two) to ensure that all exposed employees are included in their hearing conservation programs.

WHERE CAN EQUIPMENT AND TECHNICAL ADVICE BE OBTAINED?

Noise monitoring equipment may be either purchased or rented. Sound level meters cost about $500 to $1,000, while dosimeters range in price from about $750 to $1,500. Smaller companies may find it more economical to rent equipment rather than to purchase it. Names of equipment suppliers may be found in the telephone book (Yellow Pages) under headings such as: "Safety Equipment," "Industrial Hygiene," or "Engineers-Acoustical." In addition to providing information on obtaining noise monitoring equipment, many companies and individuals included under such listings can provide professional advice on how to conduct a valid noise monitoring program. Some audiological testing firms and industrial hygiene firms also provide noise monitoring services. Universities with audiology, industrial hygiene, or acoustical engineering departments may also provide information or may be able to help employers meet their obligations under this amendment.

Free, on-site assistance may be obtained from OSHA-supported state and private consultation organizations. These safety and health consultative entities generally give priority to the needs of small businesses.

Availability of referenced documents - 1910.95 App H

Regulations (Standards - 29 CFR) - Table of Contents

- **Part Number:** 1910
- **Part Title:** Occupational Safety and Health Standards
- **Subpart:** G
- **Subpart Title:** Occupational Health and Environment Control
- **Standard Number:** 1910.95 App H
- **Title:** Availability of referenced documents

Paragraphs (c) through (o) of 29 CFR 1910.95 and the accompanying appendices contain provisions which incorporate publications by reference. Generally, the publications provide criteria for instruments to be used in monitoring and audiometric testing. These criteria are intended to be mandatory when so indicated in the applicable paragraphs of 1910.95 and appendices.

It should be noted that OSHA does not require that employers purchase a copy of the referenced publications. Employers, however, may desire to obtain a copy of the referenced publications for their own information.

The designation of the paragraph of the standard in which the referenced publications appear, the titles of the publications, and the availability of the publications are as follows:

Paragraph designation	Referenced publication	Available from --
Appendix B	"List of Personal Hearing Protectors and Attenuation Data," HEW Pub. No. 76-120, 1975. NTIS-PB267461.	National Technical Information Service, Port Royal Road, Springfield, VA 22161.
Appendix D	"Specification for Sound Level Meters," S1.4-1971 (R1976).	American National Standards Institute, Inc., 1430 Broadway, New York, NY 10018.
1910.95(k)(2), Appendix E ...	"Specifications for Audiometers," S3.6-1969.	American National Standards Institute, Inc., 1430 Broadway, New York, NY 10018.

Appendix D	"Specification for Octave, Half-Octave and Third-Octave Band Filter Sets," S1.11-1971 (R1976).	Back Numbers Department, Dept. STD, American Institute of Physics, 333 E. 45th St., New York, NY 10017; American National Standards Institute, Inc., 1430 Broadway, New York, NY 10018.

The referenced publications (or a microfiche of the publications) are available for review at many universities and public libraries throughout the country. These publications may also be examined at the OSHA Technical Data Center, Room N2439, United States Department of Labor, 200 Constitution Avenue, NW., Washington, DC 20210, (202) 219-7500 or at any OSHA Regional Office (see telephone directories under United States Government - Labor Department).

Definitions - 1910.95 App I

Regulations (Standards - 29 CFR) - Table of Contents

- **Part Number:** 1910
- **Part Title:** Occupational Safety and Health Standards
- **Subpart:** G
- **Subpart Title:** Occupational Health and Environment Control
- **Standard Number:** 1910.95 App I
- **Title:** Definitions

These definitions apply to the following terms as used in paragraphs (c) through (n) of 29 CFR 1910.95.

Action level - An 8-hour time-weighted average of 85 decibels measured on the A-scale, slow response, or equivalently, a dose of fifty percent.
Audiogram - A chart, graph, or table resulting from an audiometric test showing an individual's hearing threshold levels as a function of frequency.
Audiologist - A professional, specializing in the study and rehabilitation of hearing, who is certified by the American Speech-Language-Hearing Association or licensed by a state board of examiners.
Baseline audiogram - The audiogram against which future audiograms are compared.
Criterion sound level - A sound level of 90 decibels.
Decibel (dB) - Unit of measurement of sound level.
Hertz (Hz) - Unit of measurement of frequency, numerically equal to cycles per second.
Medical pathology - A disorder or disease. For purposes of this regulation, a condition or disease affecting the ear, which should be treated by a physician specialist.
Noise dose - The ratio, expressed as a percentage, of (1) the time integral, over a stated time or event, of the 0.6 power of the measured SLOW exponential time-averaged, squared A-weighted sound pressure and (2) the product of the criterion duration (8 hours) and the 0.6 power of the squared sound pressure corresponding to the criterion sound level (90 dB).
Noise dosimeter - An instrument that integrates a function of sound pressure over a period of time in such a manner that it directly indicates a noise dose.
Otolaryngologist - A physician specializing in diagnosis and treatment of disorders of the ear, nose and throat.
Representative exposure - Measurements of an employee's noise dose or 8-hour time-weighted average sound level that the employers deem to be representative of the exposures of other employees in the workplace.
Sound level - Ten times the common logarithm of the ratio of the square of the measured A-weighted sound pressure to the square of the standard reference pressure of 20 micropascals. Unit: decibels (dB). For use with this regulation, SLOW time response, in accordance with ANSI S1.4-1971 (R1976), is required.

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Sound level meter - An instrument for the measurement of sound
 level.
Time-weighted average sound level - That sound level, which if
 constant over an 8-hour exposure, would result in the same noise
 dose as is measured.
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[39 FR 23502, June 27, 1974, as amended at 46 FR 4161, Jan. 16, 1981; 46 FR 62845, Dec. 29, 1981; 48 FR 9776, Mar. 8, 1983; 48 FR 29687, June 28, 1983; 54 FR 24333, June 7, 1989; 61 FR 5507, Feb. 13, 1996; 61 FR 9227, March 7, 1996]

January 1, 2004 Brings More Changes to OSHA 300 Log

Are you aware that on Jan. 1, 2004, the OSHA 300 Logs will change…again?

The 2004 OSHA 300 and 300A forms have changed in several important ways from the 2003 recordkeeping forms.

Although much ado was made about OSHA **not** adding a column to the 300 Form for musculoskeletal injuries, the agency **did** add a column for occupational hearing loss. The change was made to the Form 300, Log of Work-Related Injuries and Illnesses, on July 1, 2002, and takes effect on Jan. 1, 2004. The new forms:

Modify the current 2003 300 and 300A forms to include the new hearing loss column data.

Reverse two columns on the 300 and 300A forms.

Employers must begin to use the new forms on Jan. 1, 2004. If you have recordkeeping software, you must upgrade to a version with the new forms.

"This decision does not change the current way injuries or illnesses are recorded and does not affect an employer's obligation to record work-related injuries," said OSHA Administrator John Henshaw. "Employers will continue to check the column for 'injury' or 'all other illness,' depending on the circumstances of the case."

OSHA made several other changes to the forms to make recordkeeping less difficult:

- The number of days away and job transfer/restriction days columns have been reversed so they are in the same sequence as the preceding columns requiring an "X" for the same classifications. The days "away from work" column now comes before days "on job transfer or restriction." (K and L reversed)
- OSHA clarified the formulas for calculating incidence rates.
- The new column for reporting hearing loss is M5. The old column heading for M5, "All Other Illnesses," is now M6.
- The column heading "Classify the Case" is now more prominent to make it clear that employers should mark only one selection among the four columns offered.

Standard Interpretations

03/04/2004 - Recording criteria for recordkeeping cases involving occupational hearing loss.

Standard Interpretations - Table of Contents

- **Standard Number:** 1904; 1904.10(b)(4); 1910.95(m)(2)

This letter constitutes OSHA's interpretation only of the requirements discussed and may not be applicable to any situation not delineated within the original correspondence.

March 4, 2004

Mr. Carl O. Sall, CIH
Director of Occupational Safety
and Health Compliance
Comprehensive Health Services, Inc.
8229 Boone Boulevard, Suite 700
Vienna, VA 22182-2623

Dear Mr. Sall:

This is in response to your letter dated February 13, 2003. Thank you for your comments pertaining to the Occupational Safety and Health Administration's (OSHA) Injury and Illness Recording and Reporting Requirements contained in 29 CFR Part 1904. In your letter you requested clarifications on some issues related to the recording criteria for cases involving occupational hearing loss. Your questions are summarized below, followed by our responses.

Question: Does the thirty-day retest start on the day the initial hearing exam was completed, or on the date that the results are given to the employer?

Response: For OSHA purposes, the thirty-day retest begins from the date of the first test under Section 1904.10(b)(4) in the regulation. Also, see the September 4, 1991 letter of interpretation to Mr. Paul V. Williams from Patricia Clark. A retest audiogram may not be substituted for an initial audiogram unless it is obtained within thirty calendar days of the date of initial audiogram regardless of the fact that an outside evaluating concern is used.

Question: Can I correct my OSHA 300 Log if on a subsequent exam an employee's hearing improves to a point that is no longer recordable?

Response: For purposes of OSHA recordkeeping, 1904.10(b)(4) states that "If subsequent audiometric testing indicates that a Standard Threshold Shift (STS) is not persistent, you may erase or line-out the recorded entry." While the recordkeeping rule does not require the employer to maintain documentation concerning the removal of cases, Section 1910.95(m)(2) of the noise standard requires the employer to keep records of all audiometric tests that are performed. Therefore, those records will be available, should they be needed for future reference.

Question: Does the hearing loss recordkeeping requirement apply to the Construction Industry?

Response: Yes. Employers in the construction industry are required to follow the recordkeeping requirements of 1904. Hearing losses of employees that meet the recording criteria set forth in 29 CFR 1904.10 must be recorded.

Finally, you have asked OSHA to review your draft examples of how to properly record an occupational hearing loss case. Work-related hearing loss cases must be recorded if they meet the requirements of 1904.10. Two basic questions must be answered:

1. Did the employee suffer a Standard Threshold Shift (STS) of 10 dB or more in one or both ears?

2. Is the employee's overall hearing level 25 dB or more above audiometric zero in the same or both ears?

If both questions can be answered yes, then it must be recorded on the OSHA 300 log. A decision tree has been enclosed to aid you with your recordkeeping requirements.

Thank you for your interest in occupational safety and health. We hope you find this information helpful. OSHA requirements are set by statute, standards, and regulations. Our interpretation letters explain these requirements and how they apply to particular circumstances, but they cannot create additional employer obligations. This letter constitutes OSHA's interpretation of the requirements discussed. Note that our enforcement guidance may be affected by changes to OSHA rules. Also, from time to time we update our guidance in response to new information. To keep appraised of such developments, you can consult OSHA's website at http://www.osha.gov. If you have any further questions, please contact the Division of Recordkeeping Requirements, at 202-693-1702.

Sincerely,

Frank Frodyma, Acting Director
Directorate of Evaluation and Analysis

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3. **Violations of the Noise Standard.** Current enforcement policy regarding 29 CFR 1910.95(b)(1) allows employers to rely on personal protective equipment and a hearing conservation program rather than engineering and/or administrative controls when hearing protectors will effectively attenuate the noise to which the employee is exposed to acceptable levels as specified in Tables G-16 or G-16a of the standard. Professional judgment is necessary to supplement the general guidelines provided here.

a. Citations for violations of 29 CFR 1910.95(b)(1) shall be issued when engineering and/or administrative controls are feasible, both technically and economically; and

(1) Employee exposure levels are so high that hearing protectors alone may not reliably reduce noise levels received by the employee's ear to the levels specified in Tables G-16 or G-16a of the standard. Given the present state of the art, hearing protectors which offer the greatest attenuation may not reliably be used when employee exposure levels border on 100 dBA (See OSHA Instruction CPL 2-2.35A, Appendix.); or

(2) The costs of engineering and/or administrative controls are less than the cost of an effective hearing conservation program.

NOTE: See Chapter III for guidelines on technical and economic feasibility. The director of Technical Support can provide additional information on engineering control costs and technological feasibility when requested by the regional administrator.

b. A control is not reasonably necessary when an employer has an ongoing hearing conservation program and the results of audiometric testing indicate that existing controls and hearing protectors are adequately protecting employees. (In making this decision, such factors as the exposure levels in question, the number of employees tested, and the duration of the testing program shall be taken into consideration.)

c. When employee noise exposures are less than 100 dBA but the employer does not have an ongoing hearing conservation program or the results of audiometric testing indicate that the employer's existing program is not working, the CSHO shall consider whether:

(1) Reliance on an effective hearing conservation program would be less costly than engineering and/or administrative controls.

(2) An effective hearing conservation program can be established or improvements can be made in an existing hearing conservation program which could bring the employer into compliance with Tables G-16 or G-16a.

(3) Engineering and/or administrative controls are both technically and economically feasible.

d. If noise levels received by the employee's ear can be reduced to the levels specified in Tables G-16 or G-16a by means of hearing protectors and an effective hearing conservation program, citations under the hearing conservation standard shall normally be issued rather than citations requiring engineering controls.

(1) If improvements in the hearing conservation program cannot be made or, if made, cannot be expected to reduce exposure sufficiently and feasible controls exist, a citation under 1910.95(b)(1) shall normally be issued.

(2) The area director shall discuss such cases with the regional administrator prior to issuing a citation. If the regional administrator agrees that controls are justifiable, a citation shall be issued.

e. When hearing protection is required but not used and employee exposure exceeds the limits of Table G-16, 29 CFR 1910.95(i)(2)(i) shall be cited and classified as serious (See C.3.h.) whether or not the employer has instituted a hearing conservation program. 29 CFR 1910.95(a) shall no longer be cited except in the case of the oil and gas drilling industry.

NOTE: Citations of 29 CFR 1910.95(i)(2)(ii)(b) shall also be classified as serious.

f. If an employer has instituted a hearing conservation program and a violation of the hearing conservation amendment (other than 1910.95 (i)(2)(i) or (i)(2)(ii)(b)) is found, a citation shall be issued if employee noise exposures equal or exceed an 8-hour time-weighted average of 85 dB.

g. If the employer has not instituted a hearing conservation program and employee noise exposures equal or exceed an 8-hour time-weighted average of 85 dB, a citation for 1910.95(c) only shall be issued.

h. Violations of 1910.95(i)(2)(i) from the hearing conservation amendment may be grouped with violations of 29 CFR 1910.95(b)(1) and classified as serious when an employee is exposed to noise levels above the limits of Table G-l6 and:

    (1) Hearing protection is not utilized or is not adequate to prevent overexposure to an employee; or

    (2) There is evidence of hearing loss which could reasonably be considered:

        (a) To be work-related, and

        (b) To have been preventable, at least to some degree, if the employer had been in compliance with the cited provisions.

i. When an employee is overexposed but effective hearing protection is being provided and used, an effective hearing conservation program has been implemented and no feasible engineering or administrative controls exist, a citation shall not be issued.

This is the OSHA field operations manual link for noise.

http://www.osha-slc.gov/dts/osta/otm/otm_iii/otm_iii_5.html

Audiometric Testing Vans - Ohio

L.L. Miller
Industrial Mobile Hearing Testing
P.O. Box 242 · Hartville, OH 44632-0242
Phone: (330) 877-8383 · Fax: (330) 877-8408

Fisher-Titus Medical Center
272 Benedict Avenue, Norwalk, OH 44857
(419) 668-8101 www.fisher-titus.com

HTI Mobile Health Testing and Consultation
500 West Wilson Bridge Road, Suite 105
Worthington, Ohio 43085
Phone: (614)885-2997

MOBILE AUDIOMETRIC TESTING SERVICES*

CURRENT AS OF: November 2001
(covering all of Northwest Ohio)

- - - - - - - - - - - - -

Fisher-Titus Medical Center (419) 668-8101 ext. 6464
(Norwalk, Ohio)

- - - - - - - - - - - - -

HCI, Inc. (815) 964-4465
(Rockford, Illinois)

- - - - - - - - - - - - -

HTI, Inc. (800) 685-2997
(Columbus, Ohio)

- - - - - - - - - - - - -

Midwest Audiology Inc (216) 287-0112
(Euclid, Ohio)

- - - - - - - - - - - - -

Toledo Hearing & Speech Center (419) 241-6219
(Toledo, Ohio)

- - - - - - - - - - - -

TK Group, Inc (815) 964-5445
(Rockford, Illinois) www.tkontheweb.com

- - - - - - - - - - - -

ZENZA Mobile Medical Service (800) 688-6246
(Twinsburg, Ohio)

Non-Mobile: Toledo Hearing & Speech Center (419) 241-6219
One Stranahan Sq, Ste 470
Toledo, Ohio

* Information is provided solely as a service to Ohio employers and should not be construed as an endorsement by the Division of Safety & Hygiene, nor is this list all-inclusive of agencies providing this type of service.

Noise Control Consultants

Acoustical Systems, Inc. 20 S. Perry Street, Vandalia, OH 45377
937.898.3198

J.H. Bennett and Company, 10314 Brecksville Road, Brecksville, OH 44141 Matt Specht
800.726.0117

BRD Noise and Vibration Control, 4370 Winterringer St. Hilliard OH 43026 Robert Kienzle
614.527.9444

United McGill, 190 East Broadway Ave, Westerville, OH 43081 - Jerry Schmelzer
614.882.5455

Beta Associates, Cincinnati, OH - Bob Willson
513.772.9296

One Hour Safety Presentation

The main goal of the Division of Safety & Hygiene is the reduction of accidents and illnesses in the workplace. Toward this goal, the One Hour Safety presentation is designed to support the delivery of a presentation to co-workers in your workplace to help them understand and promote safer and healthier work environments. It is recommended that you take the DSH Training Center course as a background for using One Hour Safety Presentation to train others at your workplace. Call 1-800-OHIOBWC, option 2, 2, 2 for class dates and locations.

The One Hour Safety Presentation contains:

- Transparency Masters from which films can be made to use on an overhead projector,
- Instructor Notes which gives the instructor suggestions and script notations to use during the presentation, and
- Student Handouts which can be copied for those attending the presentation.

Materials are included for a one-hour presentation on each of these topics:

- ✓ Accident Analysis
- ✓ Bloodborne Pathogens
- ✓ Effective Safety Teams
- ✓ Enhancing Safety through a Drug-Free Workplace
- ✓ Ergonomics Basic Principles
- ✓ Ergonomics Developing an Effective Process
- ✓ Hazard Communication
- ✓ Lockout/Tagout and Safety-related Work Practices
- ✓ Machine Guarding Basics
- ✓ Measuring Safety Performance
- ✓ Powered Industrial Trucks Training Program
- ✓ Respiratory Protection
- ✓ Violence in the Workplace

Applications used:

1) Text documents (ending in .txt) can be opened with any word processing program.
2) Microsoft PowerPoint slides (ending in .ppt) can be opened with the Microsoft PowerPoint program. If you do not have PowerPoint and you do have Windows 95, 98, 2000 or Windows NT operating system, you can view the PowerPoint slides by downloading a free PowerPoint Viewer from the following website: http://office.microsoft.com/downloads/default.aspx?Product=PowerPoint&Version=95|97|98|2000|2002&Type=Converter|Viewer
3) Adobe Reader document (ending in .pdf) contains the One Hour Safety Presentation in read-only format. It can be opened when you download Adobe Reader, which is available free of charge at the following website: http://www.adobe.com/products/acrobat/readstep2.html

If you have comments or questions about these materials for One Hour Safety Presentation, please e-mail us: OCOSHTrng@bwc.state.oh.us

Transparency Masters

Hearing Conservation

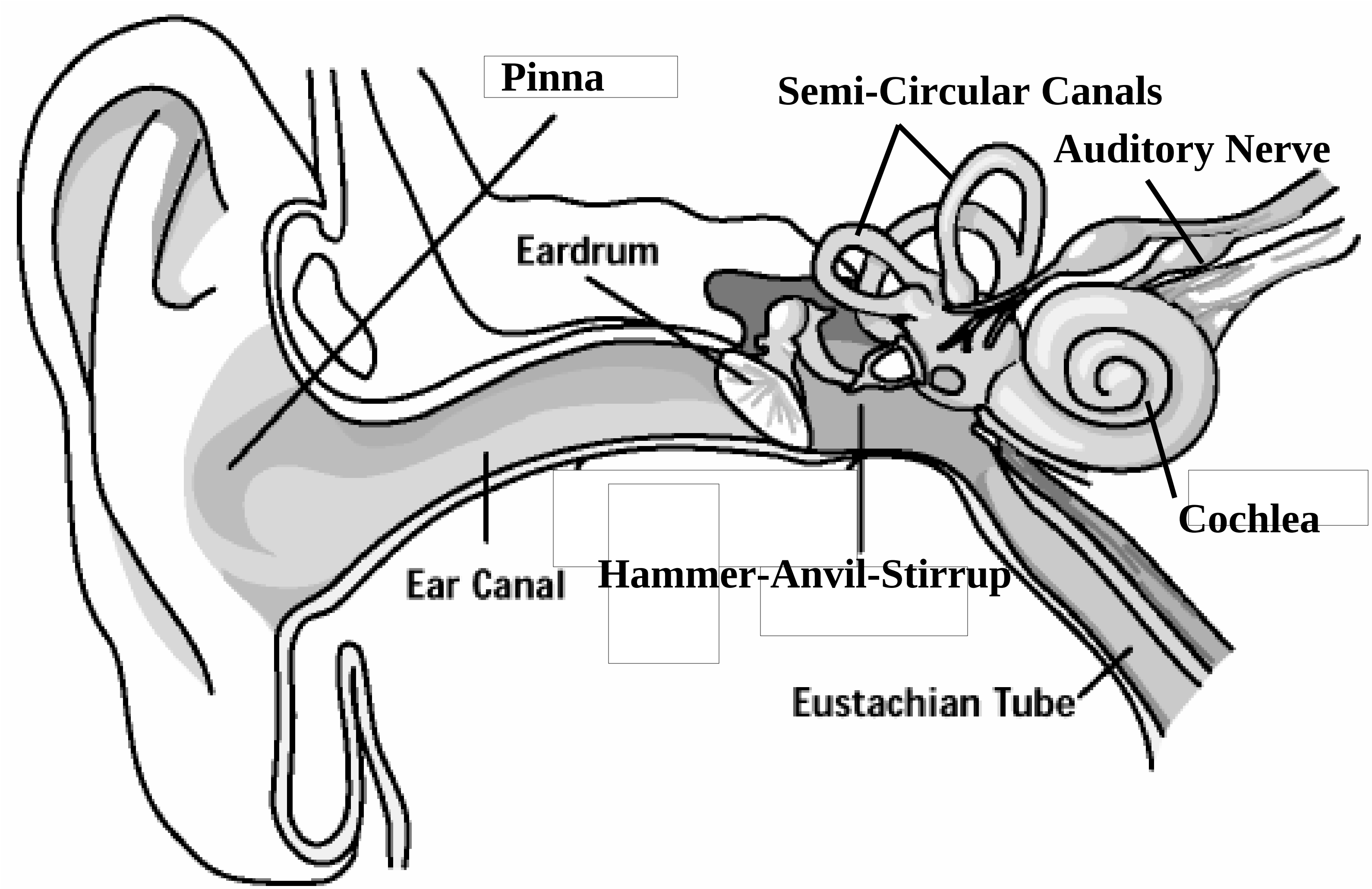
and

Noise Control

WHY??????

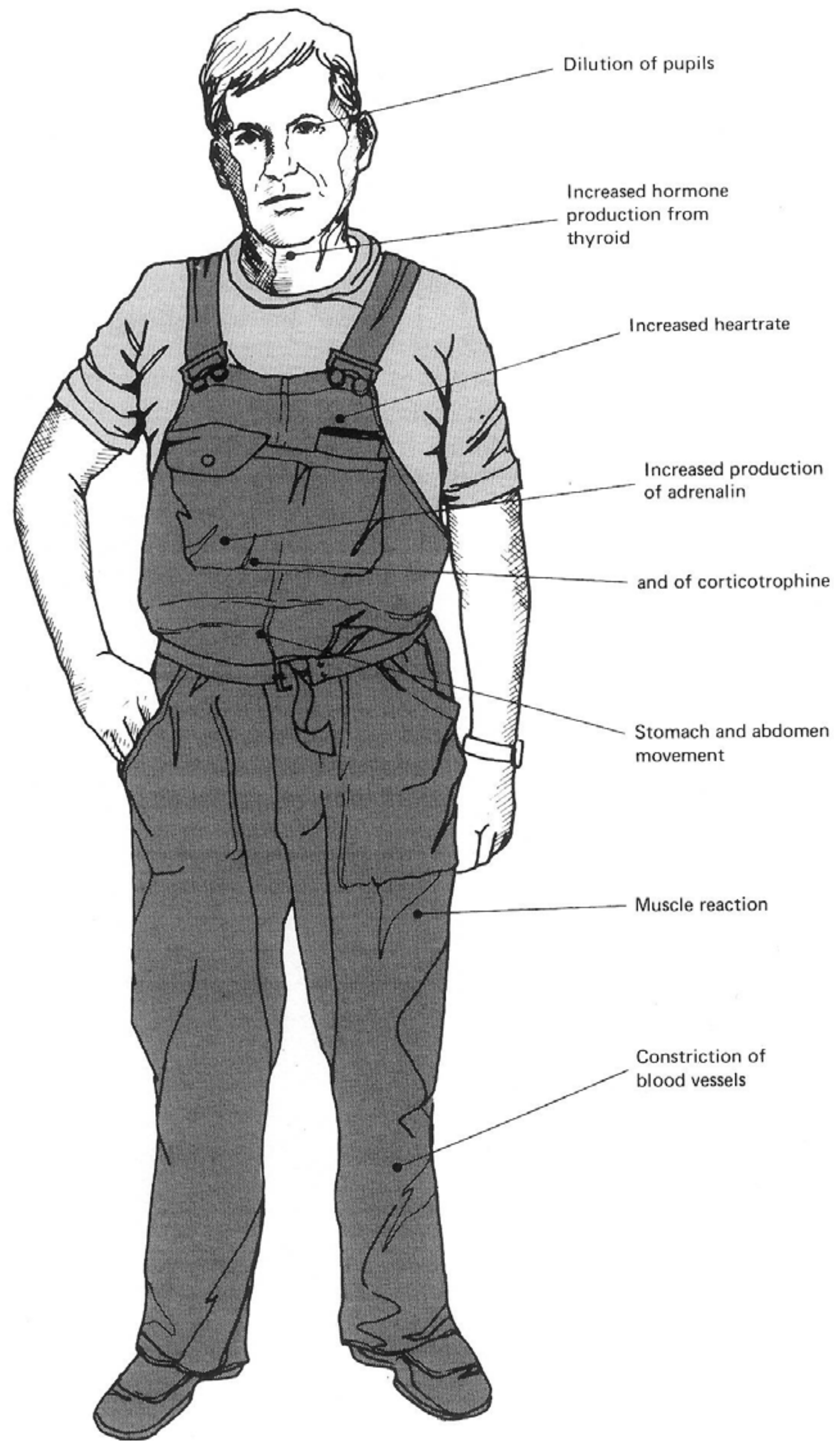
- It’s the LAW
- Quality of Life
- Gradual / Painless

Anatomy of the Ear



Types of Hearing Loss

- Conductive
- Central
- Sensorineural


Dilution of pupils
Increased hormone production from thyroid
Increased heartrate
Increased production of adrenalin
and of corticotrophine
Stomach and abdomen movement
Muscle reaction
Constriction of blood vessels

Degree of Risk

- Frequency
- Intensity
- Duration
- Individual Variability

How Loud is Loud?

- Jet engine 140 db
- Threshold of Pain 125 db
- Pneumatic hammer 110 db
- Compressed Air 105+ db
- Punch Press 95 db
- Lawn Mower 90 db
- Conversation 65 db

Personal Protective Equipment

advantages / disadvantages

- Cotton Balls
- Canal Blockers
- Ear Muffs
- Ear Plugs
- NRRs (example on next page)

NRRs

- EPA protocol
- For “A” scale measurements NRR – 7

Noise exposure 92 dBA

Manufacturer’s NRR 32

32 – 7 = 25 (effective noise exposure reduction)

92 – 25 = 67 dBA

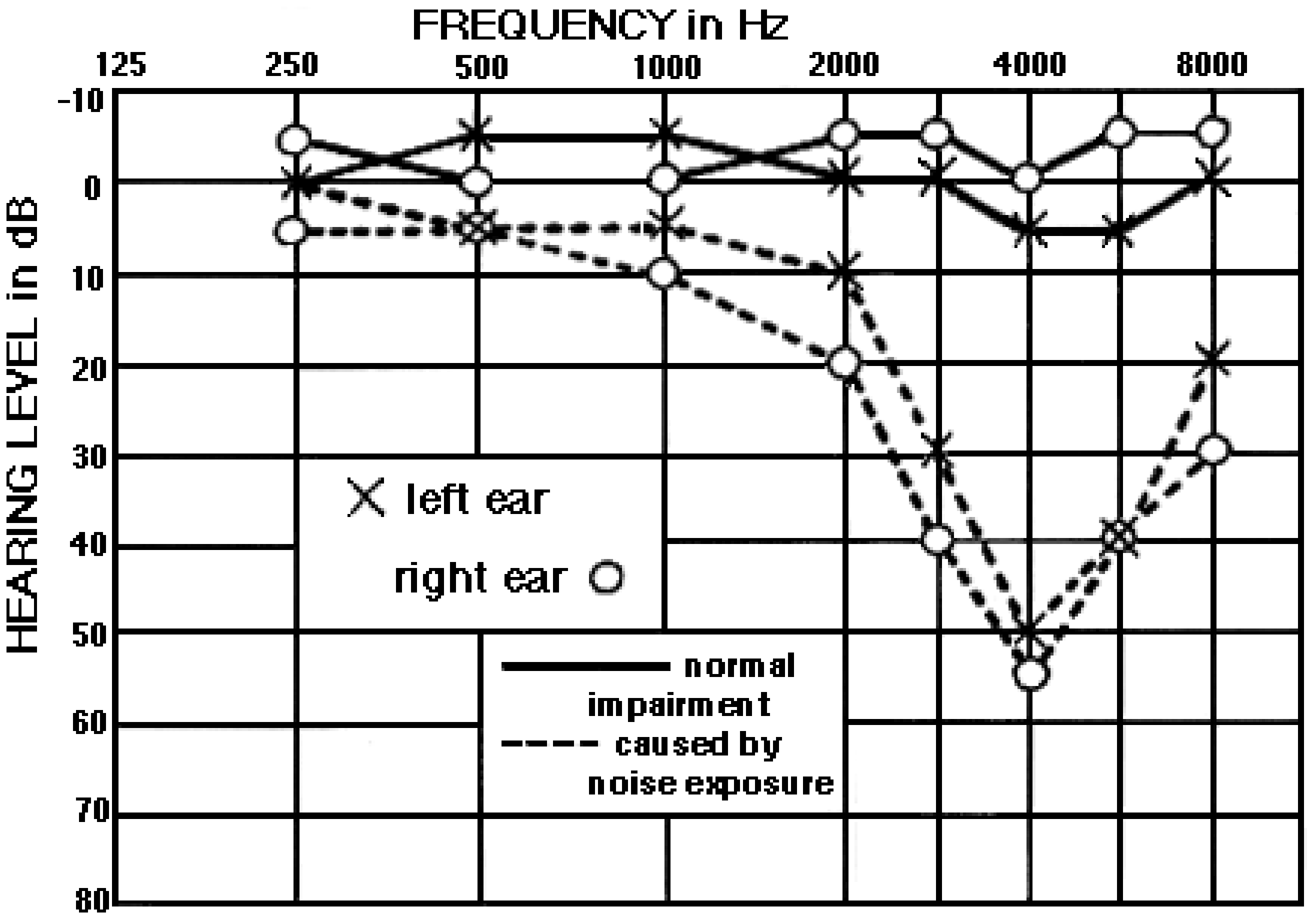
Exposure Limits

• ACGIH	85 dBA
• NIOSH	85 dBA
• OSHA	84↓ dBA
	85 - 89 dBA
	90 dBA

Noise Monitoring

- Required by the OSHA standard to identify all noise above 80 dBA
- Monitoring must be performed whenever there is an increase in production or equipment is added that could increase the noise level

Audiograms


FREQUENCY in Hz
125
250
500
1000
2000
4000
8000
HEARING LEVEL in dB
-10
0
10
20
30
40
50
60
70
80
left ear
right ear
normal
impairment
caused by
noise exposure

Training requirements

- Annual Training
- Hearing Conservation Elements
- Hearing Protectors

Recordkeeping

- Monitoring records
- Audiometric testing records

Noise Control

- Engineering
- Administrative
- Personal Protective Equipment

What we’re doing to control noise

- Fill in here what you’re company is doing to reduce exposure to noise……..

Instructor Notes

Thank you for your interest in teaching the basics of Noise and Hearing Conservation to your employees and for promoting self-sufficiency on behalf of the Division of Safety & Hygiene.

A few points to keep in mind while teaching this class to your employees.

Try to do everything you can to get your students "involved" with the information that you will be presenting. This means using actual work place examples wherever possible. Try to use your own work area noises, your own hearing conservation program, your own types of hearing protection and certainly refer to your company specific procedures when at all possible.

If possible, incorporate some exercises into your training. These exercises might be as simple as reviewing how to properly insert earplugs, or as involved as having people actually measuring noise levels. The key is to get your class involved so that they are not just listening to you lecture.

Encourage questions and repeat questions for clarity to be sure that everyone has heard and understood. Even if you know the answer, a good technique is to ask the class if anyone can answer the question. On questions where you're not sure of the answer or there is disagreement within the class, tell the class that you'll check on it during a break or as soon after the class as possible. Follow-up and make sure everyone gets the information.

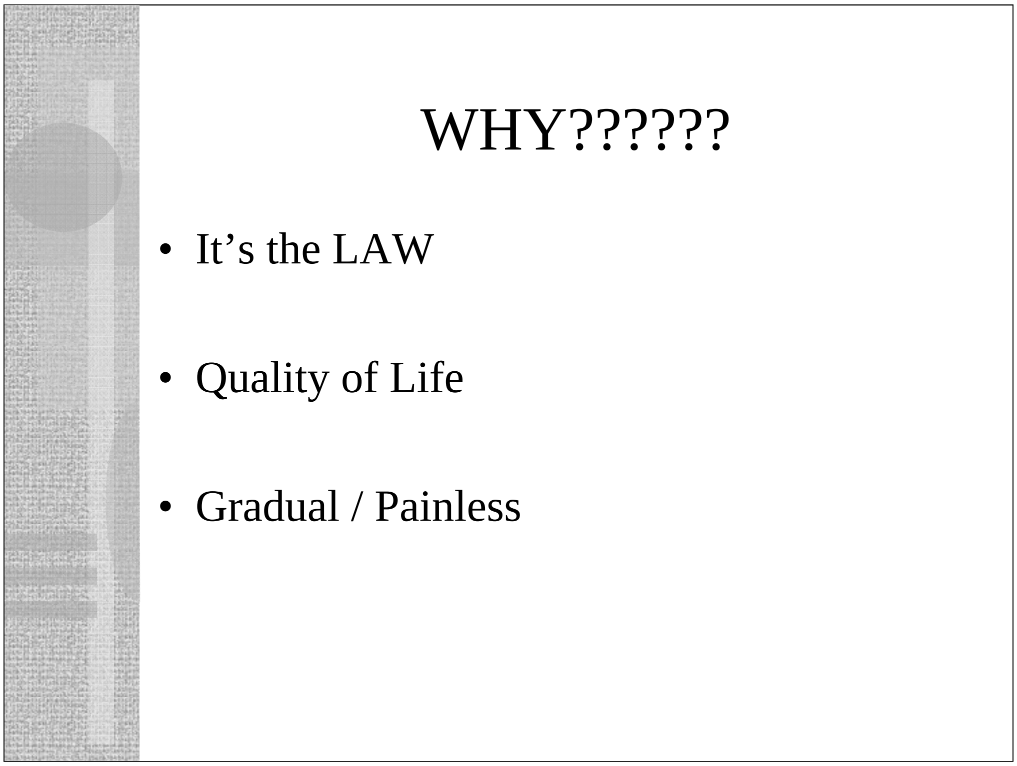
Remember, your goal is to teach your employees to be safe and to provide accurate information about noise and hearing conservation and your specific hearing conservation program.

Hearing Conservation

and

Noise Control

Exposure to noise in the workplace where the noise level, expressed in decibels, exceeds 85 dBA requires the implementation of an effective hearing conservation program. If the noise level is above 90 dBA then requirements to reduce the noise level with noise control devices **must** be performed.

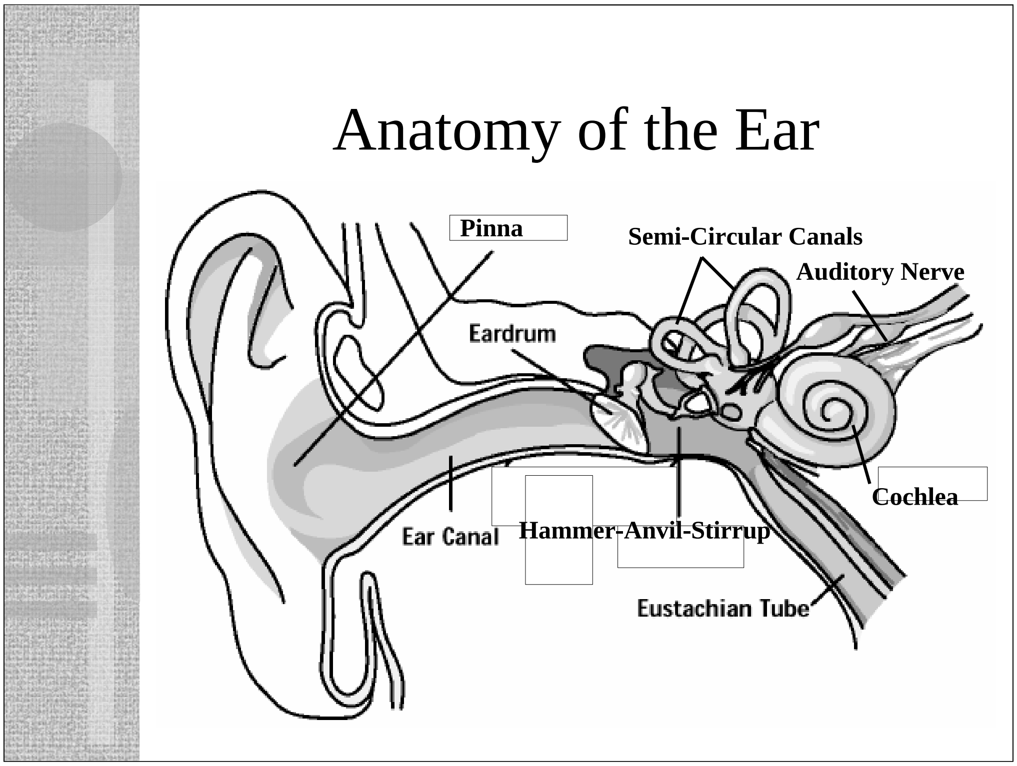


Why have a hearing conservation program?

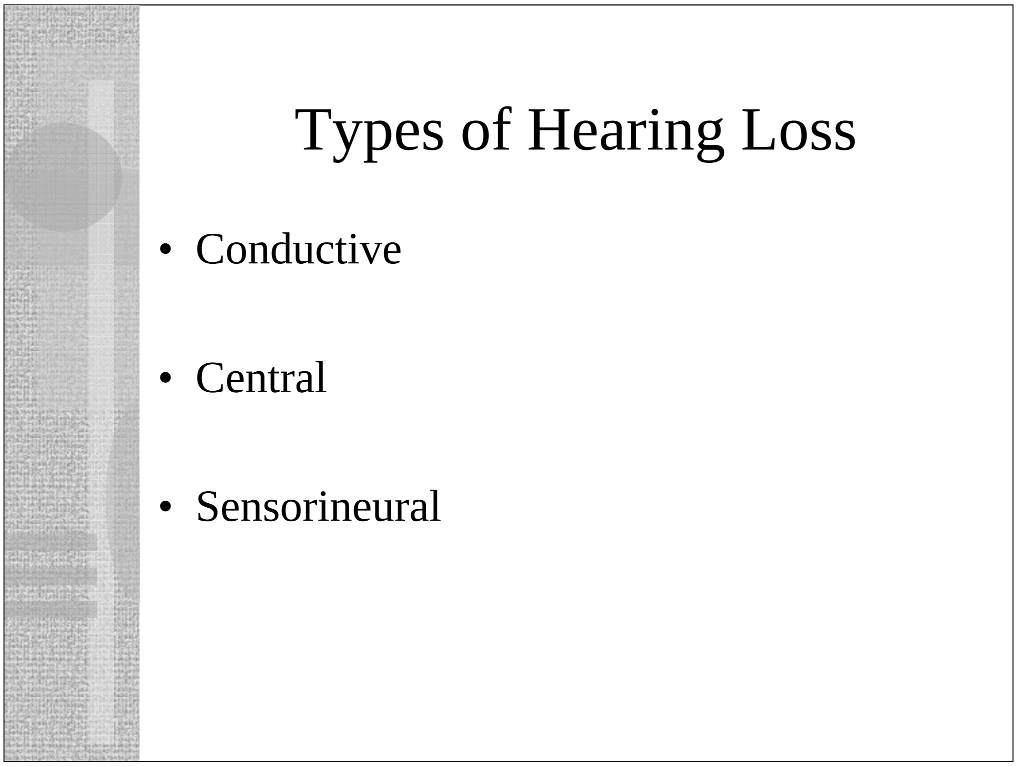
It is required by OSHA regulation 1910.95

Quality of life issues

Most sensroineural hearing loss occurs very gradually and is painless.



The eardrum consists of 3 parts known as the outer ear, the middle ear, and the inner ear. The outer ear consists of the pinna and the ear canal. This part of the ear directs noise into the ear. The middle ear includes the eardrum and occicles (bones of the middle ear). This part of the ear converts the transverse wave into mechanical vibrations. The vibrations are then transferred to the inner ear where the cochlea interprets the mechanical vibrations, converts it to electrical impulses, and sends the message through the auditory nerve to the brain.

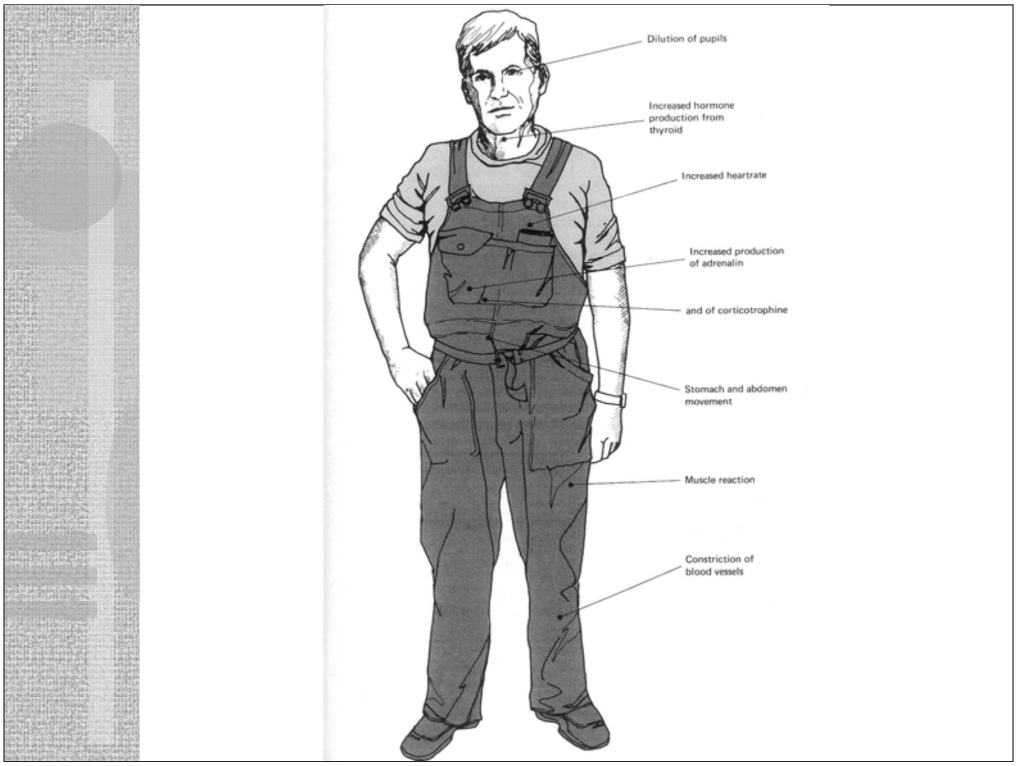


Types of hearing loss;

Conductive occurs in the ear canal, ear drum, ossicles. These can generally be corrected surgically.

Central hearing loss is damage to auditory nerve.

Sensorineural is NERVE damage that occurs in the cochlea.



Health effects other than hearing loss.

In addition to noise induced hearing loss, noise causes dilution of the pupils, increase in hormone and adrenalin production, increased heart rate, causes the muscles to react, and causes construction of the blood vessels.

Degree of Risk

- Frequency
- Intensity
- Duration
- Individual Variability

Factors influencing hearing loss:

Frequency = how often are workers exposed

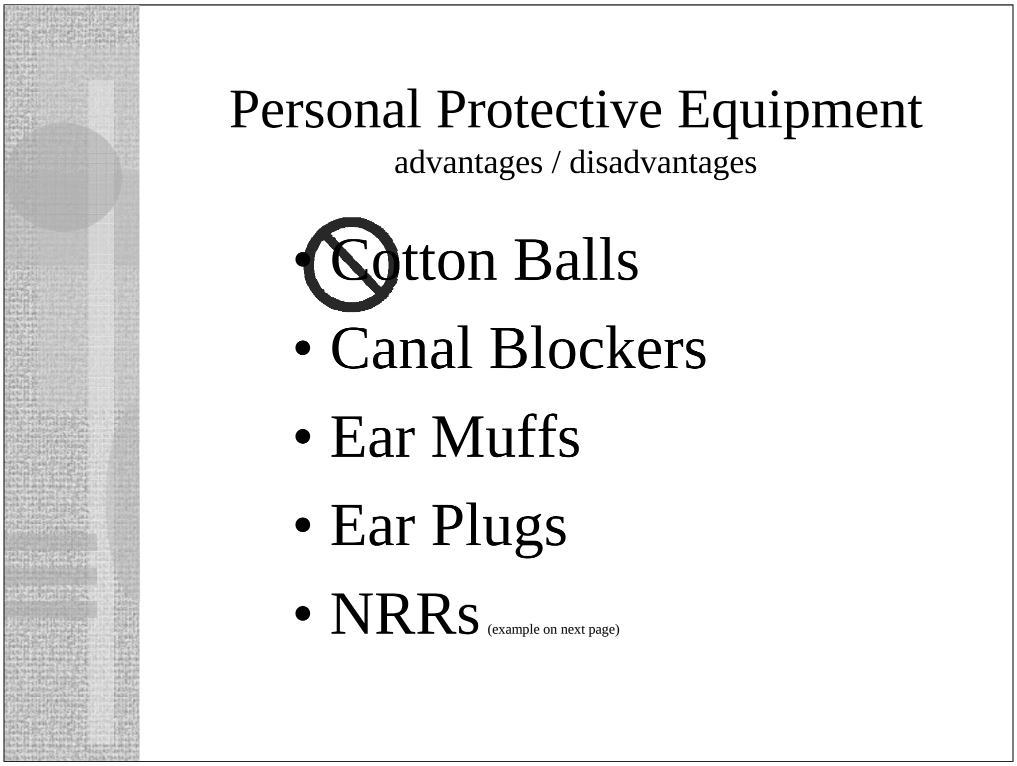
Intensity = how loud is the noise

Duration = how long are workers exposed

Individual Variability = differences in individuals "resistance"

How Loud is Loud?

• Jet engine	140 db
• Threshold of Pain	125 db
• Pneumatic hammer	110 db
• Compressed Air	105+ db
• Punch Press	95 db
• Lawn Mower	90 db
• Conversation	65 db



Types of hearing protectors

Cotton Balls provide NO protection.

Canal Blockers are basically caps like mushroom caps that only cover the opening of the ear canal

Ear muffs

Ear plugs

NRR = Noise Reduction Rating. Must subtract 7 from the manufacturer's NRR if noise is measured on the A scale.

no need to subtract 7 if the noise is measured on the C scale.

The business about dividing by two after subtracting 7 is for two purposes.

1. to yield an indication of "real world" protection factor
2. for engineering control purposes.

NRRs

- EPA protocol
- For “A” scale measurements NRR – 7

Noise exposure 92 dBA

Manufacturer’s NRR 32

32 – 7 = 25 (effective noise exposure reduction)

92 – 25 = 67 dBA

Briefly work through the example

Exposure Limits

• ACGIH	85 dBA
• NIOSH	85 dBA
• OSHA	84↓ dBA
	85 - 89 dBA
	90 dBA

OSHA's Permissible Exposure Limit (PEL) is 90dBA and they added the hearing conservation amendment in 1983 that created an action level at 85 dBA which requires the five basic elements of the hearing conservation program.

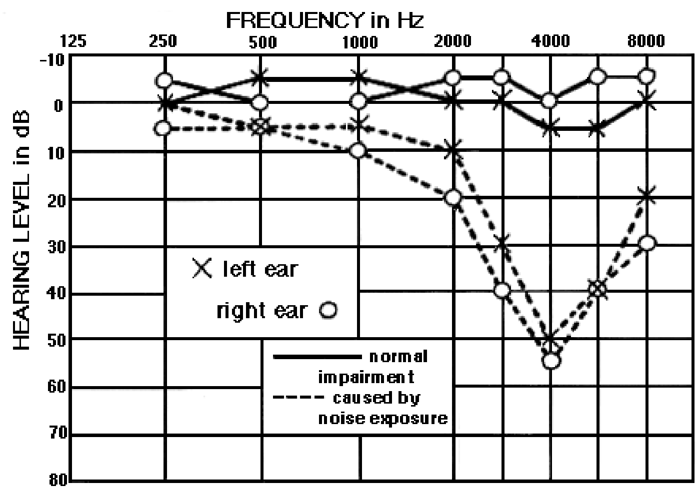
The five elements are: monitoring, audiometric testing, hearing protectors, training, and recordkeeping.

NIOSH and ACGIH have updated their respective noise recommended exposure levels and threshold limit values (TLVs) to be more protective of an individual's hearing and their limits are 85 dBA.

Noise Monitoring

- Required by the OSHA standard to identify all noise above 80 dBA
- Monitoring must be performed whenever there is an increase in production or equipment is added that could increase the noise level

Audiograms



Audiograms are required every year to identify if there has been a loss of hearing. The audiogram above shows two audiograms. The solid line shows a normal result with no hearing loss. The dotted line represents a typical noise induced hearing loss (NIHL). The 4000 Hz notch is readily apparent on all NIHL.

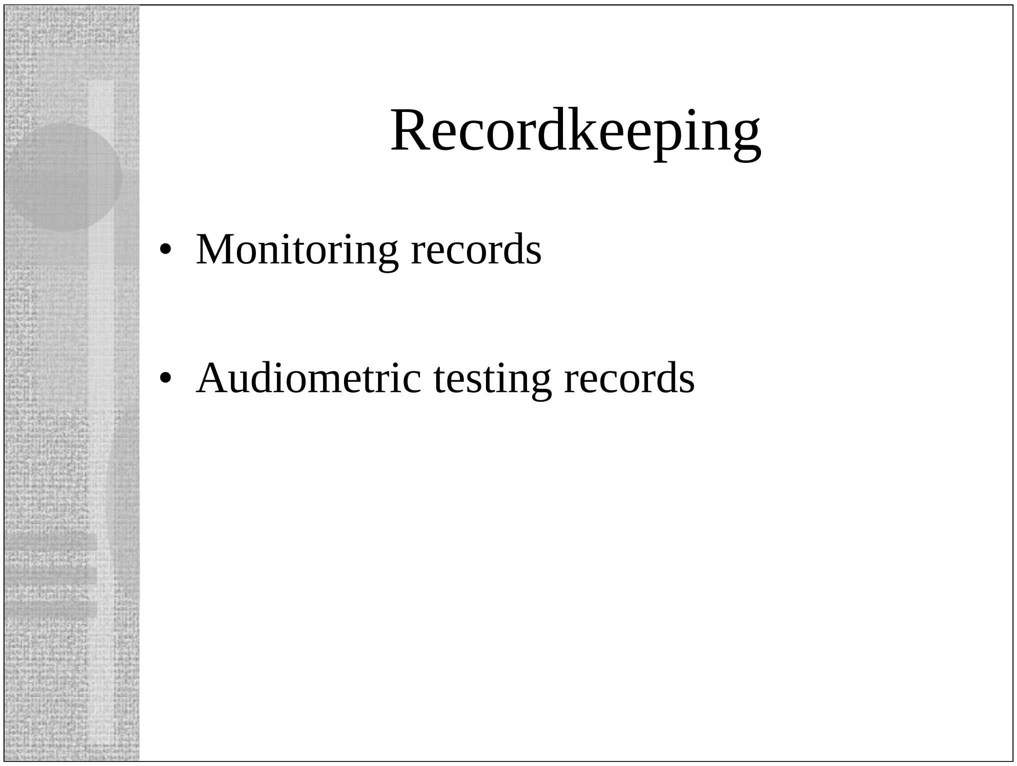
Training requirements

- Annual Training
- Hearing Conservation Elements
- Hearing Protectors

The five elements include, monitoring, audiometric testing, training, hearing protectors, and recordkeeping.

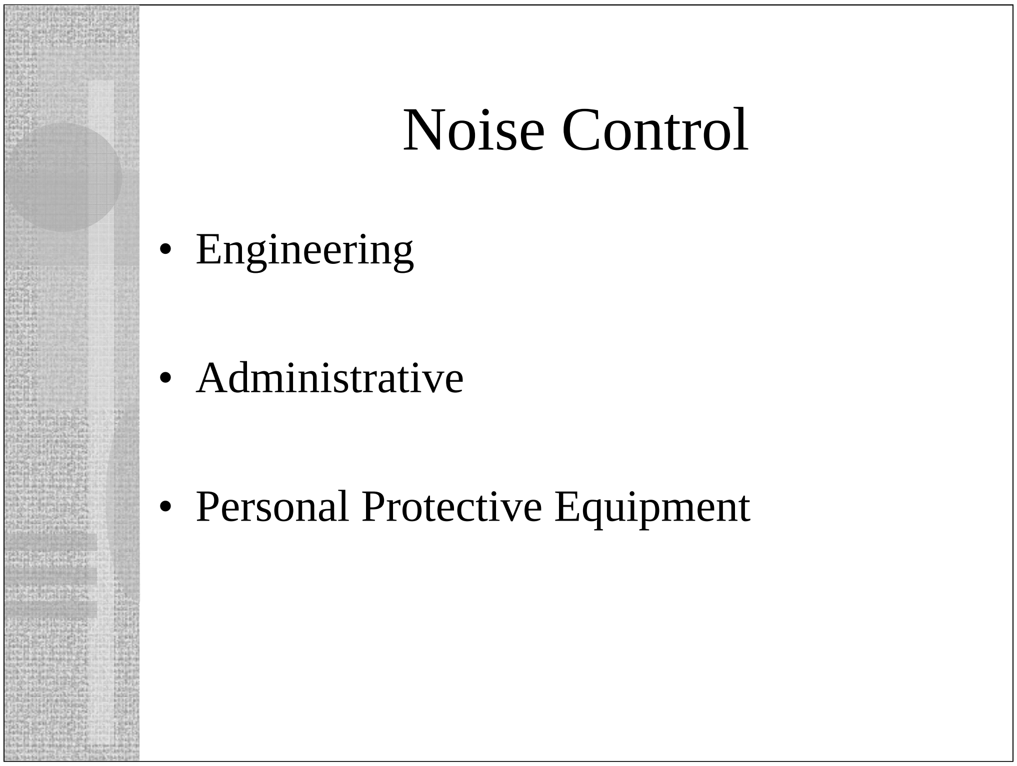
Employees need to understand noise, its effect on your body, and the requirements of the hearing conservation amendment and the protection that it provides to the employees.

Hearing protectors can be insert type, canal caps, or ear muffs. Each of these basic types have several choices as an example insert type includes, foam inserts, plastic inserts, or custom fitted protection. Each has advantages and disadvantages including comfort, fit factor, cleanliness, and cost.



Monitoring records must be kept for two years by the OSHA standard, however, records that indicate actual exposures in the workplace should be maintained and made available as needed (OSHA inspection, change in safety, HR, or administrative personnel).

Audiometric testing results must be kept for the period of employment.



If noise levels are above 90dBA, OSHA requires engineering controls to reduce the noise in the workplace. Interpretation of this requirement over the years has identified that if it's economically and technically feasible, noise control needs to be implemented between 90 and 100 dBA. Above 100 dBA, if it's technically feasible then noise control **must** be implemented regardless of cost.

Administrative controls while an option, are not typically used to control noise exposures.

PPE is the control method that is typically used.

What we're doing to control noise

- Fill in here what you're company is doing to reduce exposure to noise……..

Generate discussion about your company's efforts to reduce noise levels.

Noise and Hearing Conservation
Frequently Asked Questions

Q. What is hearing conservation?

A. Hearing conservation is the concerted effort by employers, medical providers, and state and federal governments to minimize occupational noise-induced hearing loss and the costs associated with it. A comprehensive hearing conservation program includes monitoring, audiometric testing, employee training, hearing protection and record-keeping.

Q. Why is hearing conservation important to my company?

A. Approximately 30 million people in the United States are exposed to hazardous noise in occupational settings. About 10 million people have noise-induced hearing loss, nearly all of which was caused by occupational exposures. Fortunately, the incidence of occupational noise-induced hearing loss can be reduced or eliminated through the successful application of engineering controls and hearing conservation programs.

Q. Am I required by OSHA to have a hearing conservation program?

A. OSHA's hearing conservation program is designed to protect workers with significant occupational noise exposure from suffering material hearing impairment. Employers are required to implement a program for employees who are exposed to noise at or above 85 decibels (dB) averaged over eight working hours, or an eight-hour time weighted average (TWA). That is, employers must monitor all employees whose noise exposure is equivalent to or greater than a noise exposure received in eight hours where the noise level is constantly 85dB.

Q. What is the difference between a baseline and an annual audiogram?

A. The baseline audiogram is the reference audiogram against which future audiograms are compared. Baseline audiograms must be provided within six months of an employee's first exposure at or above an eight-hour time weighted average (TWA) of 85dB.

The annual audiogram identifies deterioration in hearing ability so that protective follow-up measures can be initiated before hearing loss progresses. Annual audiograms must be routinely compared to baseline audiograms to determine whether the audiogram is valid and to determine whether the employee has lost hearing ability. Annual audiograms must be conducted within one year of the baseline.

Q. Who is required to wear hearing protection?

A. Hearing protectors must be available to all workers exposed to eight-hour time weighted average (TWA) noise levels of 85dB or above. With the help of a person who is trained in fitting hearing protectors, employers should determine what size and type of protector is most suitable for their working environment. Employers must re-evaluate the suitability of the employee's current protector whenever there is a change in working conditions that may cause the hearing protector to be inadequate or if a standard threshold shift (STS) has occurred in the worker's hearing.

Q. How long am I required to maintain records?

A. OSHA requires noise exposure measurement records be kept for two years and staff audiometric test results maintained for the duration of employment. NIOSH recommends that noise exposure measurement records and audiometric test results be maintained for the duration of employment plus 30 years.

Q. What is CAOHC?

A. CAOHC, or the Council for Accreditation in Occupational Hearing Conservation, is dedicated to the establishment and maintenance of training standards for those who safeguard hearing in the workplace. CAOHC certification is required for all individuals who provide audiometric testing and offers credibility and also serves as verification that medical providers have been trained to the highest standards.

Q. What is noise?

A. Any disturbing, harmful, or unwanted sound.

Q. What are the different types of noise?

A. Noise can be continuous or steady. Examples include power tools, vehicles, and aircraft. Noise can also be impulsive (banging) such as certain industrial machinery.

Q. Will noise toughen your ears?

A. No! Noise destroys your ability to hear and to understand speech.

Q. When and where can noise impair your hearing?

A. Noise can damage your hearing at work, at home, and during recreational activities. Noise in combination with some chemical exposures can increase hearing damage. For example toluene, lead, carbon monoxide, etc.

Student Handouts

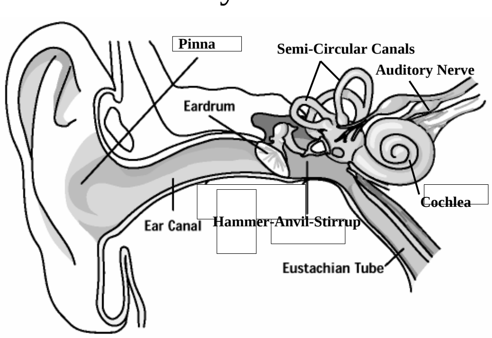
Hearing Conservation

and
Noise Control

WHY??????

- It's the LAW
- Quality of Life
- Gradual / Painless

Anatomy of the Ear



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advantages / disadvantages

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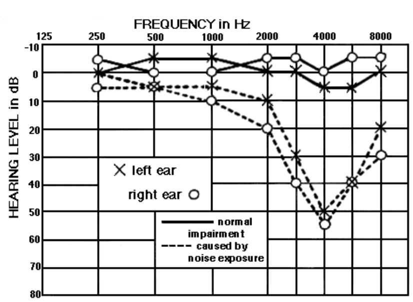

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Noise Control

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Glossary Of Common Terms

ACGIH – The American Conference of Governmental Industrial Hygienists.

Action level – The OSHA action level is an 8-hour time-weighted average of 85 decibels measured on the A-scale, slow response, or equivalently, a dose of fifty percent.

Audiogram - A chart, graph, or table resulting from an audiometric test showing an individual's hearing threshold levels as a function of frequency.

Audiologist - A professional, specializing in the study and rehabilitation of hearing, who is certified by the American Speech-Language-Hearing Association or licensed by a state board of examiners.

Baseline audiogram - The audiogram against which future audiograms are compared.

Criterion sound level - A sound level of 90 decibels per the OSHA standard and 85 decibels is recommended by ACGIH.

Decibel (dB) - Unit of measurement of sound level.

Hertz (Hz) - Unit of measurement of frequency, numerically equal to cycles per second.

Noise dose - The numerical expression of exposure where 100% would be equal to an average exposure of 90 dBA.

Noise dosimeter - An instrument that integrates a function of sound pressure over a period of time in such a manner that it directly indicates a noise dose.

Otolaryngologist - A physician specializing in diagnosis and treatment of disorders of the ear, nose and throat.

Permissible Exposure Limit (PEL) – OSHA's PEL is presently 90 dBA. A time weighted average exposure that must not be exceeded during any 8-hour work shift of a 40-hour work week.

Representative exposure - Measurements of an employee's noise dose or 8-hour time-weighted average sound level that the employers deem to be representative of the exposures of other employees in the workplace.

Sound level – A measured sound pressure level as it relates to a reference pressure level expressed in decibels.

Sound level meter - An instrument for the measurement of sound level.

Standard Threshold Shift (STS) – OSHA uses the term to describe a change in hearing threshold relative to the baseline audiogram of an average of 10 dB or more at 2000, 3000, and 4000 Hz in either ear. OSHA uses an STS to trigger additional audiometric testing and follow-up.

Significant Threshold Shift – Used by the National Institute of Occupational Safety and Health (NIOSH) to describe a change of 15 dB or more at any frequency, 500 through 6000 Hz, from baseline levels that is present on an immediate retest in the same ear and at the same frequency.

Threshold limit value (TLV) – A guideline provided by the American Conference of Governmental Industrial Hygienists (ACGIH) to denote the exposure, which when reached or exceeded, may be hazardous. For noise the TLV is 85 dBA.

Time-weighted average (TWA) sound level - That sound level, which if constant over an 8-hour exposure, would result in the same noise dose as is measured.