CHARLES CITY COUNTY
PLANNING COMMISSION MEETING
September 22, 2016 @ 7 PM
Government/School Board Administration Building
Auditorium

AGENDA

I. CALL TO ORDER

II. MINUTES
- August 25, 2016 Minutes

III. UNFINISHED BUSINESS

IV. NEW BUSINESS
1) Zoning Ordinance Amendment to Planned Development-Industrial Park Zoning District, Section 13-3 Uses with Special Use Permit to include the use "Recreational Facility, Private".

V. PLANNING DIRECTOR
1) Joint Public Hearing scheduled for September 27, 2016 at 7:30 PM to hear comment on Application #REZ-02-2016, Ron Marshburn, and #SUP-02-2015, New Lexington, August Amendment.

2) Noise Levels Comparisons
   - OSHA, Section III, Chapter 5, Noise
   - The Latest Illustrated Book of Development Definitions
     Table D-1: Sound Levels and Human Response
   - Other Charts

VI. PUBLIC COMMENT

VII. ADJOURNMENT

VIRGINIA:

The Charles City County Planning Commission met on August 25, 2016, in the 241st year of the Commonwealth and the 382nd year of the County. Chairman Edward L. Baber, Jr. called the meeting to order at 7:00 P.M.

PRESENT: Edward L. Baber, Jr., Chairman
C. Linny Miles, Vice-Chairman
Andrew Adams
Brenda Adkins
Barney Lomax
Kevin R. Pittman
Gilbert A. Smith
Yvonne Smith-Jones

OTHERS: Rachel Chieppa, Director of Planning
Rebecca H. Stewart, Recording Secretary

ABSENT: William B. Bailey

RE: MINUTES

The Commission minutes for July 28, 2016 were presented for approval. Mr. Gilbert Smith made a motion to approve, as corrected, the minutes for July 28, 2016. The motion was seconded by Mr. Kevin Pittman, and carried by a vote of 8:0.

RE: SUP-03-2016, CHARLES CITY COUNTY, AUGUST 2016 AMENDMENT

Charles City County requests to amend #SUP-03-2015, Approved 5/28/2015, Amended 12/9/2015, Condition #24 to read, **"Noise levels at the property lines shall not exceed 85 decibels."** Mrs. Rachel Chieppa, Planning Director, presented the staff report.

The Board of Supervisors approved on May 28, 2015, and amended on December 9, 2015 a special use permit to construct and operate a central utility system in conjunction with a right-of-way greater than or equal to 30 feet in width in order to operate a 1,100 megawatt combined cycle natural gas power plant, with secondary solar power, and incidental switching station and fuel storage. Applicant is requesting to amend Condition #24 to allow noise level to increase so that at the property lines the decibels shall not exceed 85 decibels. Charles City County Noise Ordinance, Sec. 20-176, exempts noise that customarily accompanies industrial uses.

Planning Commissioners discussed the noise decibel levels and requested that staff provide more information on decibel levels. Mrs. Brenda Adkins made a motion to forward to the Board of Supervisors for the scheduling of a joint public hearing, SUP-03-2015, Charles City County (Approved 5/28/15; amended 12/9/15), August 2016 amendment to Condition #24. The motion was seconded by Mr. Andrew Adams, and carried by a vote of 8:0.

RE: SUP-02-2015, NEW LEXINGTON LLC, AUGUST 2016 AMENDMENT

New Lexington, LLC, requests to amend #SUP-02-2015, Approved 5/28/2015, Condition #1 and #24 to read as follows:

Condition #1 **The permit is for the construction and operation of a central utility system in conjunction with a right of way greater than or equal to 30 feet in width in order to operate up to a 1,500 megawatt natural gas power plant with incidental switching station and fuel storage, and/or a utility scaled solar farm in excess of 20 megawatt name plate capacity. The facility shall be constructed, operated, and maintained in accordance with all rules and regulations of the Charles City County Zoning Ordinance, with any and all terms and conditions of this special use permit, and in compliance with all federal, state, and other local laws and regulations for this use.**

Condition #24 **Noise levels at the property lines and public streets shall not exceed 85 decibels.**

Mr. Tom Vosnick was present to answer any questions the Commission may have. Mrs. Rachel Chieppa, Planning Director, presented the staff report.

The Board of Supervisors approved on May 28, 2015, a special use permit to construct and operate a central utility system in conjunction with a right-of-way greater than or equal to 30 feet in width in order to operate up to a 1,000 megawatt natural gas power plant with incidental switching station and fuel storage, and/or a utility scaled solar farm in excess of 20 megawatt name plat capacity. Applicant is requesting to amend Condition #1 to increase the megawatts to 1,500; and to amend Condition #24 to allow the noise levels to increase so that at the property lines and streets the decibels shall not exceed 85 decibels. Charles City County Noise Ordinance, Sec. 20-176, exempts noise that customarily accompanies industrial uses.

Mr. Linny Miles made a motion to forward to the Board of Supervisors for the scheduling of a joint public hearing, SUP-02-2015, New Lexington LLC (Approved 5/28/15), August 2016 amendment to Conditions #1 and #24. The motion was seconded by Mr. Kevin Pittman, and carried by a vote of 8:0.

RE: MEETING

There being no items to discuss at the Work Session scheduled for September 8, 2016, Mr. Gilbert Smith made a motion to cancel the September 8, 2016, Commission meeting. The motion was seconded by Mr. Andrew Adams, and carried by a vote of 8:0.

RE: ADJOURNMENT

The Commission meeting adjourned at 8:00 P.M.

_____ _____

Edward L. Baber, Jr., Chairman Rebecca H. Stewart, Recording Secretary

Commonwealth of Virginia
County of Charles City
Planning/Economic Development

TO: Planning Commission

FROM: Rachel Chieppa, Director
Planning /Economic Development

DATE: September 12, 2016

SUBJECT: Amendment to PD-IP Zoning District

The Planning Department has received a request to amend the Planned Development-Industrial Park (PD-IP) Zoning District to include the use "Recreational Facility, Private". Approval of this amendment would allow a property owner of an existing building the ability to covert his industrial building into a batting cage to be used by ball teams to practice. Please see the attached email from Thomas Wilson describing the plans for using the building and the opening of New Kent Sports Academy.

The intent of the PD-IP District is to provide opportunities for light and medium intensity industrial activities, warehousing and distribution centers, and office/research buildings in a comprehensively designed and managed setting. The PD-IP District will enable the clustering of industrial, warehousing and office uses into a park like setting thereby blending in with the rural atmosphere prevalent and desired in the County, and making delivery of services more cost effective.

Post Office Box 66, Charles City, VA 23030
(804) 652-4707

My name is Thomas G. Wilson IV. I am a current resident of New Kent County and graduate of New Kent High School. I am contacting you in reference to a small business I am attempting to open up at 104 Roxbury Industrial in Charles City County.

My business is a small sports training facility for the youth of New Kent and Charles City Counties. Within this facility youth will learn the fundamentals of baseball, football, as well strength and conditioning. I anticipate offering classes for adults such as Zumba and other cardiovascular classes that involve music to add to the appeal of everyone getting up and moving around a bit more.

Each season I coach a variety of different sports within the New Kent County Parks and Recreation Department to include Football, Basketball and Baseball. I am currently the Head Coach of the New Kent Faclon's 10u football team. This team consists of three very talented players that live in Charles City County.

It was disheartening to hear in late July that Charles City County was unable to field a football team for the age group that I coach, as I have always looked forward to this friendly rivalry that dates back to when I was in high school. Kids that live in Charles City are just as talented as any other kids in surrounding counties, across the state and country for that matter.

My father was a lifelong resident of Charles City County. Although I lived in New Kent County I spent countless days, weekends and summers spending time and playing baseball at Harrison Park for Charles City Little League.

My vision going forward is to give the youth of both counties and abroad the access to quality instruction in various sports. Kids in surrounding counties have closer access to facilities such as the one I am attempting to open. There are at least two of these facilities in Williamsburg and one in Mechanicsville that other kids have access to. This year-round access gives other localities a bit of an edge when it comes to sports.

Now I do realize that sports are not everything. As a vast majority of youth will not go on to play on the professional level. However, I am a firm believer that youth sports provide constructive use of their time as well as life lessons that they will remember forever.

I kindly request a meeting soon with you and other Zoning Commission members to discuss the possibility of allowing this place of business to be permitted. As I have already spent a fair amount of money on remodeling this space, along with batting cages, baseball tees, artificial turf, baseballs, softballs, batting mats, televisions and furniture for the area where parents can sit and relax while their children are training.

I am currently in a lease agreement with the building owner Tim Carroll, as a deposit and 1st months rent has been paid. Rent is due again on October 1st, 2016. I understand that the next Zoning Commission meeting is September 22, 2016 at 7:30 pm. This leaves me in between a rock and a hard place as I do not know whether to continue to finish the space as I do not have approval from the county. This also pushes back my anticipated opening day pending approval which does not allow for any revenue to be produced.

Also, please see links provided as they will give you a better idea of the type of business I am attempting to open.

https://www.youtube.com/watch?v=8KRiy2Iqmrl

Thank your for time.

Sincerely,
Thomas G. Wilson, IV
804-912-5852

September 12, 2016 Amendment

Amend Section 13-3 USES WITH SPECIAL USE PERMIT to include the use 'RECREATIONAL FACILITY, PRIVATE".

RECREATIONAL FACILITY, PRIVATE is defined as a "Facility open to the public for recreation and amusement. (i.e. miniature golf, batting cage, bowling alley, skating rink, billiards, pool room or a golf range without golf course."

SECTION 13 - PLANNED DEVELOPMENT-INDUSTRIAL PARK DISTRICT (PD-IP)

13-1 STATEMENT OF INTENT

The Planned Development-Industrial Park District (PD-IP) is established to provide opportunities for light and medium intensity industrial activities, warehousing and distribution centers, and office/research buildings in a comprehensively designed and managed setting. The PD-IP District will enable the clustering of industrial, warehousing and office uses into a park like setting thereby blending in with the rural atmosphere prevalent and desired in the County, and making delivery of services more cost effective. The PD-IP District is designed to:

- ✓ increase the flexibility of design and development;
- ✓ ensure the compatible operation of productive activities and community growth;
- ✓ provide development sites for small, medium and large-sized industrial firms;
- ✓ provide location opportunities for industries with high growth which are likely to be attracted to the County;
- ✓ assist the County by attracting new employment opportunities;
- ✓ expand the fiscal capacity of the County by broadening the tax base;
- ✓ contribute positively to community appearance; and,
- ✓ respect the natural rural environment.

13-2 PERMITTED USES

The PD-IP Zoning District permits uses that carry on processes within completely enclosed buildings. Any structure to be erected or land to be used shall be for one or more of the following uses provide that there are no inherent hazards associated with such uses and further provide that no nuisance may occur from fire or explosion, toxic or corrosive fumes, gas, smoke, odors, obnoxious dust or vapor, offensive noise or vibrations, glare, flashes or objectionable effluent and electrical interference which may adversely affect or impair the normal use of any other property.

.10 Alternative Support Structure (10/27/2015)

1. Business service facilities

2. Business, wholesale

2.2 Commercial Subdivision (8/28/2012)

2.8 Data Pole **(10/27/2015)**

2.9 Family Subdivision **(8/28/2012)**

3. Garage, Business
   a. All work to be within an enclosed facility.

   b. No more than five vehicles stored outside.

   c. All vehicles stored outside are to be operable.

4. Governmental activity

4.1 Industrial Sales & Service, provided that tall work, other than limited incidental work, must be done within a completely enclosed building, and outside storage is permitted so long as such storage ia screened from view from public roads. **(10/28/2008)**

5. Manufacturing, light

6. Mini-warehouse
   a. All storage buildings shall face the center of the property. All circulation on-site shall be designed to be internal; no aisles shall be placed between a building and a property line unless only one building is proposed on site.

   b. All interior driveways shall be at least 26 feet wide when cubicles open onto one side only and at least 30 feet wide when cubicles open onto both sides to accommodate loading and unloading at individual cubicles. When interior drives are specified to be "one way only" the widths shall be at least 26 feet wide. Adequate turning radiuses shall be provided, where appropriate, for a 30-foot long single unit truck or moving van.

   c. Activity on site other than storage of customers' goods and wares shall be prohibited.

   d. Outdoor storage areas shall be used for the storage of motor vehicles, trailers, boats, and recreational vehicles only. All outdoor storage areas shall be screened from adjoining properties according to section 24 of this article.

e. Mini-warehouse developments shall not be accessible to the general public (excluding on-site managers) between the hours of 12:00 p.m. (midnight) and 5:00 a.m.

f. The minimum lot size for a mini-warehouse development shall be two acres, and the maximum developed area for a mini-warehouse shall be four acres.

g. No door openings for a cubicle shall be constructed facing any residential use type.

7. Professional service facilities

8. Use, accessory

9. Warehousing

13-3 USES WITH SPECIAL USE PERMIT

~~None~~

1. Recreational Facility, Private

13-4 AREA REQUIREMENTS

There is no minimum area requirement for lots within planned development industrial parks serviced by public utilities.

13-5 SETBACK REQUIREMENTS

1. Buildings shall be located a minimum 100 feet from any public street right-of-way except that lots fronting on a public street or right-of-way entirely within the subdivision of which the lot is a part, shall be a minimum of 35 feet.

2. The minimum setback shall be as 35 feet.

3. Outside storage of raw materials, work in progress and finished goods shall not be permitted between the building setback and any public vehicular right-of-way. All outside storage areas shall be screened from public view.

13-6 WIDTH REQUIREMENTS

The minimum width for permitted uses is that width which is sufficient to meet all setback requirements.

13-7 YARD REQUIREMENTS

1. Side yard: ten feet

2. Total of both side yards: 35 feet

3. Rear yard: 35 feet

4. Side and rear yards adjacent to residential districts: 50 feet

13-8 HEIGHT REQUIREMENTS

1. The maximum height of all buildings excluding chimneys, flues, cooling towers, flagpoles, and communications towers shall be 50 feet.

2. Chimneys, flues, cooling towers, flagpoles, radio or communication towers or their accessory facilities not normally occupied by workmen are allowed up to 75 feet.

3. Parapet walls are permitted up to four feet above the limited height of the building on which the walls rest.

13-9 OFF-STREET PARKING REQUIREMENTS

All parking required for the Planned Development-Industrial Park District shall comply with the Off-Street Parking section of this Ordinance. In addition, the following standards shall apply:

1. Parking shall be provided in accordance with the following standards related to space utilization:
   a. Warehousing: one space per 1,000 square feet of gross floor area

   b. Manufacturing: one space per 500 square feet of gross floor area

   c. Office: one space per 200 square feet of gross floor area

2. Storage and parking areas shall be located 25 feet from property lines adjacent to areas zoned residential.

3. No parking shall be located in the required 35-foot front yard setback.

4. Parking areas shall be located no closer than ten feet to any side or rear property line.

5. The number of required parking spaces constructed can be waived if the applicant can demonstrate to the Zoning Administrator that the Off-Street Parking section requires the installation of more parking spaces than are needed by a specific business or industry. Waivers can only be granted by the Zoning Administrator if a land area on

the lot large enough to accommodate the difference in the number of parking spaces installed versus parking spaces required is left vacant. These additional spaces shall be constructed within 45 days of written notice by the Zoning Administrator if, in the Administrator's opinion based upon observed parking demand, they become necessary.

13-10 UTILITY REQUIREMENTS

Water and Sewer: The developer shall receive the approval of the Department of Health relative to the provision of a potable water supply and adequate sewage disposal facilities. The Zoning Administrator may require a greater area if considered necessary by health officials.

13-11 LANDSCAPING REQUIREMENTS

1. Structures and uses within the Planned Development Industrial Park section shall comply with the landscape standards set forth in the Landscape, Screening and Buffer section of this Ordinance.

2. Landscaping information shall be included on the plan. Landscaping should be provided for climate control (for example, shade trees to shield buildings and parked automobiles from the summer sun and evergreens to serve as windbreaks from winter winds), to accent and compliment buildings, at entrances deserving special landscape treatment and as buffers to minimize the effect of any adverse impacts of nuisance on adjacent properties.

3. Screening and buffering plan must be submitted for the approval of the Zoning Administrator prior to the issuance of a building permit.

13-12 SIGNAGE REQUIREMENTS

All signage permitted in this section must comply with the Sign section of this Ordinance.

13-13 ACCESSORY USES AND STRUCTURES

1. Cafeterias for employees of the permitted use in which it is located.

2. Day care

3. Day care center

4. Dwelling, company

5. Factory outlets and retailing provided the use is clearly incidental to the permitted use and products sold originated at the site.

6. Garages and storage buildings.

7. Outside storage to be screened and no more than 25% of footprint of building is allowed.

8. Parks

9. Playground

10. Radio and/or signal transmission towers less that 75 feet in height above ground level, located in the rear or side yard.

13-14 SPECIAL CONDITIONS

1. Before a building permit shall be issued or construction commenced on any permitted use in this district, the plans, in sufficient detail to show the operations and processes, shall be submitted to the zoning administrator for study. The Zoning Administrator may refer these plans to the Planning Commission for recommendation.

2. The maximum lot coverage of buildings shall not exceed 60 percent. The maximum lot coverage shall be determined by dividing the gross land area within a lot into the portion of the lot covered by the ground floor of all buildings.

3. An erosion and sediment control plan shall accompany each submission.

4. The Zoning Administrator shall act on any complete permit application reviewed within 20 days after receiving the application. If formal notice in writing is given to the applicant, the time for action may be extended for a 20-day period. Failure on the part of the Zoning Administrator to act on the application within the established time limit shall be deemed to constitute approval of the application.

5. Lighting information shall be included on the plan. Lighting shall be installed in parking areas and along walkways if nighttime operations are anticipated. Lighting shall be directed downward or upward in order to minimize shining into adjacent windows or onto streets and driveways to avoid interfering with or distracting driver vision.

13-15 ENVIRONMENTAL AND SITE PLAN REQUIREMENTS

All uses and structures shall comply with all other Environmental and Site Plan Ordinances and regulations.

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Noise

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The mention of trade names, commercial products, or organizations does not imply endorsement by OSHA or the U.S. Government.

I. Introduction

Noise, or unwanted sound, is one of the most common occupational hazards in American workplaces. The National Institute for Occupational Safety and Health (NIOSH) estimates that 30 million workers in the United States are exposed to hazardous noise. Exposure to high levels of noise may cause hearing loss, create physical and psychological stress, reduce productivity, interfere with communication, and contribute to accidents and injuries by making it difficult to hear warning signals.

This chapter provides technical information and guidance to help Compliance Safety and Health Officers (CSHOs) evaluate noise hazards in the workplace. The content is based on currently available research publications, OSHA standards, and consensus standards.

The chapter is divided into six main sections. Following this introduction, the second section provides background information about noise and noise regulations and an overview of noise controls. The third section describes worksite noise evaluations, including noise measurement equipment, noise evaluation procedures, and noise sampling. The fourth section offers investigative guidelines (including methods for planning the investigation) and outlines a strategy for conducting noise evaluations. The fifth section describes noise hazard abatement and control, including engineering and administrative controls, hearing protection, noise conservation programs, cost comparisons between noise hazard abatement options, and case studies. The final two sections provide references used to produce this chapter and resources for obtaining additional information. Following the main sections, the appendices provide a glossary of terms, sample calculations, and expanded discussion of certain topics introduced in the chapter.

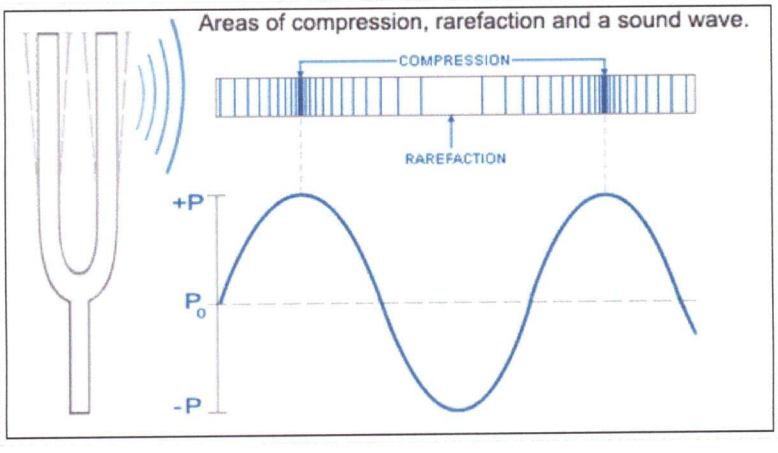
II. Background Information

A. What Is Noise?

Occupational noise can be any sound in any work environment.

A textbook definition of sound is "a rapid variation of atmospheric pressure caused by some disturbance of the air." Sound propagates as a wave of positive pressure disturbances (compressions) and negative pressure disturbances (rarefactions), as shown in Figure 1. Sound can travel through any elastic medium (e.g., air, water, wood, metal).

Figure 1. Sound Waves



When air molecules are set to vibrate, the ear perceives the variations in pressure as sound (OTM/Driscoll). The vibrations are converted into mechanical energy by the middle ear, subsequently moving microscopic hairs in the inner ear, which in turn convert the sound waves into nerve impulses. If the vibrations are too intense, over time these microscopic hairs can be damaged, causing hearing loss. Noise is unwanted sound. In the workplace, sound that is intense enough to damage hearing is unwanted and, therefore, is considered to be noise.

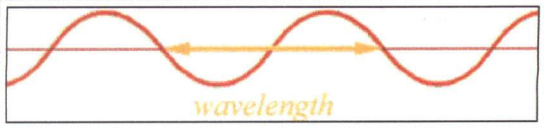
Several key terms describe the qualities of sound. These qualities influence how it affects hearing and health, how it is measured, and how it can be controlled. Effective occupational noise investigations require the investigator to understand these basic terms.

B. Basic Qualities of Sound

Figure 2. Wavelength

1. **Wavelength**
   The wavelength (λ) is the distance traveled by a sound wave during one sound pressure cycle, as shown in Figure 2. The wavelength of sound is usually measured in meters or feet. Wavelength is important for designing engineering controls. For example, a sound-

absorbing material will perform most effectively if its thickness is at least one-quarter the wavelength.



2. **Frequency**
   Frequency, f, is a measure of the number of vibrations (i.e., sound pressure cycles) that occur per second. It is measured in hertz (Hz), where one Hz is equal to one cycle per second.

   Sound frequency is perceived as pitch (i.e., how high or low a tone is). The frequency range sensed by the ear varies considerably among individuals. A young person with normal hearing can hear frequencies between approximately 20 Hz and 20,000 Hz. As a person gets older, the highest frequency that he or she can detect tends to decrease.

   Human speech frequencies are in the range of 500 Hz to 4,000 Hz. This is significant because hearing loss in this range will interfere with conversational speech. The portions of the ear that detect frequencies between 3,000 Hz and 4,000 Hz are the earliest to be affected by exposure to noise. Audiograms often display a 4,000-Hz "Notch" in patients who are developing the beginning stages of sensorineural hearing loss

3. **Speed**
   The speed at which sound travels, c, is determined primarily by the density and the compressibility of the medium through which it is traveling. The speed of sound is typically measured in meters per second or feet per second.

   Speed increases as the density of the medium increases and its elasticity decreases. For example:

   - In air, the speed of sound is approximately 344 meters per second (1,130 feet per second) at standard temperature and pressure.
   - In liquids and solids, the speed of sound is much higher. The speed of sound is about 1,500 meters per second in water and 5,000 meters per second in steel.

   The **frequency, wavelength,** and **speed** of a sound wave are related by the equation

$$c = f \lambda$$

   Where c = speed of sound in meters or feet per second, f = frequency in Hz, and λ = wavelength in meters or feet.

4. **Sound Pressure**
   The vibrations associated with sound are detected as slight variations in pressure. The range of sound pressures perceived as sound is extremely large, beginning with a very weak pressure causing faint sounds and increasing to noise so loud that it causes pain.

   The threshold of hearing is the quietest sound that can typically be heard by a young person with undamaged hearing. This varies somewhat among individuals but is typically in the micropascal range. The reference sound pressure is the standardized threshold of hearing and is defined as 20 micropascals (0.0002 microbars) at 1,000 Hz.

   The threshold of pain, or the greatest sound pressure that can be perceived without pain, is approximately 10 million times greater than the threshold of hearing. It is, therefore, more convenient to use a relative (e.g., logarithmic) scale of sound pressure rather than an absolute scale (OTM/Driscoll).

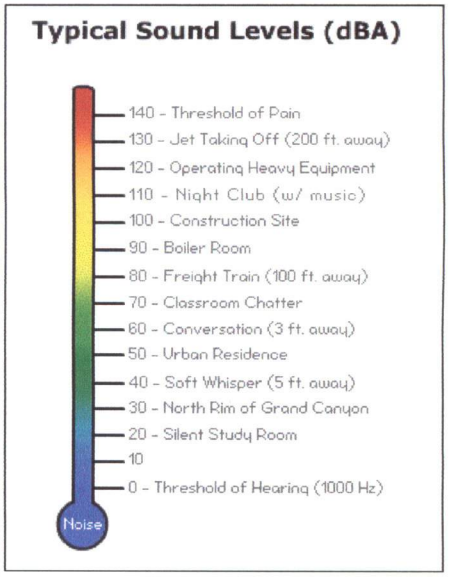
5. **Decibels**
   Noise is measured in units of sound pressure called decibels (dB), named after Alexander Graham Bell. The decibel notation is implied any time a "sound level" or "sound pressure level" is mentioned.

   Click here to compare the decibel levels generated by familiar noise sources.

   Decibels are measured on a logarithmic scale: a small change in the number of decibels indicates a huge change in the amount of noise and the potential damage to a person's hearing.

   The decibel scale is convenient because it compresses sound pressures important to human hearing into a manageable scale. By definition, 0 dB is set at the reference sound pressure (20 micropascals at 1,000 Hz, as stated earlier). At the upper end of human hearing, noise causes pain, which occurs at sound pressures of about 10 million times that of the threshold of hearing. On the decibel scale, the threshold of pain occurs at 140 dB. This range of 0 dB to 140 dB is not the entire range of sound, but is the range relevant to human hearing (Figure 3).

   Figure 3. Decibel Scale



   Decibels are logarithmic values, so it is not proper to add them by normal algebraic addition. See Appendix B for information on the cumulative effects of multiple sound sources on the decibel level.

   The decibel is a dimensionless unit; however, the concepts of distance and three-dimensional space are important to understanding how noise spreads through an environment and how it can be controlled. Sound fields and sound power are terms used in describing these concepts.

6. **Sound Fields**
   Many noise-control problems require a practical knowledge of the relationships between:

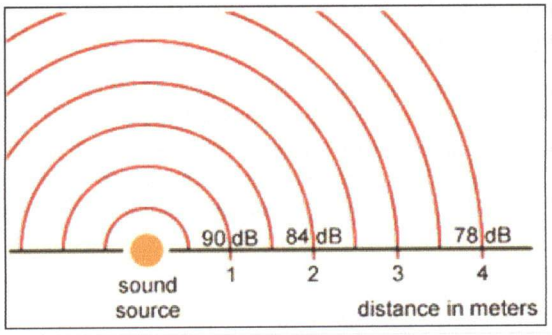
   - A sound field (a region in which sound is propagating) and two related concepts.
   - Sound pressure (influenced by the energy [in terms of pressure] emitted from the sound source, the distance from the sound source, and the surrounding environment) (OTM/Driscoll).
   - Sound power (sound energy emitted from a sound source and not influenced by the surrounding environment).

   Sound fields are categorized as near field or far field, a distinction that is important to the reliability of measurements. The near field is the space immediately around the noise source, sometimes defined as within the wavelength of the lowest frequency component (e.g., a little more than 4 feet for a 25-Hz tone, about 1 foot for a 1,000-Hz tone, and less than 7 inches for a 2,000-Hz tone). Sound pressure measurements obtained with standard instruments within the near field are not reliable because small changes in position can result in big differences in the readings.

The far field is the space outside the near field, meaning that the far field begins at a point at least one wavelength distance from the noise source. Standard sound level meters (i.e., type I and type II) are reliable in this field, but the measurements are influenced by whether the noise is simply originating from a source (free field) or being reflected back from surrounding surfaces (reverberant field).

A free field is a region in which there are no reflected sound waves. In a free field, sound radiates into space from a source uniformly in all directions. The sound pressure produced by the source is the same in every direction at equal distances from the point source. As a principle of physics, the sound pressure level decreases 6 dB, on a Z-weighted (i.e., unweighted) scale, each time the distance from the point source is doubled. This is a common way of expressing the inverse-square law in acoustics and is shown in Figure 4.

Figure 4. Sound Pressure Levels in a Free Field

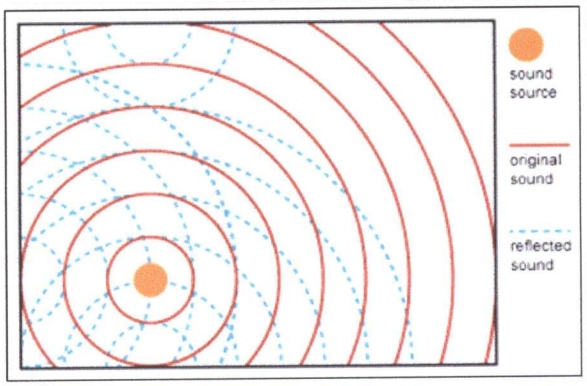


If a point source in a free field produces a sound pressure level of 90 dB at a distance of 1 meter, the sound pressure level is 84 dB at 2 meters, 78 dB at 4 meters, and so forth. This principle holds true regardless of the units used to measure distance.

Free field conditions are necessary for certain tests, where outdoor measurements are often impractical. Some tests need to be performed in special rooms called free field or anechoic (echo-free) chambers, which have sound-absorbing walls, floors, and ceilings that reflect practically no sound.

In spaces defined by walls, however, sound fields are more complex. When sound-reflecting objects such as walls or machinery are introduced into the sound field, the wave picture changes completely. Sound reverberates, reflecting back into the room rather than continuing to spread away from the source. Most industrial operations and many construction tasks occur under these conditions. Figure 5 diagrams sound radiating from a sound source and shows how reflected sound (dashed lines) complicates the situation.

Figure 5. Original and Reflected Sound Waves



The net result is a change in the intensity of the sound. The sound pressure does not decrease as rapidly as it would in a free field. In other words, it decreases by less than 6 dB each time the distance from the sound source doubles.

Far from the noise source--unless the boundaries are very absorbing--the reflected sound dominates. This region is called the reverberant field. If the sound pressure levels in a reverberant field are uniform throughout the room, and the sound waves travel in all directions with equal probability, the sound is said to be diffuse.

In actual practice, however, perfectly free fields and reverberant fields rarely exist--most sound fields are something in between.

7. **Sound Power**

Up to this point, this discussion has focused on sound pressure. Sound power, however, is an equally important concept. Sound power, usually measured in watts, is the amount of energy per unit of time that radiates from a source in the form of an acoustic wave. Generally, sound power cannot be measured directly, but modern instruments make it possible to measure the output at a point that is a known distance from the source.

Understanding the relationship between sound pressure and sound power is essential to predicting what noise problems will be created when particular sound sources are placed in working environments. An important consideration might be how close workers will be working to the source of sound. As a general rule, doubling the sound power increases the noise level by 3 dB.

As sound power radiates from a point source in free space, it is distributed over a spherical surface so that at any given point, there exists a certain sound power per unit area. This is designated as intensity, I, and is expressed in units of watts per square meter.

Sound intensity is heard as loudness, which can be perceived differently depending on the individual and his or her distance from the source and the characteristics of the surrounding space. As the distance from the sound source increases, the sound intensity decreases. The sound power coming from the source remains constant, but the spherical surface over which the power is spread increases--so the power is less intense. In other words, the sound power level of a source is independent of the environment. However, the sound pressure level at some distance, r, from the source depends on that distance and the sound-absorbing characteristics of the environment (OTM/Driscoll).

8. **Filtering**

Most noise is not a pure tone, but rather consists of many frequencies simultaneously emitted from the source. To properly represent the total noise of a source, it is usually necessary to break it down into its frequency components. One reason for this is that people react differently to low-frequency and high-frequency sounds. Additionally, for the same sound pressure level, high-frequency noise is much more disturbing and more capable of producing hearing loss than low-frequency noise. Engineering solutions to reduce or control noise are different for low-frequency and high-frequency noise. As a general guideline, low-frequency noise is more difficult to control.

Certain instruments that measure sound level can determine the frequency distribution of a sound by passing that sound successively through several different electronic filters that separate the sound into nine octaves on a frequency scale. Two of the most common reasons for filtering a sound include 1) determining its most prevalent frequencies (or octaves) to help engineers better know how to control the sound and 2) adjusting the sound level reading using one of several available weighting methods. These weighting methods (e.g., the A-weighted network, or scale) are intended to indicate perceived loudness and provide a rating of industrial noise that indicates the impact that particular noise has on human hearing. The following paragraphs provide more detailed information.

9. **Octave Bands (Frequency Bands)**

Octave bands, a type of frequency band, are a convenient way to measure and describe the various frequencies that are part of a sound. A frequency band is said to be an octave in width when its upper band-edge frequency, f_2, is twice the lower band-edge frequency, f_1: $f_2 = 2 f_1$.

Each octave band is named for its center frequency (geometric mean), calculated as follows: $f_c = (f_1 f_2)^{1/2}$, where f_c = center frequency and f_1 and f_2 are the lower and upper frequency band limits, respectively. The center, lower, and upper frequencies for the commonly used octave bands are listed in Table II-1.

Table II-1. Octave Band Filters and Frequency Range

NOTE:This table is best viewed on tablets, notebooks, and desktop computer screens.

Lower Band Limit (Hz)	Band Center Frequency (Geometric Mean in Hz)	Upper Band Limit (Hz)
22	**31.5**	44
44	**63**	88
88	**125**	177
177	**250**	354
354	**500**	707
707	**1,000**	1,414
1,414	**2,000**	2,828
2,828	**4,000**	5,656
5,656	**8,000**	11,312
11,312	**16,000**	22,624

Each octave band is named for its center frequency.

The width of a full octave band (its bandwidth) is equal to the upper band limit minus the lower band limit. For more detailed frequency analysis, the octaves can be divided into one-third octave bands; however, this level of detail is not typically required for evaluation and control of workplace noise.

Electronic instruments called octave band analyzers filter sound to measure the sound pressure (as dB) contributed by each octave band. These analyzers either attach to a type 1 sound level meter or are integral to the meter. Both the analyzers and sound level meters are discussed further in Section III.

10. **Loudness and Weighting Networks**

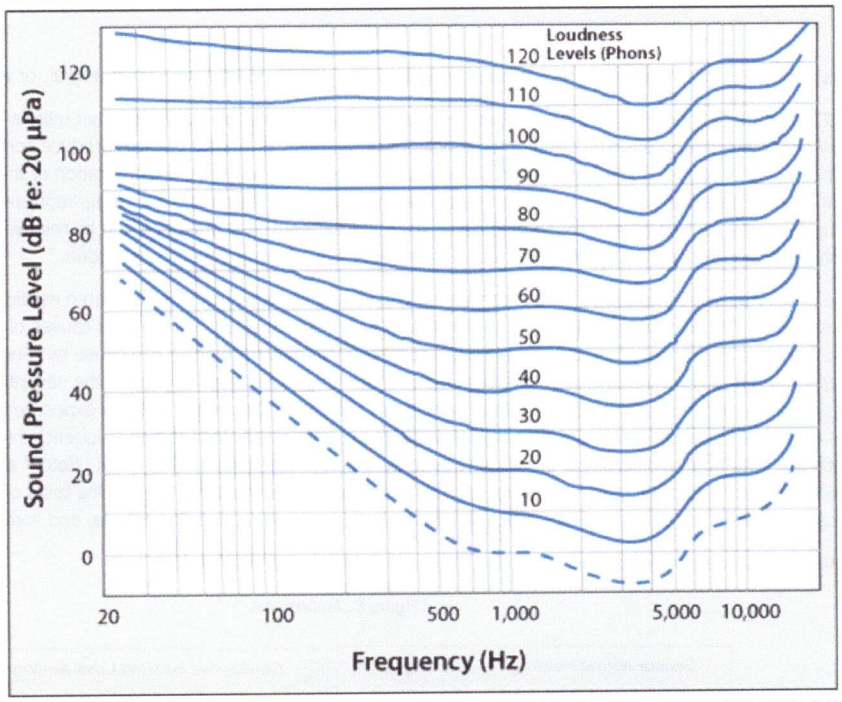
Loudness is the subjective human response to sound. It depends primarily on sound pressure but is also influenced by frequency.

Three different internationally standardized characteristics are used for sound measurement: weighting networks A, C, and Z (or "zero" weighting). The A and C weighting networks are the sound level meter's means of responding to some frequencies more than others. The very low frequencies are discriminated against (attenuated) quite severely by the A-network and hardly attenuated at all by the C-network. Sound levels (dB) measured using these weighting scales are designated by the appropriate letter (i.e., dBA or dBC).

The A-weighted sound level measurement is thought to provide a rating of industrial noise that indicates the injurious effects such noise has on human hearing and has been adopted by OSHA in its noise standards (OTM/Driscoll). In contrast, the Z-weighted measurement is an unweighted scale (introduced as an international standard in 2003), which provides a flat response across the entire frequency spectrum from 10 Hz to 20,000 Hz. The C-weighted scale is used as an alternative to the Z-weighted measurement (on older sound level meters on which Z-weighting is not an option), particularly for characterizing low-frequency sounds capable of inducing vibrations in buildings or other structures. A previous B-weighted scale is no longer used.

The networks evolved from experiments designed to determine the response of the human ear to sound, reported in 1933 by a pair of investigators named Fletcher and Munson. Their study presented a 1,000-Hz reference tone and a test tone alternately to the test subjects (young men), who were asked to adjust the level of the test tone until it sounded as loud as the reference tone. The results of these experiments yielded the frequently cited Fletcher-Munson, or "equal-loudness," contours, which are displayed in Figure 6.

Figure 6. The Fletcher-Munson Contours



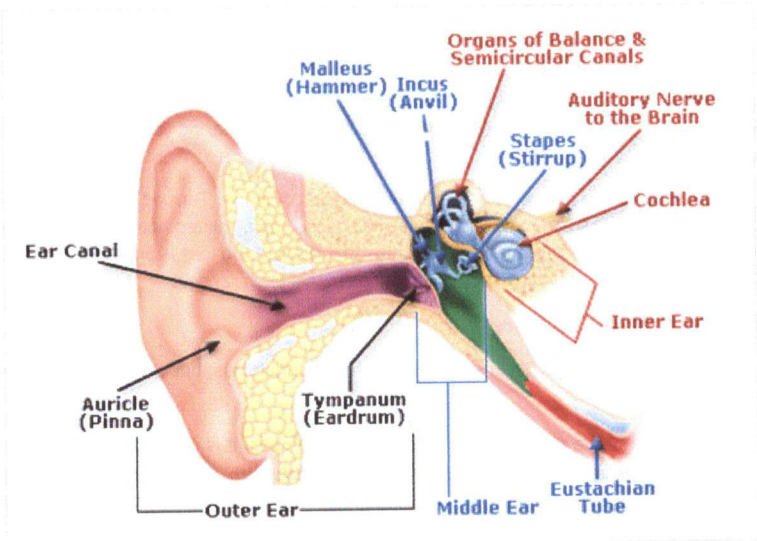
These contours represent the sound pressure level necessary at each frequency to produce the same loudness response in the average listener. The nonlinearity of the ear's response is represented by the changing contour shapes as the sound pressure level is increased (a phenomenon that is particularly noticeable at low frequencies). The lower, dashed curve indicates the threshold of hearing and represents the sound-pressure level necessary to trigger the sensation of hearing in the average listener. Among healthy individuals, the actual threshold may vary by as much as 10 decibels in either direction.

Ultrasound is not listed in Figure 6 because it has a frequency that is too high to be audible to the human ear. See Appendix C for more information about ultrasound and its potential health effects and threshold limit values.

C. How We Hear

The ear is the organ that makes hearing possible. It can be divided into three sections: the external or outer ear, the middle ear, and the inner ear. Figure 7 shows the parts of the ear.

Figure 7. Anatomy of the Human Ear



The function of the ear is to gather, transmit, and perceive sounds from the environment. This involves three stages:

- Stage 1: Modification of the acoustic wave by the outer ear, which receives the wave and directs it to the eardrum. Sound reaches the eardrum as variations in air pressure.
- Stage 2: Conversion and amplification of the modified acoustic wave to a vibration of the eardrum. These vibrations are amplified by the ossicles, small bones located in the middle ear that transmit sound pressure to the inner ear. The vibrations are then transmitted as wave energy through the liquid of the inner ear (the cochlea).
- Stage 3: Transformation of the mechanical movement of the wave into nerve impulses that will travel to the brain, which then perceives and interprets the impulse as sound. The cilia of nerve cells in the inner ear, called hair cells, respond to the location of movement of the basilar membrane and, depending on their position in the decreasing radius of the spiral-shaped cochlea, activate the auditory nerve to transmit information that the brain can interpret as pitch and loudness.

Impaired function at any of these stages will affect hearing.

Additional information on the outer ear, middle ear, and inner ear is available in OSHA's eTool [links to Noise eTool (App I:B)].

D. Hearing Loss

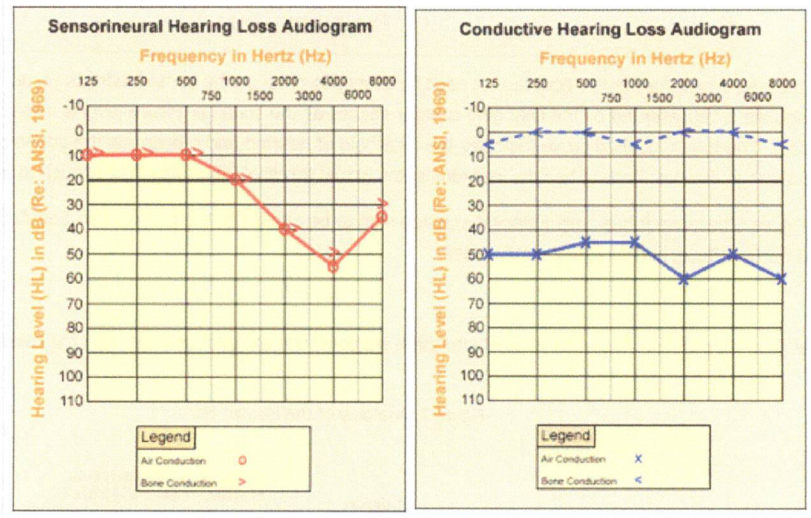
To categorize different types of hearing loss, the impairment is often described as either conductive or sensorineural, or a combination of the two.

Conductive [links to Noise eTool App I:C-1] hearing loss results from any condition in the outer or middle ear that interferes with sound passing to the inner ear. Excessive wax in the auditory canal, a ruptured eardrum, and other conditions of the outer or middle ear can produce conductive hearing loss. Although work-related conductive hearing loss is not common, it can occur when an accident results in a head injury or penetration of the eardrum by a sharp object, or by any event that ruptures the eardrum or breaks the ossicular chain formed by the small bones in the middle ear (e.g., impulsive noise caused by explosives or firearms). Conductive hearing loss may be reversible through medical or surgical treatment. It is characterized by relatively uniformly reduced hearing across all frequencies in tests of the ear, with no reduction during hearing tests that transmit sound through bone conduction.

Sensorineural [links to Noise eTool App I:C-2] hearing loss is a permanent condition that usually cannot be treated medically or surgically and is associated with irreversible damage to the inner ear. The normal aging process and excessive noise exposure are both notable causes of sensorineural hearing loss. Studies show that exposure to noise damages the sensory hair cells that line the cochlea. Even moderate noise can cause twisting and swelling of hair cells and biochemical changes that reduce the hair cell sensitivity to mechanical motion, resulting in auditory fatigue. As the severity of the noise exposure increases, hair cells and supporting cells disintegrate and the associated nerve fibers eventually disappear. Occupational noise exposure is a significant cause of sensorineural hearing loss, which appears on sequential audiograms as declining sensitivity to sound, typically first at high frequencies (above 2,000 Hz), and then lower frequencies as damage continues. Often the audiogram of a person with sensorineural hearing loss will show a "Notch" at 4,000 Hz. This is a dip in the person's hearing level at 4,000 Hz and is an early indicator of sensorineural hearing loss. Results are the same for hearing tests of the ear and bone conduction testing. Sensorineural hearing loss can also result from other causes, such as viruses (e.g., mumps), congenital defects, and some medications.

Figure 8 shows the typical audiogram patterns for people with conductive and sensorineural hearing loss.

Figure 8. Audiograms



Additional information [links to Noise eTool] on hearing loss is also available in OSHA's eTool. Appendices 1:C-1 and 1:C-2 of the eTool provide additional examples of conditions that cause these types of hearing loss. Also, download the NIOSH "Hearing Loss Simulator" to understand more about the effects of noise exposure and age on hearing.

It is important to note that some hearing loss occurs over time as a normal condition of aging. Termed presbycusis, this gradual sensorineural loss decreases a person's ability to hear high frequencies. Presbycusis can make it difficult to diagnose noise-related hearing loss in older people because both affect the upper range of an audiogram. An 8,000-Hz "Notch" in an audiogram often indicates that the hearing loss is aged-related as opposed to noise-induced. As humans begin losing their hearing, they often first lose the ability to detect quiet sounds in this pitch range.

E. Effects of Excessive Occupational Noise Exposure

Workplace noise affects the human body in various ways. The most well-known is hearing loss, but work in a noisy environment also can have other effects.

1. **Auditory Effects**
   Although noise-induced hearing loss is one of the most common occupational illnesses, it is often ignored because there are no visible effects. It usually develops over a long period of time, and, except in very rare cases, there is no pain. What does occur is a progressive loss of communication, socialization, and responsiveness to the environment. In its early stages (when hearing loss is above 2,000 Hz), it affects the ability to understand or discriminate speech. As it progresses to the lower frequencies, it begins to affect the ability to hear sounds in general.

The primary effects of workplace noise exposure include noise-induced temporary threshold shift, noise-induced permanent threshold shift, acoustic trauma, and tinnitus. A noise-induced temporary threshold shift is a short-term decrease in hearing sensitivity that displays as a downward shift in the audiogram output. It returns to the pre-exposed level in a matter of hours or days, assuming there is not continued exposure to excessive noise.

If noise exposure continues, the shift can become a noise-induced permanent threshold shift, which is a decrease in hearing sensitivity that is not expected to improve over time. A standard threshold shift is a change in hearing thresholds of an average of 10 dB or more at 2,000, 3,000, and 4,000 Hz in either ear when compared to a baseline audiogram. Employers can conduct a follow-up audiogram within 30 days to confirm whether the standard threshold shift is permanent. Under 29 CFR 1910.95(g)(8), if workers experience standard threshold shifts, employers are required to fit or refit the workers with hearing protectors, train them in the use of the hearing protectors, and require the workers to use them. Recording criteria for cases involving occupational hearing loss can be found in 29 CFR 1904.10.

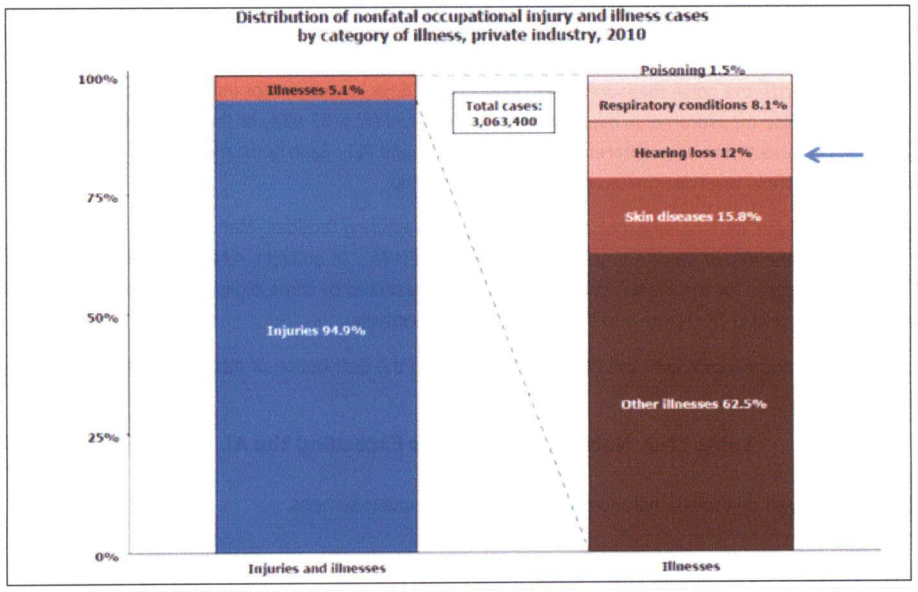
The effects of excessive noise exposure are made worse when workers have extended shifts (longer than 8 hours). With extended shifts, the duration of the noise exposure is longer and the amount of time between shifts is shorter. This means that the ears have less time to recover between noisy shifts. As a result, short-term effects, such as temporary threshold shifts, can become permanent more quickly than would occur with standard 8-hour workdays.

Tinnitus, or "ringing in the ears," can occur after long-term exposure to high sound levels, or sometimes from short-term exposure to very high sound levels, such as gunshots. Many other physical and physiological conditions also cause tinnitus. Regardless of the cause, this condition is actually a disturbance produced by the inner ear and interpreted by the brain as sound. Individuals with tinnitus describe it as a hum, buzz, roar, ring, or whistle, which can be short term or permanent.

Acoustic trauma refers to a temporary or permanent hearing loss due to a sudden, intense acoustic or noise event, such as an explosion.

2. **Worker Illness and Injury Reports**
The U.S. Bureau of Labor Statistics (BLS) publishes annual statistics for occupational injuries (including hearing loss) reported by employers as part of required recordkeeping. The BLS data show that hearing loss represented 12% of the occupational illnesses reported in 2010 (Figure 9). This represents more than 18,000 workers who experienced significant loss of hearing due to workplace noise exposure.

Figure 9. Distribution of Occupational Injury and Illness Cases



Nonfatal occupational injuries accounted for the overwhelming majority of cases reported for the SOII in 2010--94.9 percent--with illness accounting for the remaining 5.1 perfect of cases. Most illness cases fall into the "All other illnesses" category, which includes such things as repetitive motion cases and systemic diseases and disorders.

Source: Bureau of Labor Statistics, U.S. Department of Labor, October 2011

3. **Other Effects**
Other consequences of excessive workplace noise exposure include interference with communications and performance. Workers might find it difficult to understand speech or auditory signals in areas with high noise levels. Noisy environments also lead to a sense of isolation, annoyance, difficulty concentrating, lowered morale, reduced efficiency, absenteeism, and accidents.

> As a general guideline, the work area is too noisy if a worker cannot make himself understood without raising his or her voice while talking to a co-worker 3 feet away.

In some individuals, excessive noise exposure can contribute to other physical effects. These can include muscle tension and increased blood pressure (hypertension). Noise exposure can also cause a stress reaction, interfere with sleep, and cause fatigue.

F. Ultrasonics

Ultrasound is high-frequency sound that is inaudible (i.e., cannot be heard) by the human ear. However, it still might affect hearing and produce other health effects. For more information, see Appendix C.

Factors to consider regarding ultrasonics include:

- The upper frequency of audibility of the human ear is approximately 15 to 20 kilohertz (kHz). This is not a set limit: some individuals may have higher or lower (usually lower) limits. The frequency limit normally declines with age.
- Most of the audible noise associated with ultrasonic sources, such as ultrasonic welders or ultrasonic cleaners, consists of subharmonics of the machine's major ultrasonic frequencies.

Example: Many ultrasonic welders have a fundamental operating frequency of 20 kHz, a sound that is at the upper frequency of audibility of the human ear. However, a good deal of noise may be present at 10 kHz, the first subharmonic frequency of the 20-kHz operating frequency, which is audible to most people.

G. Noise and Solvent Interactions

Animal experiments have indicated that combined exposure to noise and solvents induces synergistic adverse effects on hearing. Experimental studies have explored specific substances, including toluene, styrene, ethylbenzene, and trichloroethylene.

A number of epidemiological studies have investigated the noise-solvent relationship in humans. Overall, the evidence strongly suggests that combined exposure to noise and organic solvents can have interactive effects (either additive or synergistic), in which solvents exacerbate noise-induced impairments even though the noise intensity is below the permissible limit value. In addition to the synergistic effects with solvents, noise may also have additive, potentiating, or synergistic ototoxicity with asphyxiants (such as carbon monoxide) and metals (such as lead). See Appendix D for additional information and additional sources of information on this topic.

About IMIS Data

In reviewing IMIS data, note that the exposure levels are not necessarily typical of all worksites and occupations within an industry. Rather, IMIS provides insight regarding the noise exposure levels for workers in the jobs that OSHA monitored while visiting workplaces. Typically, OSHA identified those jobs as having some potential for noise exposure.

H. Affected Industries and Workers

1. **Affected Industries**

Workplace noise exposure is widespread. Analysis of OSHA's Integrated Management Information System (IMIS) data for 1979 through 2006 showed that workers were exposed to hazardous noise levels in every major industry sector. Although this time span covers many years, the recent decade is well represented: 58,297 (27#) of the personal noise exposure levels in IMIS were measured in 2000 or later.

Table II-2 through II-5 summarize the noise measurements obtained by OSHA in each major industry sector[1]. These tables also present the median noise levels and the percentage of noise measurements over either the action level (AL), 85 dBA, or the permissible exposure limit (PEL), 90 dBA[2]. The data appear in separate tables because OSHA uses different criteria for the AL and PEL. Each noise measurement entered into IMIS is related to either the AL or the PEL, depending on the threshold level designated during dosimeter setup.

OSHA obtained the vast majority of IMIS noise exposure records in manufacturing facilities. Manufacturing is among the loudest industries, with 43# of the IMIS noise samples exceeding the PEL of 90 dBA time-weighted average (TWA). In addition, 47# of the samples taken in the construction industry exceeded the PEL. The IMIS exposure records for the manufacturing industry are presented by three-digit North American Industrial Classification System (NAICS) codes in two tables (Table II-4 and II-5) (relative to the AL and PEL, respectively).

In addition to median decibels and percent over the PEL, Table II-5 shows the distribution of manufacturing industry dosimetry measurements at the PEL and higher (by decibel level).

Table II-2. Noise Measurements Exceeding the AL, IMIS (1979 - 2006)

NOTE:This table is best viewed on tablets, notebooks, and desktop computer screens.

Industry	Total Records	Median dBA	# Over the AL
Agriculture	206	86.83	64#
Utilities	396	82.82	36#
Mining	40	88.04	78#
Construction	1,382	86.91	62#
Manufacturing	80,120	87.32	67#
Wholesale/retail	2,908	85.61	54#
Transportation	1,190	82.63	36#
Finance	71	78.20	27#
Services	5,107	83.90	44#
All other private sector	34	90.58	88#

Government	935	83.68	44#

Table II-3. Noise Measurements Exceeding the PEL, IMIS (1979 - 2006)

NOTE:This table is best viewed on tablets, notebooks, and desktop computer screens.

Industry	Total Records	Median dBA	# Over the PEL
Agriculture	354	86.80	33#
Utilities	513	81.19	19#
Mining	56	85.55	27#
Construction	3,133	89.22	47#
Manufacturing	116,983	88.74	43#
Wholesale/retail	3,342	86.67	33#
Transportation	1,261	80.89	16#
Finance	88	75.20	15#
Services	5,167	83.21	23#
All other private sector	231	89.76	47#
Government	822	82.29	23#

Table II-4. Manufacturing Industry Noise Measurements Obtained Using AL Criteria, IMIS (1979 - 2006)

NOTE:This table is best viewed on tablets, notebooks, and desktop computer screens.

NAICS	NAICS Title	Total Records	Median dBA	# Over the AL
311	Food Manufacturing	6,100	88.60	79#
312	Beverage and Tobacco Product Manufacturing	34	87.39	85#
314	Textile Product Mills	1,749	87.32	69#
315	Apparel Manufacturing	817	82.73	36#
316	Leather and Allied Product Manufacturing	406	86.56	61#
321	Wood Product Manufacturing	9,836	89.34	79#
322	Paper Manufacturing	2,879	86.90	65#
323	Printing and Related Support Activities	2,256	84.08	43#
324	Petroleum and Coal Products Manufacturing	217	86.32	57#
325	Chemical Manufacturing	1,762	85.56	54#
326	Plastics and Rubber Products Manufacturing	6,381	86.39	61#
327	Nonmetallic Mineral Product Manufacturing	4,034	87.00	63#
331	Primary Metal Manufacturing	6,306	89.25	80#

332	Fabricated Metal Product Manufacturing	15,248	87.60	69#
333	Machinery Manufacturing	7,514	85.47	53#
334	Computer and Electronic Product Manufacturing	219	85.00	50#
335	Electrical Equipment, Appliance, and Component Manufacturing	2,679	85.84	57#
336	Transportation Equipment Manufacturing	5,660	87.38	67#
337	Furniture and Related Product Manufacturing	3,867	86.83	64#
339	Miscellaneous Manufacturing	2,156	85.62	55#

Table II-5. Manufacturing Industry Noise Measurements Obtained Using PEL Criteria, IMIS (1979 - 2006)

NOTE: This table is best viewed on tablets, notebooks, and desktop computer screens.

NAICS	NAICS Title	Total Records	Median dBA	# Over the PEL	# Noise Measurements in dB Range			
					90 to 94 dB	95 to 100 dBA	100 to 104 dBA	105 dBA+
311	Food Manufacturing	9,070	89.51	47#	34#	11#	2#	0#
312	Beverage and Tobacco Product Manufacturing	40	85.64	25#	25#	0#	0#	0#
314	Textile Product Mills	2,790	89.40	47#	31#	11#	4#	1#
315	Apparel Manufacturing	828	81.32	12#	9#	4#	0#	0#
316	Leather and Allied Product Manufacturing	551	89.71	48#	35#	11#	2#	0#
321	Wood Product Manufacturing	16,330	91.72	60#	30#	22#	7#	1#
322	Paper Manufacturing	4,344	87.90	38#	28#	8#	1#	0#
323	Printing and Related Support Activities	2,620	82.22	17#	15#	2#	0#	0#
324	Petroleum and Coal Products Manufacturing	376	86.72	27#	22#	5#	1#	0#
325	Chemical Manufacturing	2,611	85.20	24#	18#	5#	1#	0#
326	Plastics and Rubber Products Manufacturing	7,627	86.07	30#	21#	6#	2#	0#
327	Nonmetallic Mineral Product Manufacturing	5,772	88.39	41#	26#	10#	4#	1#
331	Primary Metal Manufacturing	13,196	91.32	58#	34#	19#	5#	1#
332	Fabricated Metal Product Manufacturing	20,549	88.86	44#	27#	13#	3#	1#
333	Machinery Manufacturing	10,156	86.22	31#	21#	8#	2#	0#
334	Computer and Electronic Product Manufacturing	360	85.28	29#	23#	6#	1#	0#
335	Electrical Equipment, Appliance, and Component Manufacturing	3,889	86.54	32#	22#	8#	2#	0#
336	Transportation Equipment Manufacturing	7,812	88.36	41#	24#	12#	4#	1#
337	Furniture and Related Product Manufacturing	5,292	87.83	38#	27#	9#	2#	0#
339	Miscellaneous Manufacturing	2,770	86.78	35#	24#	8#	3#	0#

Interior finish	89.4	Welding	94.9
Manual material handling	89.4	"Other" tasks	95.3
Layout	90.5		

CEMENT MASONS

Floor leveling	70.4	Placing concrete	87.8
Break, rest, lunch, cleanup	83.3	Repairing concrete	88.9
Finishing concrete	84.4	Patching concrete	92.6
Setting forms	86.5	"Other" tasks	93.1
Manual material handling	86.5	Grinding	95.2

ELECTRICIANS

Operating work vehicle	79.2	Installing slab conduit	91.0
Sheet metal work	81.6	Installing wall conduit	91.1
Manual material handling	86.5	Installing cable tray	91.8
Panel wiring, installing fixtures	87.0	Pulling wire	95.6
Break, rest, lunch, cleanup	87.0	Installing trench conduit	95.8
"Other" tasks	90.5		

INSULATION WORKERS

Sheet metal work	77.8	"Other" tasks	83.4
Applying insulation by hand	83.0	Manual material handling	84.6
Break, rest, lunch, cleanup	83.3		

IRONWORKERS

Operating forklift	87.1	Manual materials handling	94.3
Setting forms	87.9	"Other" tasks	94.7
Operating work vehicle	88.5	Tying and placing rebar	95.5
Erecting iron	91.8	Break, rest, lunch, cleanup	95.6
Grinding	91.9	Welding and burning	98.4
Rigging	93.6	Laying metal deck	99.6
Bolt up	93.7		

LABORERS

Layout	80.1	Placing concrete	91.5
Manual material handling	82.7	Stripping forms	91.7
Interior finish	85.2	Building forms	92.1
Operating forklift	85.3	Break, rest, lunch, cleanup	92.3
Finishing concrete	85.3	Rigging	92.6

2. **Historically Affected Jobs in General Industry**

Noise is a potential hazard for most jobs that involve abrasive or high-power machinery, impact of rapidly moving parts (product or machinery), or power tools. According to IMIS noise measurements, workers in certain occupations within specific industries are exposed to excessive noise more frequently than others. While many jobs have noise exposure, historically, some of the occupations with the most extreme exposures (listed by Standard Industrial Classification, or SIC) have included:

- **SIC 20 and 21 (food, beverages, and tobacco industry):** slaughterers and meat packers.
- **SIC 22, 23, and 31 (textile, apparel, and leather industry):** textile winders, shoe and leather workers and repairers, textile knitting and weaving machine operators.
- **SIC 24 (lumber and wood products industry, including logging and lumber mill operations):** most occupations (except cabinetmakers).
- **SIC 25 (furniture and fixtures industry):** machine feeders.
- **SIC 26 (paper and paper industry):** paper goods machine operators.
- **SIC 28 through 30 (printing and publishing, chemicals and petroleum, and plastics and rubber industries):** chemical equipment operators (SIC 28 and 29), laborers and freight movers (SIC 28 and 29), grinding machine operators (SIC 30), and helpers (SIC 30).
- **SIC 32 (nonmetallic minerals industry):** inspectors, testers, and sorters; extruding, forming, and pressing machine operators; hoist and winch operators; unspecified "operators."
- **SIC 33 and 34 (primary metal and fabricated metal products industries):** forging machine operators, grinding and lapping machine operators, and welders.
- **SIC 35 through 39 (various equipment manufacturers):** milling and planing machine operators, coil winders and tapers, forging machine operators, grinding and lapping machine operators, and abrasive blasters.

3. **Summary of Construction Industry Noise Exposure by Trade and Activity**

Table II-6. Summary of Average TWA Construction Noise Exposure from University of Washington Noise Monitoring Research

NOTE:This table is best viewed on tablets, notebooks, and desktop computer screens.

Trades Monitored	Number of Measurements	OSHA TWA Mean dBA	OSHA TWA Percent >90 dBA
Brick/Tile Worker	28	75.2	8
Bricklayer	15	83.8	4
Carpenter	82	82.3	11
Cement Mason	26	78.9	10
Electrician	208	80.0	4
Insulation Worker	22	74.5	5
Iron Worker	59	82.1	10
Laborer	58	83.3	14
Operating Engineer	44	83.5	14
Sheet Metal Worker	38	80.4	0

Source: Adapted from Seixas and Neitzel,2002. (Submittal to OSHA's Advance Notice of Proposed Rulemaking Docket H-011G).

Table II-7. Task-Specific Average Noise Levels by Construction Trade

NOTE:This table is best viewed on tablets, notebooks, and desktop computer screens.

TRADE (Tasks)	Average dBA for Each Task Event	TRADE (Tasks)	Average dBA for Each Task Event
CARPENTER			
Operating work vehicle	80.1	Wood framing	91.0
Break, rest, lunch, cleanup	87.8	Building forms	92.9
Shop work	88.8	Stripping forms	94.8

Grouting	86.1	"Other" tasks	95.4
Wood framing	86.5	Demolition	99.3
Floor leveling	87.5	Chipping concrete	102.9
MASONRY TRADES			
Bricking, blocking, tiling	90.2	Manual material handling	88.4
Break, rest, lunch, cleanup	86.4	"Other" tasks	94.4
Forklift operation	88.5	Pointing, cleaning, caulking	91.6
Grinding	97.0	Weatherproofing	84.2
Grouting, tending, mortaring	91.4	Work vehicle operation	96.3
OPERATING ENGINEERS			
Break, rest, lunch, cleanup	85.7	Layout	89.3
Rigging	86.6	Grade checking	89.6
"Other" tasks	86.9	Welding	91.2

Source: Adapted from Seixas and Neitzel, 2004.

I. Regulations and Standards

1. **Brief History of Occupational Noise Standards**

The Occupational Safety and Health Act (OSH Act) of 1970 built upon earlier attempts in the United States to regulate noise hazards associated with occupational hearing loss. In 1969, the Walsh-Healey Public Contract Act added the Occupational Noise Exposure Standard as an amendment, basing it on the American Conference of Governmental Industrial Hygienists (ACGIH) noise threshold limit value (TLV) in effect at that time. This set an 8-hour TWA of 90 dBA and a 5-dBA exchange rate for any company with a federal contract worth more than $10,000. This effort to reduce occupational noise hazards was not far-reaching but was a first attempt to regulate noise hazards. Adopted into the OSH Act in 1970, it served as the basis for OSHA's Noise standard. The same 8-hour TWA and exchange rate are still used by OSHA today.

Also in 1969, the Bureau of Labor Standards promulgated an occupational construction noise standard under the Construction Safety Act, which was later adopted by OSHA in 1971. Soon after, in 1972, NIOSH published recommendations for an OSHA occupational noise standard, which included a recommended 8-hour TWA exposure limit of 85 dBA and a 5-dBA exchange rate. However, in 1973, OSHA's Standards Advisory Committee maintained the 90-dBA 8-hour TWA with a 5-dBA exchange rate. Even though noise energy exposure doubles every 3 dB, OSHA thought it important to account for the time during the workday that a worker was not exposed to noise hazards. At the time, using a 5-dB exchange rate was viewed as a sufficient way to account for this.

In 1974, OSHA published a proposed occupational noise standard, which included a requirement for employers to provide a hearing conservation program for workers exposed to an 8-hour TWA of 85 dBA or more. This provision was adopted as part of the amendments of 1981 and 1983. The 8-hour TWA for OSHA's noise standard remained at 90 dBA with a 5-dBA exchange rate and included a requirement for a hearing conservation program for workers exposed to an 8-hour TWA of at least 85 dBA. While OSHA provided requirements for hearing conservation programs in general industry, the construction industry standard remained less specific in that regard. More recently, in the 2002 recordkeeping standard (29 CFR Part 1904), OSHA clarified the criteria for reporting cases involving occupational hearing loss.

In 1979, the U.S. Environmental Protection Agency (EPA) developed labeling requirements for hearing protectors, which required hearing protector manufacturers to measure the ability of their products to reduce noise exposure--called the noise reduction rating (NRR). OSHA adopted the NRR but later recognized that the NRR listed on hearing protectors often did not reflect the actual level of protection, which likely was lower than indicated on the label because most workers were not provided with fit-testing, and donning methods in a controlled laboratory setting were not representative of the donning methods that workers used in the field. EPA is considering options for updating this rule. See Appendix E for current information on NRRs and hearing protection labeling requirements. In special cases, noise exposure originates from noise-generating headsets. See Appendix F for a discussion of the techniques used to evaluate the noise exposure levels of these workers.

2. **OSHA Noise Standards**

General Industry: 29 CFR 1910.95, "Occupational Noise Exposure." This standard is designed to protect general industry workers, such as those working in the manufacturing, utilities, and service sectors. The General Industry standard establishes permissible noise exposures, requires the use of engineering and administrative controls, and sets out the requirements of a hearing conservation program. Paragraphs (c) through (n) of the General Industry standard do not apply to the oil and gas well-drilling and servicing operations; however, paragraphs (a) and (b) do apply.

The general industry noise standard contains two noise exposure limit tables. Each table serves a different purpose:

- **Table G-16:** This table applies to the engineering and administrative controls section, which provides a 90-dBA criterion for an 8-hour TWA PEL and is measured using a 90-dBA threshold (i.e., noise below 90 dBA is not integrated into the TWA). This table limits short-term noise exposure to a level not greater than 115 dBA (for up to 15 minutes).
- **Table G-16A:** This table, presented in Appendix A of 29 CFR 1910.95, provides information (e.g., reference durations) useful for calculating TWA exposures when the workshift noise exposure is composed of two or more periods of noise at different levels. Although this table lists noise levels

exceeding 115 dBA, these listings are only intended as aids in calculating TWA exposure levels; the listings for higher noise exposure levels do not imply that these noise levels are acceptable.

Additional information [Links to App II:A of the Noise eTool] on the general industry standard is also available.

Construction Industry: Noise in construction is covered under29 CFR 1926.52, "Occupational Noise Exposure," and 29 CFR 1926.101, "Hearing Protection." Under 29 CFR 1926.52, employers are required to use feasible engineering or workplace controls when workers are exposed to noise at or above permissible noise exposures, which are listed in Table D-2 [1926.52(d)(1)]. The PEL of 90 dBA for an 8-hour TWA is measured using a 90-dBA threshold (this is the only threshold used for the construction industry noise standards). 29 CFR 1926.101 requires employers to provide hearing protectors that have been individually fitted (or determined to fit) by a competent person if it is not feasible to reduce noise exposure below permissible levels using engineering or workplace controls.

The requirements for permissible noise exposures and controls under the Construction standard are the same as those under the general industry standard (1910.95), though other requirements differ. Continuing effective hearing conservation programs are required in all cases where the sound levels exceed the values shown in Table D-2 (1926.52(d)(1)). When a hearing conservation program is required, employers must incorporate as many elements listed in the Standard Interpretation titled "Effective Hearing Conservation Program Elements for Construction Industry" (08/04/1992) into their program as feasible.

Agricultural Worksites: Although there is no standard for occupational noise exposure in agriculture, the evaluation and control methods discussed in this chapter are still valid. For any potential citations, CSHOs must use the guidance in the Field Operations Manual.

Maritime Worksites: Marine terminals and longshoring operations fall under the requirements of the general industry noise standard; therefore, employers in such operations must meet the elements of the general industry Hearing Conservation Amendment, 29 CFR 1910.95(c) through (o).

J. Noise Exposure Controls - Overview

Noise controls should minimize or eliminate sources of noise; prevent the propagation, amplification, and reverberation of noise; and protect workers from excessive noise exposure. Ideally, the use of engineering controls should reduce noise exposure to the point where the risk to hearing is significantly reduced or eliminated.

Engineering and administrative controls are essential to an effective hearing loss prevention program. They are technologically feasible for most noise sources, but their economic feasibility must be determined on an individual basis. In some instances the application of a relatively simple noise-control solution reduces the hazard to the extent that the other elements of the program, such as audiometric testing and the use of hearing protection devices, are no longer necessary. In other cases, the noise reduction process may be more complex and must be accomplished in stages over a period of time. Even so, with each reduction of a few decibels, the risk of hearing loss is reduced, communication is improved, and noise-related annoyance is reduced.

The first step in noise control is to identify the noise sources and their relative importance. This can be difficult in an industrial setting with many noise sources. It can be accomplished through several methods used together: obtain a frequency spectrum from an octave band analyzer, turn various components in the factory on and off or use temporary mufflers or enclosures to isolate noise sources, and probe areas close to equipment with a sound level meter to pinpoint areas where sound is dominant. These measures will aid in identifying the sound sources that affect workers the most and should be prioritized when implementing noise controls. Once the noise sources have been identified, it is possible to proceed in choosing an engineering control, administrative control, or a form of personal protective equipment to reduce the noise level if noise exposure is too high (Driscoll, Principles of Noise Control).

1. **Hierarchy of Controls for Noise**
   The hierarchy of controls for noise can be summarized as: 1) prevent or contain the escape of the hazardous workplace agent at its source (engineering controls), 2) control exposure by changing work schedules to reduce the amount of time any one worker spends in the hazard area (administrative controls), and 3) control the exposure with barriers between the worker and the hazard (personal protective equipment). This hierarchy highlights the principle that the best prevention strategy is to eliminate exposure to hazards that can lead to hearing loss. Corporations that have started buy-quiet programs are moving toward workplaces where no harmful noise will exist. Many companies are automating equipment or setting up procedures that can be managed by workers from a quiet control room free from harmful noise. When it is not possible to eliminate the noise hazard or relocate the worker to a safe area, the worker must be protected with personal protective equipment.

   Note: See CPL 02-00-160 - Field Operations Manual (FOM) for current citation policy when addressing engineering/administrative controls versus hearing conservation program.

2. **Noise-Control Engineering--Concepts and Options**
   The rest of this section, until the discussion of administrative controls, presents information adapted from material developed under contract for the Noise eTool by Dennis Driscoll in 2002.

   Much industrial noise can be controlled through simple solutions. It is important, however, that all individuals administering abatement projects have a good understanding of the principles of noise control and proper use of acoustical materials. Industrial hygienists, safety professionals, facility engineers, and others can make significant progress in reducing equipment noise levels and worker noise exposures by combining their knowledge of acoustics with an understanding of the manufacturing equipment and/or processes.

   Reducing excessive equipment noise can be accomplished by treating the source, the sound transmission path, the receiver, or any combination of these options. Descriptions of these control measures follow.

   i. **Source Treatment**
   The best long-term solution to noise control is to treat the root cause of the noise problem. For source treatment to be effective, however, a comprehensive noise-control survey usually needs to be conducted to clearly identify the source and determine its relative contribution to the area noise level and worker noise exposure. At least four methods exist for treating the source: modification, retrofit, substitution, and relocation.

   Modification

   For the most part, industrial noise is caused by mechanical impacts, high-velocity fluid flow, high-velocity air flow, vibrating surface areas of a machine, and vibrations of the product being manufactured.

   Mechanical Impacts

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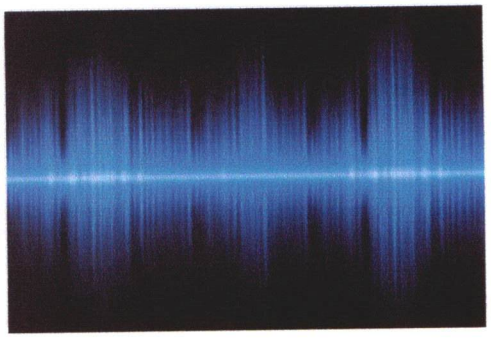
TABLE D-1: SOUND LEVELS AND HUMAN RESPONSE

Common Sounds	*Noise Level*	*Effect*
Carrier deck Jet operation Air raid siren	140	Painfully loud
Jet takeoff (200 feet) Thunderclap	130	
Discotheque Auto horn (3 feet)	120	Maximum vocal effect
Pile drivers Chain saw (2 feet)	110	
Garbage truck (50 feet) Power lawn mower (4 feet)	100	
Heavy truck (50 feet) City traffic (8 hours)	90	Very annoying Hearing damage
Alarm clock (2 feet) Hair dryer Vacuum cleaner (5 feet)	80	Annoying
Noisy restaurant Freeway traffic Man's voice (3 feet)	70	Telephone use difficult
Air-conditioning unit (20 feet)	60	Intrusive
Light auto traffic (100 feet)	50	
Living room Bedroom Quiet office	40	Quiet
Library Soft whisper (15 feet)	30	Very quiet
Broadcasting studio	20	
	10	Just audible
	0	Hearing begins

Source: City of Chula Vista, California, *Noise Control Ordinance*.



COMPARITIVE EXAMPLES OF NOISE LEVELS

Noise Source	Decibel Level	Decibel Effect
Jet take-off (at 25 meters) **Recommended product:** Outdoor Noise Barriers (http://www.industrialnoisecontrol.com/products/onb-outdoor-noise-barriers)	150	Eardrum rupture
Aircraft carrier deck	140	
Military jet aircraft take-off from aircraft carrier with afterburner at 50 ft (130 dB).	130	
Thunderclap, chain saw. Oxygen torch (121 dB).	120	Painful. 32 times as loud as 70 dB.
Steel mill, auto horn at 1 meter. Turbo-fan aircraft at takeoff power at 200 ft (118 dB). Riveting machine (110 dB); live rock music (108 - 114 dB).	110	Average human pain threshold. 16 times as loud as 70 dB.
Jet take-off (at 305 meters), use of outboard motor, power lawn mower, motorcycle, farm tractor, jackhammer, garbage truck. Boeing 707 or DC-8 aircraft at one nautical mile (6080 ft) before landing (106 dB); jet flyover at 1000 feet (103 dB); Bell J-2A helicopter at 100 ft (100 dB).	100	8 times as loud as 70 dB. Serious damage possible in 8 hr exposure.
Boeing 737 or DC-9 aircraft at one nautical mile (6080 ft) before landing (97 dB); power mower (96 dB); motorcycle at 25 ft (90 dB). Newspaper press (97 dB).	90	4 times as loud as 70 dB. Likely damage in 8 hour exposure.
Garbage disposal, dishwasher, average factory, freight train (at 15 meters). Car wash at 20 ft (89 dB); propeller plane flyover at 1000 ft (88 dB); diesel	80	2 times as loud as 70 dB

Car wash at 20 ft (89 dB); propeller plane flyover at 1000 ft (88 dB); diesel truck 40 mph at 50 ft (84 dB); diesel train at 45 mph at 100 ft (83 dB). Food blender (88 dB); milling machine (85 dB); garbage disposal (80 dB).		loud as 70 dB. Possible damage in 8 hour exposure.
Passenger car at 65 mph at 25 ft (77 dB); freeway at 50 ft from pavement edge 10 a.m. (76 dB). Living room music (76 dB); radio or TV-audio, vacuum cleaner (70 dB).	70	Arbitrary base of comparison. Upper 70s are annoyingly loud to some people.
Conversation in restaurant, office, background music, Air conditioning unit at 100 feet.	60	Half as loud as 70 dB. Fairly quiet.
Quiet suburb, conversation at home. Large electrical transformers at 100 feet.	50	One-fourth as loud as 70 dB.
Library, bird calls (44 dB); lowest limit of urban ambient sound	40	One-eighth as loud as 70 dB.
Quiet rural area.	30	One-sixteenth as loud as 70 dB. Very Quiet.
Whisper, rustling leaves	20	
Breathing	10	Barely audible

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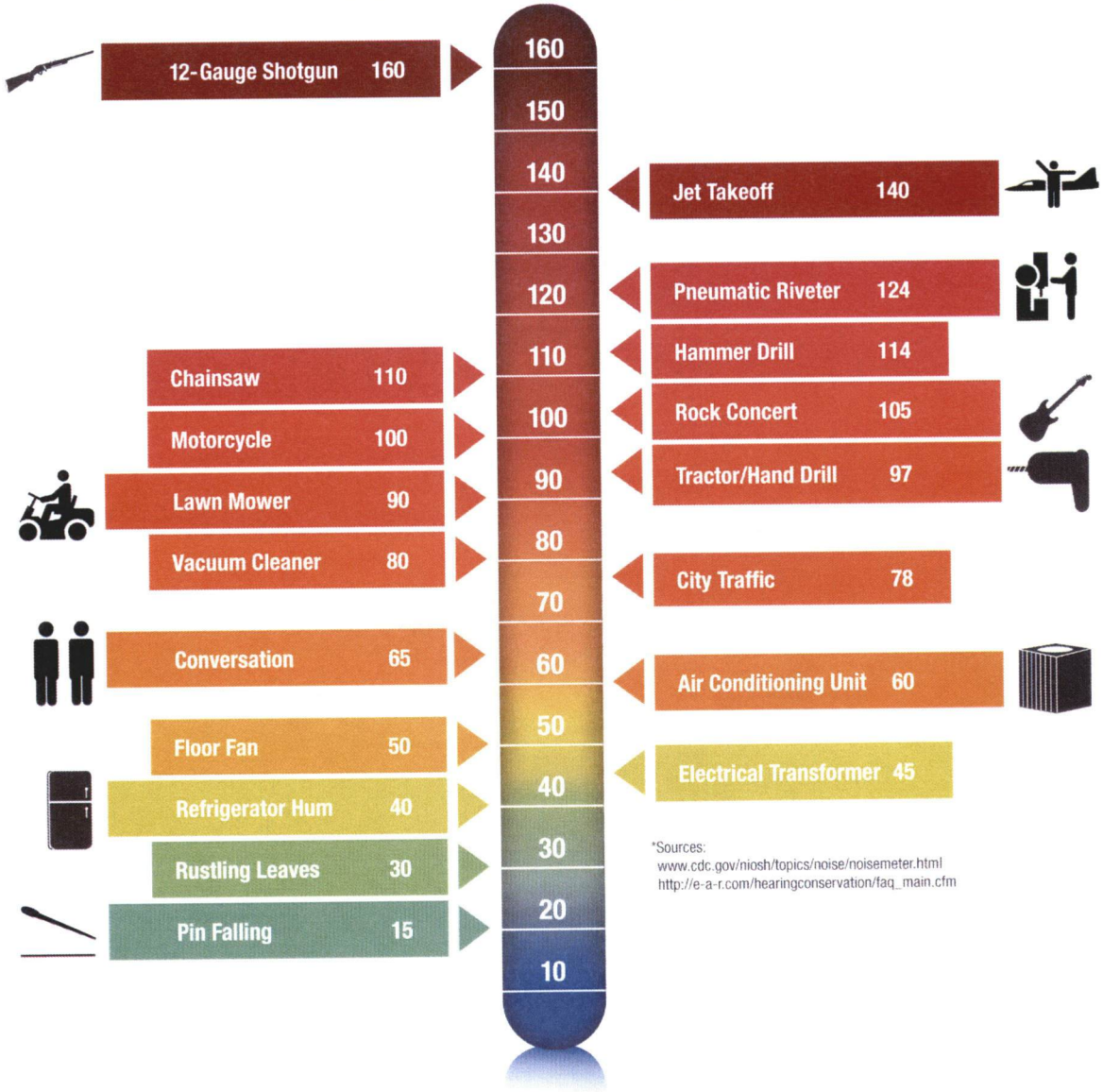
Decibel Scale (dBA)*

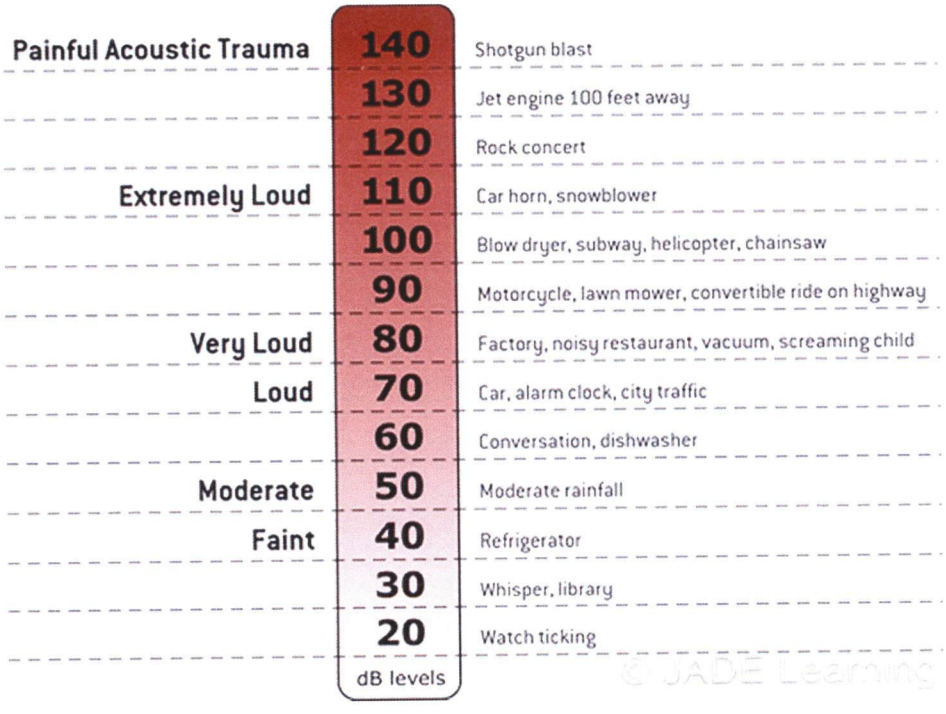


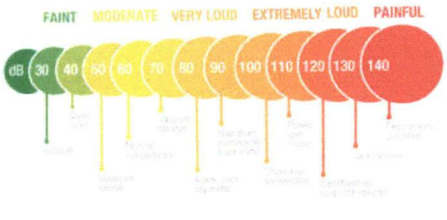
*Sources:
www.cdc.gov/niosh/topics/noise/noisemeter.html
http://e-a-r.com/hearingconservation/faq_main.cfm

	DECIBEL - dB(A)	EQUIPMENT
Double protection recommended above 105 dB(A)	112	Pile driver
	110	Air arcing gouging
	108	Impact wrench
	107	Bulldozer - no muffle
	102-104	Air grinder
	102	Crane - uninsulated cab
	101-103	Bulldozer - no cab
	97	Chipping concrete
	96	Circular saw and hammering
	96	Jack hammer
	96	Quick-cut saw
	95	Masonry saw
	94	Compactor - no cab
Hearing protection recommended above 85 dB(A)	90	Crane - insulated cab
	87	Loader/backhoe - insulated cab
	86	Grinder
	85-90	Welding machine
	85	Bulldozer - insulated cab
	60-70	Speaking voice

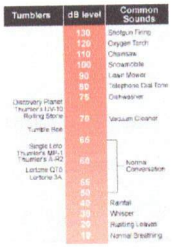
HelpCharts.com

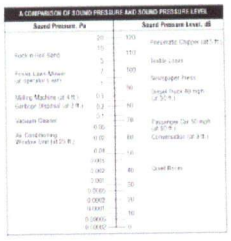
Table 1: Some typical noise levels found on construction sites

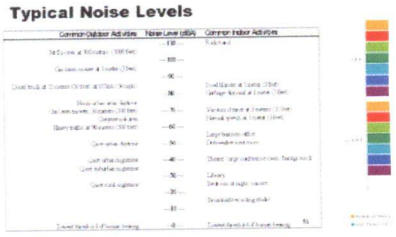


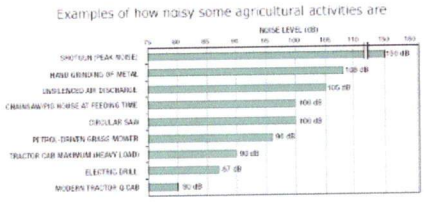

FAINT MODERATE VERY LOUD EXTREMELY LOUD PAINFUL
dB 30 40 50 60 70 80 90 100 110 120 130 140

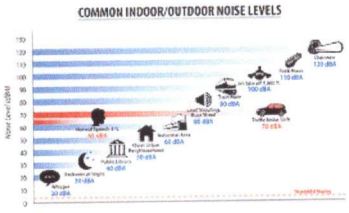
Noise destroys your hearing
13 17 97

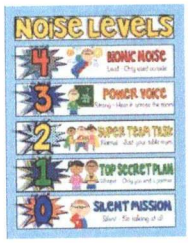

Tumblers
dB level
Common Sounds
130 Shotgun Firing
120 Oxygen Torch
110 Chainsaw
100 Snowmobile
90 Lawn Mower
80 Telephone Dial Tone
75 Dishwasher
70 Vacuum Cleaner
65
60
55
50
45 Rainfall
40 Whisper
30 Rustling Leaves
20
10 Normal Breathing
Normal Conversation


A COMPARISON OF SOUND PRESSURE AND SOUND PRESSURE LEVEL
Sound Pressure, Pa
Sound Pressure Level, dB

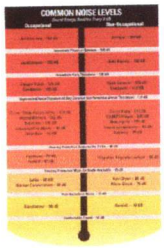

Typical Noise Levels
Common Outdoor Activities
Noise Level (dBA)
Common Indoor Activities


Examples of how noisy some agricultural activities are
NOISE LEVEL (dB)
SHOTGUN PEAK NOISE
HAND GRINDING OF METAL
UNSILENCED AIR DISCHARGE
CHAINSAW/PIG NOISE AT FEEDING TIME
CIRCULAR SAW
PETROL DRAIN GRASS MOWER
TRACTOR CAB MAXIMUM (HEAVY LOAD)
ELECTRIC DRILL
MODERN TRACTOR CAB

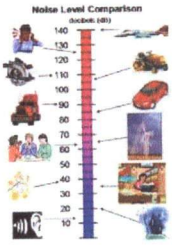

COMMON INDOOR/OUTDOOR NOISE LEVELS
Noise Level (dBA)


NOISE LEVELS
4 IRONIC NOISE
3 POWER VOICE
2 SUPER TEAM TALK
1 TOP SECRET PLAN
0 SILENT PASSION

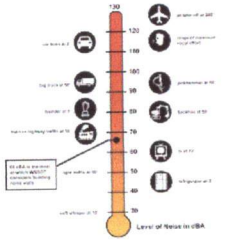
Classroom Voice Levels
5 Out of Control
4 Loud Crowd
3 Formal Normal
2 Low Flow
1 Spy Talk
0 Zero Noise Level

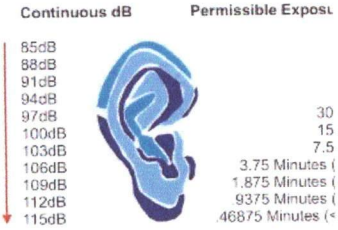

COMMON NOISE LEVELS

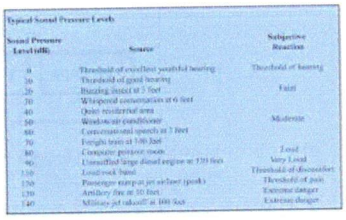
System noise levels - Load

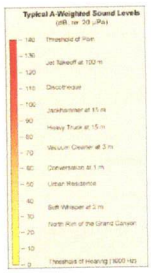

Noise Level Comparison
(decibels (dB))

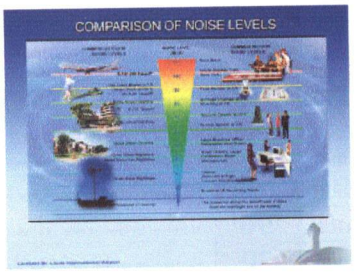
NOISE LEVELS
for Everyday Sounds

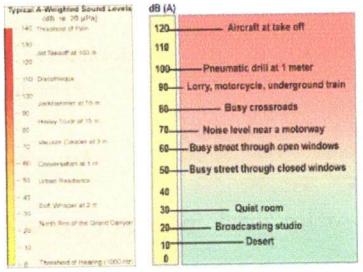

Level of Noise in dBA


Continuous dB
Permissible Exposu
85dB
88dB
91dB
94dB
97dB
100dB
103dB
106dB
109dB
112dB
115dB
30
15
7.5
3.75 Minutes
1.875 Minutes
.9375 Minutes
.46875 Minutes

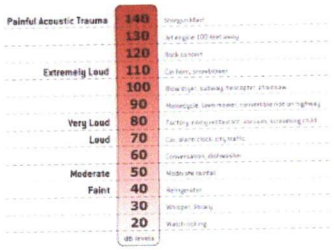

Typical Sound Pressure Levels
Sound Pressure Level (dB)
Source
Subjective Reaction

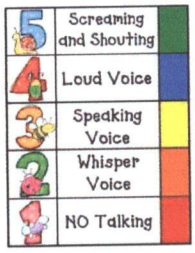

Typical A-Weighted Sound Levels
(dB re 20 μPa)

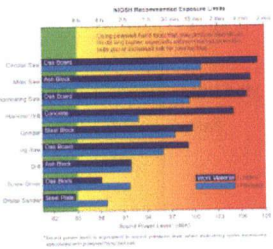

COMPARISON OF NOISE LEVELS

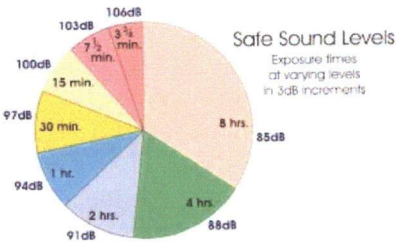

Typical A-Weighted Sound Levels
(dB re 20 μPa)
dB (A)
120 Aircraft at take off
100 Pneumatic drill at 1 meter
90 Lorry, motorcycle, underground train
80 Busy crossroads
70 Noise level near a motorway
60 Busy street through open windows
50 Busy street through closed windows
30 Quiet room
20 Broadcasting studio
10 Desert

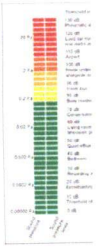
4: TOO LOUD
TALKING ACROSS THE ROOM IS OUTSIDE VOICES
3: TALK & WORK
TALKING ONLY AT YOUR TABLE
2: SECRET SPY
WHISPER! ONLY I PERSON CAN HEAR YOU
1: NINJA MODE
COMPLETE SILENCE

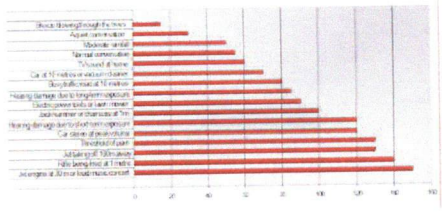

Painful Acoustic Trauma 140
130
120
Extremelig Loud 110
100
90
Verg Loud 80
Loud 70
60
Moderate 50
Faint 40
30
20
dB levels

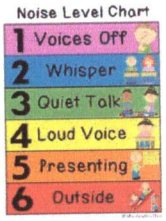

5 Screaming and Shouting
4 Loud Voice
3 Speaking Voice
2 Whisper Voice
NO Talking


NIOSH Recommended Exposure Limits

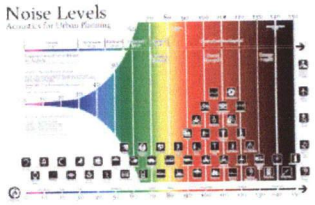

Safe Sound Levels
Exposure times at varying levels in 3dB increments
106dB
103dB
100dB
97dB
94dB
91dB
88dB
85dB
7½ min.
3¾ min.
15 min.
30 min.
1 hr.
2 hrs.
4 hrs.
8 hrs.

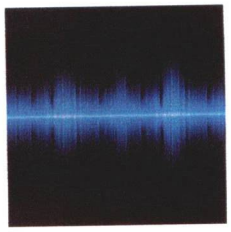


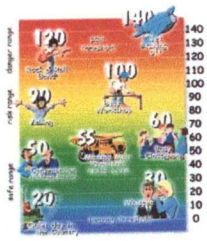



Noise Level Chart
1 Voices Off
2 Whisper
3 Quiet Talk
4 Loud Voice
5 Presenting
6 Outside

High noise levels


Noise Levels




danger range
risk range
safe range

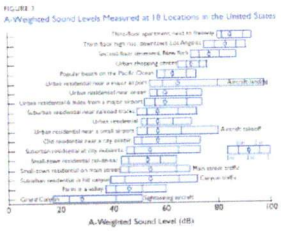
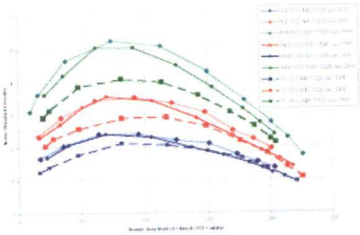


FIGURE 3
A-Weighted Sound Levels Measured at 18 Locations in the United States
A-Weighted Sound Level (dB)

JET TAKING OFF
GIG
NIGHTCLUB
PNEUMATIC DRILL
DANGER LEVEL
CITY STREET



HOW LOUD IS ..
10 decibels breathing
20 rustling leaves, whispering
30 quiet rural area
40 library, bird calls
50 conversation, lar
electrical transfo
60 office noise, air conditioning

Google Noise Levels

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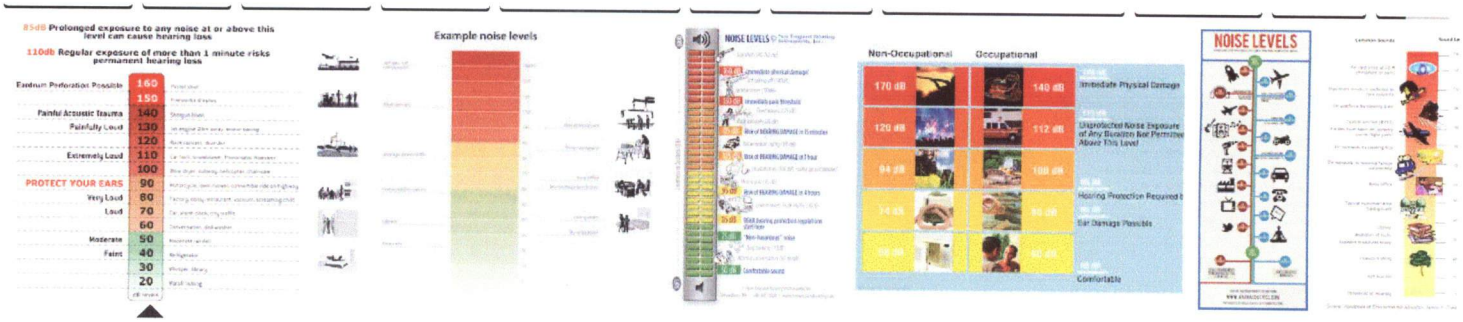

85dB Prolonged exposure to any noise at or above this level can cause hearing loss

110db Regular exposure of more than 1 minute risks permanent hearing loss

Eardrum Perforation Possible	160	Pistol shot
	150	Fireworks display
Painful Acoustic Trauma	140	Shotgun blast
Painfully Loud	130	Jet engine 25m away, motor racing
	120	Rock concert, thunder
Extremely Loud	110	Car horn, snowblower, Pneumatic Hammer
	100	Blow dryer, subway, helicopter, chainsaw
PROTECT YOUR EARS	90	Motorcycle, lawn mower, convertible ride on highway
Very Loud	80	Factory, noisy restaurant, vacuum, screaming child
Loud	70	Car, alarm clock, city traffic
	60	Conversation, dishwasher
Moderate	50	Moderate rainfall
Faint	40	Refrigerator
	30	Whisper, library
	20	Watch ticking
	dB levels	

Noise Levels
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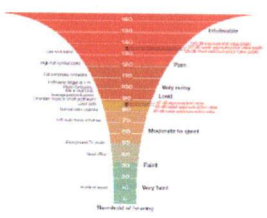

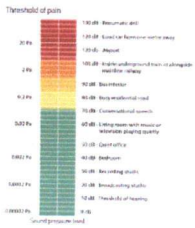

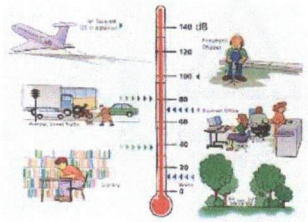

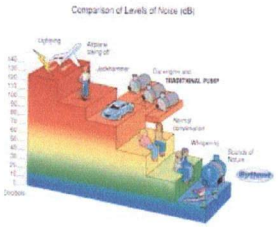

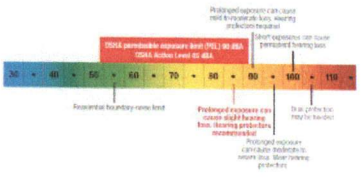

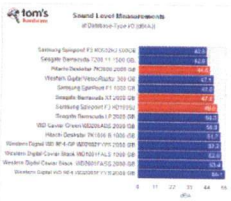

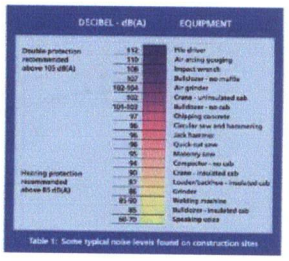

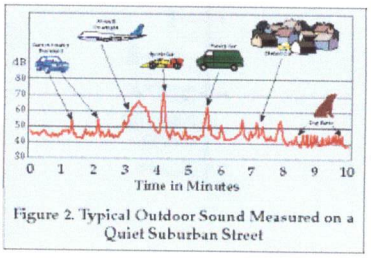
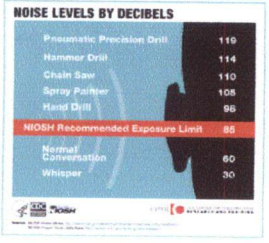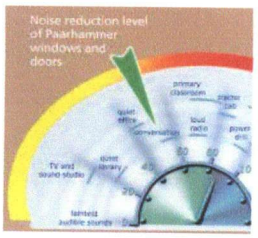
Figure 2. Typical Outdoor Sound Measured on a Quiet Suburban Street