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STATEMENT BY

DR. ALVIN F. MEYER

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

BEFORE THE

GOVERNMENT REGULATION SUBCOMMITTEE

SENATE SMALL BUSINESS COMMITTEE

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PREFACE

On behalf of the United States Environmental Protection Agency, the following information is submitted to the United States Senate Small Business Committee as background for its consideration in the regulation of hearing aids.

This document is intended to provide a broad comprehensive view of noise pollution. It will highlight the most recent findings and literature in the field. The more relevant reports are submitted to the record in their entirety.

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INTRODUCTION AND OVERVIEW

"Noise" is commonly defined as unwanted sound. Although there is great concern today over the adverse effects of noise, the problem is not new. The Romans prohibited chariot movement at night due to noise.

Sound results from a distrubance in the atmosphere that is transmitted as a pressure wave. It is a phenomena related to motion and vibration. In our dynamic, technological society that has grown so greatly in recent decades, it is no wonder that noise has proliferated.

The concern for noise is straightforward–how can we eliminate or reduce it. The solution, however, is a complex, multidisciplinary task that affects the entire population. A discussion of these complexities will provide insight as to the true nature of the problem. First, noise has dramatic psychological effects, as well as profound, irreversible physiological effects. Harmless levels of noise exposure may elicit an uncompromising annoyance response; while damaging levels may bring pleasure. An example would be the responses often associated with a barking dog and loud rock music.

Second, psychological response to noise is both subjective and statistical in nature. Sound that is very annoying to one individual may be enjoyable to another. In fact, the same sound may annoy an individual at one time and relax the same person at another. Physiological effects, though less subjective, are no less controversial. This is reflected in the multitude of different damage criteria which have been advocated over the past 25 years (1).

Third, the harmful effects of noise are cumulative and insidious. Hearing loss, for example, occurs gradually and will go unnoticed until an incurable handicap develops. Irritating noise may create tension in an individual and cause unwarranted social response.

Fourth, man's exposure to noise is often voluntary. Amplified music, snowmobiles, sport shooting and boating are examples of voluntary, recreational exposures to noise. Thus, controlling all sources of noise could impose severe restrictions on recreational hours and location. One man's voluntary exposure may lead to another's involuntary exposure and subsequent detriment.

Fifth, noise control is not a simple or straightforward science. It is often viewed as an art that utilizes certain fundamental engineering principles. Noise does not result from any specific processes, but is present wherever disturbances occur. Noise control requires a "systems or holistic approach" since it is generally intimately related to the operation or process creating it. The solution is generally costly and complex.

Sixth, sound is everywhere, all the time. It continuously varies in intensity and form. It is transient and moves with its source wherever it may go. Man's total exposure to noise has infinite variations.

Thus, noise--a pollutant we have accepted for years--is a serious, complex problem that cumulatively affects everyone throughout their entire life.

Returning to an overview of noise pollution, it was stated that noise results from a disturbance in the atmosphere that is transmitted in wave form. Sound may travel through any medium, not only air. It travels at a speed proportional to the density of the medium. For example sound travels faster in water, a dense medium, then in air.

Being a wave, sound may be described by its frequency and amplitude. An example is a musical note such as 'C', which is at 256 cycles/sec. However, noise is not often a single pure tone but rather a broad spectrum of many frequencies with different amplitudes. The amplitude is commonly measured in terms of a ratio of sound pressures known as "decibels".

Noise generally reaches man by atmospheric waves impinging on the ear. The ear is the human receptor for sound. It is a small and complex organ. Sound travels through the outer ear to the ear drum in the middle ear. Acting as a diaphram, the eardrum transmits sound to the inner ear by means of a lever system of tiny bones. The inner ear is composed of a fluid filled spiral organ that transmits sound to the auditory nerve. From here it travels to the brain, which allows perception (2,3).

Noise is commonly measured in two ways, both utilizing electronic metering instruments. The first is a single number, in decibels, that describes the entire spectrum of the noise. The other is to divide the spectrum into bands and obtain a number in decibels for each band of noise in the spectrum. Since noise is generally time varying, a variety of schemes have been developed to account for this factor. There are two common descriptors used for this purpose. The first is the equivalent noise level (L_{eq}) which is the single level that contains the same energy as the time varying levels over a given period of time. The other method is statistical and presents levels exceeded a certain percentage of time. For example, L_{90} is that level exceeded 90% of the time.

Although noise is virtually everywhere to some degree, it is possible to identify the major sources of environmental noise. By far the largest source is transportation vehicles.

This includes trucks, trains, aircraft, motorcycles, automobiles, etc. Next, is construction equipment, consisting of a multitude of powerful, special purpose machines. Third would be household appliances and products such as hairdryers, food blenders and lawnmowers. Although contributing to environmental noise, occupational noise comes from every type of machine imaginable and is usually treated separately.

The general approach to noise reduction is to first identify and control the source, then the path of transmission, and finally the receiver of the nosie. Control of the source might be the redesign of a machine to reduce the noise generated. The path would be controlled by installation of enclosures. The receiver is guarded either by physically removing the individual from noise or by providing hearing protection in the form of ear muffs or ear plugs.

The human effects of noise are broadly classified as physiological and psychological. Physiological effects are further classified as auditory and non-auditory. Auditory damage includes temporary and permanent threshold shifts. People recover entirely from temporary shifts, while there is no known cure for permanent hearing shifts due to noise exposure. Non-auditory effects include such things as headaches, nervousness, and nausea caused by changes in metabolic processes. Psychological response is any change in behavior caused by exposure to noise. They include factors such as irritability, reduction in concentration, and speech interference (2).

Society's effort to reduce noise is divided into three areas.

1. The USEPA is responsible for establishing maximum permissible limits on new products introduced into commerce,

2. The Department of Labor is responsible for establishing protective occupational noise exposure limits,

3. The State and local governments are responsible for prescribing acceptable environmental noise regulations.

Additionally, DOT/FAA are responsible for aircraft noise reduction, and many other agencies have various lesser involvement in noise.

Recognizing the multitude of efforts directed toward the control of noise, Congress designated EPA to coordinate all Federal efforts related to noise.

In the final analysis it becomes evident that noise cannot be totally eliminated. Since it is so subjective, it would require the elimination of sound, which would neither be desirable nor possible. The question, then, is what to do after all that can be done has been done. The answer is that hearing protectors may be used by individuals to reduce their reception of unwanted sound. These devices are available in many shapes and forms and must be used properly to be effective.

WHAT IS NOISE?

Noise is unwanted sound. Sound is a physical disturbance in the form of a pressure variation that can be detected by the ear. The physical disturbance is generally produced in air by the action of a vibrating object.

When a vibrating object moves outward it compresses a layer of air surrounding it. This compression travels outward, dissipating in relation to the energy that created it. As the vibrating object moves inward, the surrounding air is rarefied. This rarefaction travels outward in a manner similar to the compression. The result is therefore a series of alternating compressions and rarefactions, in sympathy with the vibrations. This is illustrated in figure 1.

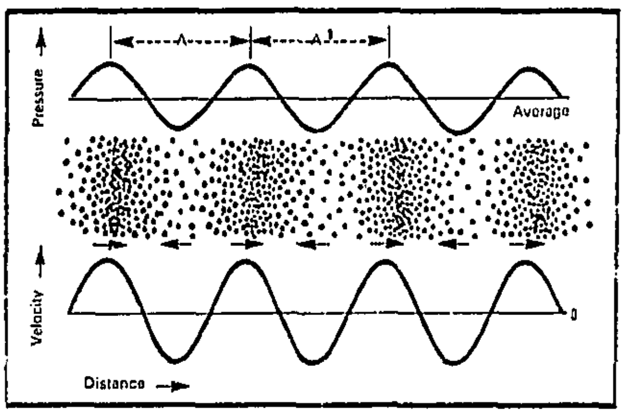


Figure 1. The graph or curve above this picture of sound waves shows how pressure varies above and below average with distance at a given time. The lower curve shows how velocity varies, above zero (that is, molecules moving to the right) and below zero (that is, molecules moving to the left). The distance (A) between crests of both curves is the wavelength of the sound.

Such a series of disturbances is called a sound wave. The number of compressions, or rarefactions, that pass a given point in a specified time period is called the frequency of the sound wave. It is generally expressed in cycles per second, which are called Hertz. The magnitude of the pressure depends upon the movement of the vibrating source. This determines the intensity of the sound wave.

Sound may be described by its frequency, amplitude, and temporal characteristics. The latter is used to determine the types of noise–ongoing noise and impulsive noise (2).

Ongoing noise continues for an appreciable period of time. It is further differentiated into steady-state, fluctuating, and intermittent noise as described in Table 1.

Impulsive noise is one or more transient acoustical events such as a gunshot, each of which lasts less that 500 milliseconds and has a change in magnitude of at least 40 decibels within that time. The basic parameters that describe impulsive noise are:

- Peak sound pressure level
- Duration of each impulse (in milliseconds or microseconds)
- Rise and decay time
- Type of waveform
- Spectrum
- Number of impulses

Two types of impulsive noise are illustrated in figure 2. In type (a) there is a rapid rise to a peak sound pressure level followed by a decay to a negligible magnitude. Though a subsequent negative pressure wave of much smaller magnitude often occurs, only the duration of the positive portion is considered as the pulse duration. In that type (b) oscillatory event, the duration is taken as being the time for the magnitude to decay 20 decibels below the peak. It is important to point out that impulse noise can be properly measured only by oscillographic techniques due to their short duration.

Table 1
Classification of Ongoing Noise Exposure (=)

Type of Exposure Steady-State	Description	Typical Examples
	Single continuous daily exposure (typically 8 hours but may be shorter or longer) at a constant level within ±5 dBA.	Weaving room noise; sound of of a waterfall; shipboard noise; interior of a vehicle or aircraft noise; turbine noise; hum of electrical sub-station.
Fluctuating Noise	Noise is continuous but level rises and falls (rapidly or gradually) more than 5 dBA during exposure.	Many kinds of processing or manufacturing noise. Traffic noise; airport noise; many kinds of recreational noise (e.g., vehicle-racing; powered lawnmowing; radio and TV).
Intermittent Noise	Noise is discontinuous: i.e., the level falls to unmeasurable low or to nonhazardous levels between periods of noise exposure of which more than one affects the ear during the day. Note: This can be regarded as a special case of fluctuating noise.	Many kinds of industrial noise (especially in construction work, ship building, forestry, aircraft maintenance, etc.); Many kinds of recreational noise (e.g., drag racing, rock concerts, chainsawing); light traffic noise; occasional aircraft flyover noise; many kinds of domestic noise (e.g., use of electrical appliances.

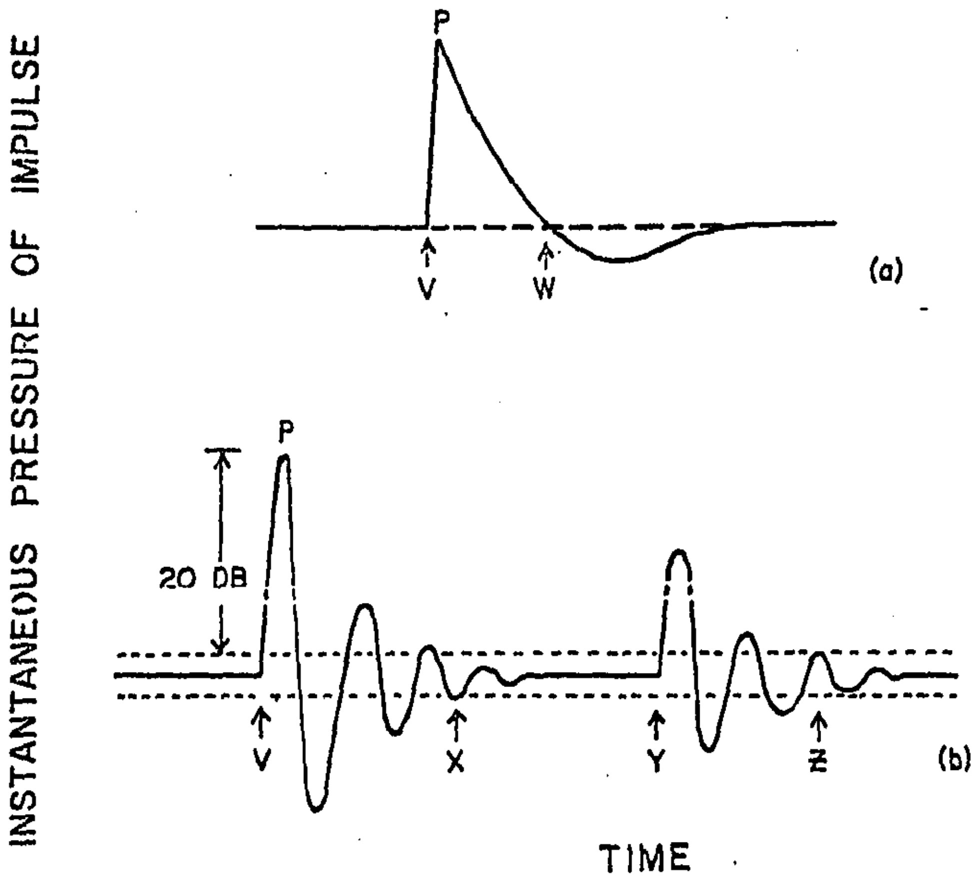


Figure 2. Types of Impulsive Noise

HOW IS NOISE PERCEIVED–THE HUMAN HEARING MECHANISM? (3)

Anatomically, the ear is divided into three sections–the outer, the middle, and the inner ears–through which air-conducted sound waves must travel for hearing to occur. The outer ear consists of the fleshy appendage attached to the head and the ear canal, both of which serve to channel sound waves toward the elastic tympanic membrane commonly known as the eardrum. The conically shaped tympanic membrane transforms the energy of sound waves into mechanical energy of the middle-ear ossicles, a set of small bones. The ossicle chain, acting as an impedance transformer, transmits the vibrations of the tympanic membrane to the oval window. This window moves in and out, much like a piston, generating pressure waves in the perilymph, a nearly incompressible fluid in the inner ear. The pressure differential that results moves the basilar membrane and the organ of Corti. The hair cells in the organ of Corti transform the mechanical motions into nerve impulses, which are transmitted through the eighth nerve into higher centers in the brain, where they are decoded and interpreted as sound. See figure 3 and figure 4.

The preceding description indicates that sound is transmitted to the brain first by conductive and then by neurological means. Conductive mechanisms–movement of membranes, bones and fluid–propagate the sound waves from the external through the middle and inner ears. In the inner ear proper, direct conductive stimulation of the tiny nerve receptors translates the previously mechanical activity to an electrical, or neurological, activity.

The importance of making this distinction between conductive and neurological transmission is simply that noise tends principally to damage the neurological auditory mechanisms–the hair cells. Most frequently, noise-induced injury first occurs to the outer- and inner-hair-cell structure; then if hazardous noise conditions persist, the organ of Corti itself is destroyed. The consequence of such damage is that nerve cells that would have transmitted the auditory signal degenerate they will never regrow and cannot be replaced. Severe damage from noise exposure, then, is permanent. The one exception to this rule is that short, intense blasts of noise can rupture an eardrum, dislodge a bone in the middle-ear chain, or otherwise damage a conductive mechanism. This acoustic trauma is often temporary and in many cases can be repaired by surgery or, if simple enough, will heal itself in time.

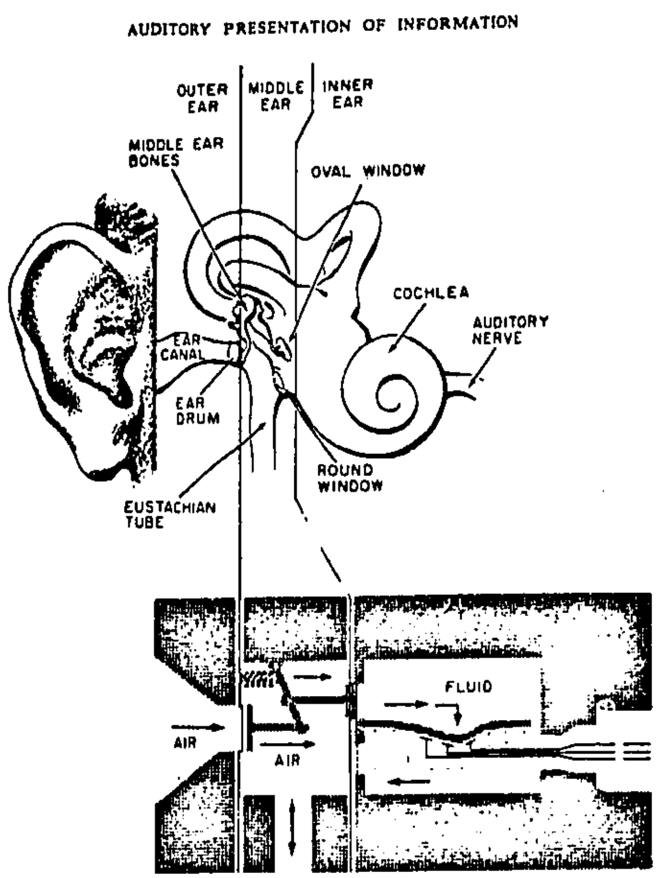


Figure 3. Functional Diagram of Ear

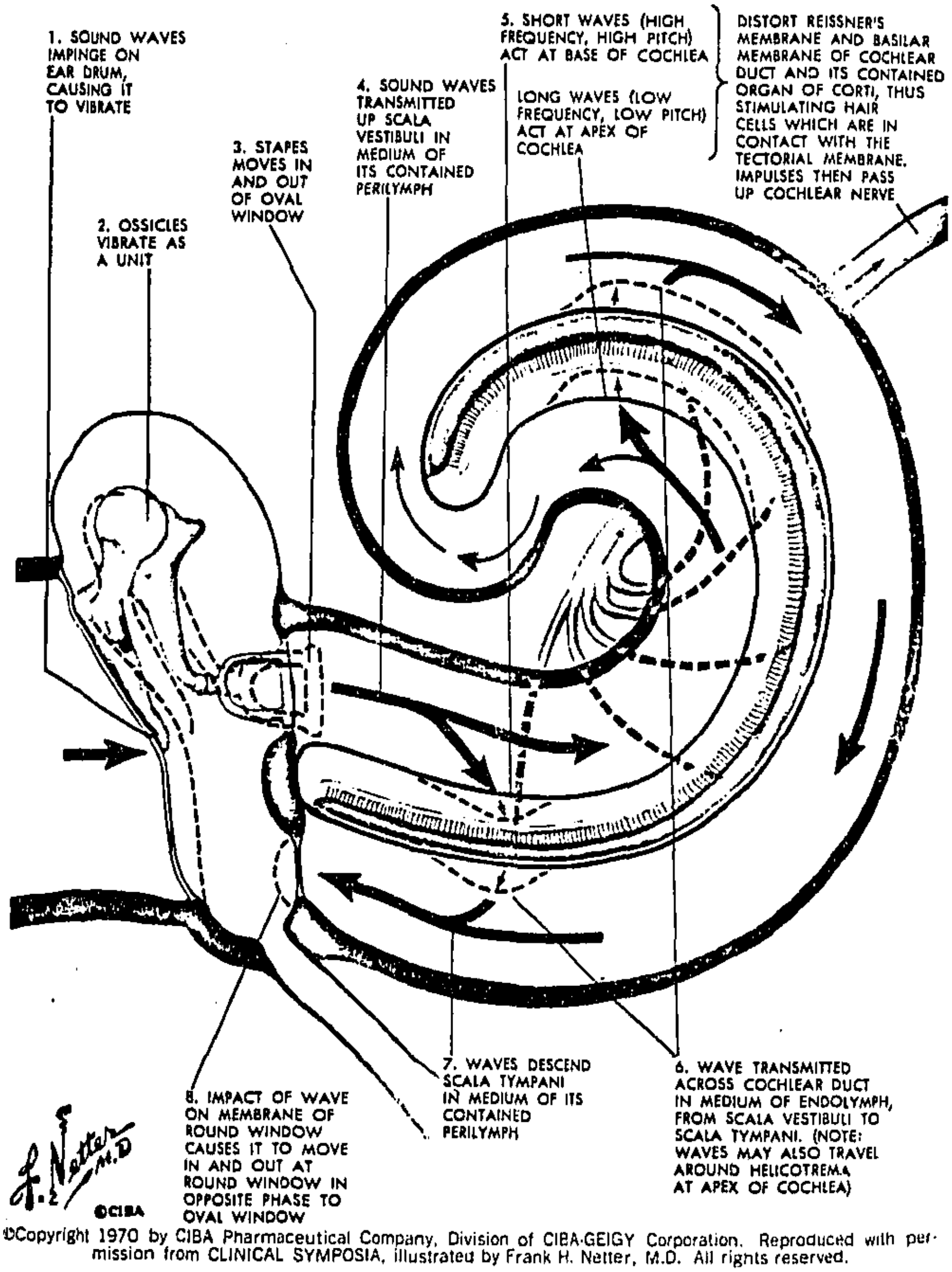


Figure 4. Transmission of Vibrations from Drums Through Cochlea

HOW IS HEARING MEASURED?

Hearing is most frequently measured with the use of an instrument called an audiometer. This device accurately produces pure tone signals at known sound pressure levels. The frequencies most commonly used in audiometric testing are 125 Hz, 250 Hz, 500 Hz, 1000 Hz, 2000 Hz, 4000 Hz and 8000 Hz. The technique consists of determining an individual's threshold of hearing at each of these frequencies. This is the minimum level at which the sound can be perceived. The levels are relative to what is believed to be the "best" hearing determined from a survey of the hearing of a large number of people. The threshold levels determined in this manner are called the hearing level at each frequency.

It is important that audiometric testing be conducted where the ambient sound levels do not interfere with the test signals. This usually requires a soundproof room or booth. Also, the instrument must be frequently checked and calibrated to maintain accuracy.

If done periodically, the "audiogram" resulting from such a test will give an indication of a change in hearing level. An audiogram typical of an individual with a noise-induced hearing loss is illustrated in figure 5. Note that the hearing loss generally occurs first at a frequency of 4000 Hz and spreads out from there.

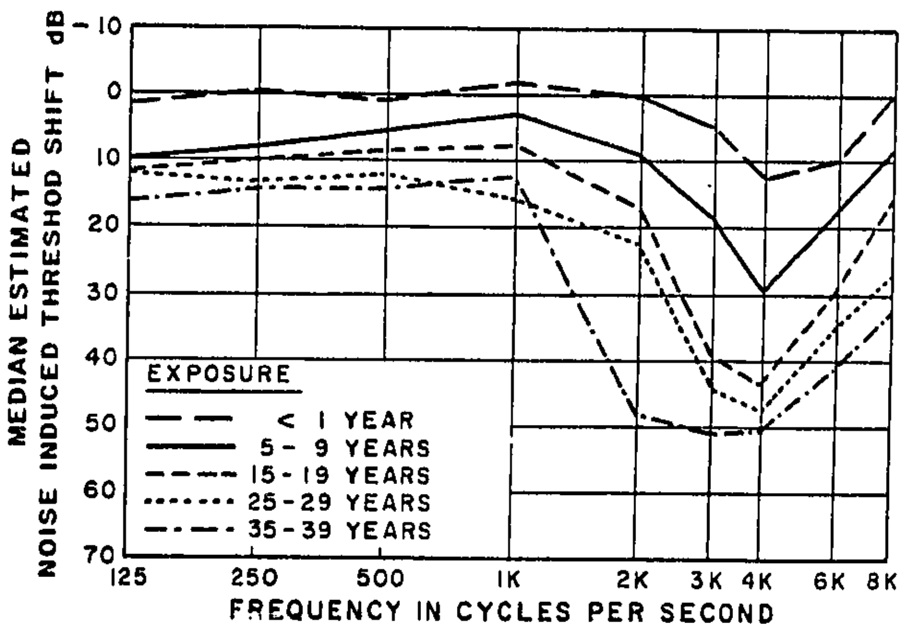


Figure 5. Median noise-induced hearing changes for jute weavers as a function of years of exposure to weaving machinery noise. Data taken from Taylor, Pearson, Mair, and Burns.

HOW IS NOISE MEASURED?

Noise is measured in different ways, depending upon the intended use of the measurement data. The two main reasons for measuring noise are:

1. To identify the source, so that it may be engineered out,

2. To obtain insight into the hyman response most likely to occur.

It is not practical to present every technique curently available to describe noise. Only the most widely used and accepted methods will be discussed. For more complete information, a copy of *Handbook of Noise Measurement* published by General Radio Corporation is being submitted (3).

THE DECIBEL–BASIC UNIT OF MEASUREMENT

The basic unit of noise measurement is the decibel. This unit stems from the ear's response to sound pressure fluctuations. The range between the smallest sound pressure sensed by the human ear and the highest sound pressure physically tolerable covers a ratio of approximately 1,000,000 to 1. While the brain has no trouble handling such a large range, it is mathematically inconvenient to deal with such large numbers. It is more convenient to base the scale on the number of zeros than the actual number. The common logarithm does just this. Thus, the logarithm of 1=0, 1000=3, and 1,000,000=6. These numbers are then proportional to the actual sound pressure. Therefore a scale of this nature used to describe what the ear can sense would range from 0 to 6. However, engineers and scientists prefer to work in terms of energy, which is proportional to the square (a quantity multiplied by itself) of sound pressure. When a logarithm is squared it simply doubles the quantity. Consequently, the scale would range from 0 to 12. These units have been termed bel in honor of Alexander Graham Bell. Since the bel is a rather large quantity, it is divided into ten smaller units, so that the scale now extends from 0 to 120 decibels, or tenths of bels.

Utilizing this basic concept the fundamental measure of noise in decibels has been defined as:

Sound Pressure Level (SPL) = $10 \log_{10} (P/P_{reference})^2$ in decibels. The Sound Pressure Level is a ratio of the pressure of a given sound to an arbitrary reference pressure. This reference pressure was chosen as being near the smallest sound pressure that we can hear (20 micro-newtons per square meter or .0000000029 pounds per square inch) (4).

Due to the logarithmic nature of the decibel, addition is not a straightforward process. It must account for the mathematical manipulation used in deriving the unit. By way of example, two identical sources of noise will produce a total sound pressure level only 3 dB greater than one source. Also, two sources differing by 15 dB will yield a total level not significantly different from the larger source (see figures 7 and 8). Figure 6 may be used to combine sources of varying levels rather easily. Where more than two sources are present, they may be dealt with two at a time until a single level is obtained. For example, take three identical sources of 100 dB. First add two sources which yields 103 dB. Next add 100 dB and 103 dB. Using the table low 1.8 dB is added to the larger source. Thus the total is 104.8 dB.

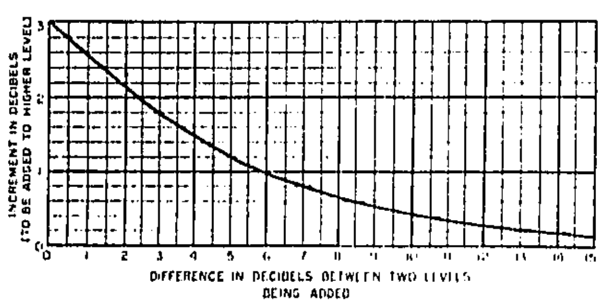


Figure 6. Chart for combining noise levels

OCTAVE BAND MEASUREMENTS

One of the fundamental characteristics of sound is frequency. The human ear can sense sounds ranging from 20 to 20,000 cycles per second. Most sound will not contain only one frequency (pure tone), but rather a considerable number of different frequencies. Each frequency could be assigned a decibel level. The impacticability of this is apparent . Instead, the convention is to divide the frequency range into octave bands. Each band has a range of 2 to 1 and is designated by the center frequency. The 10 bands which

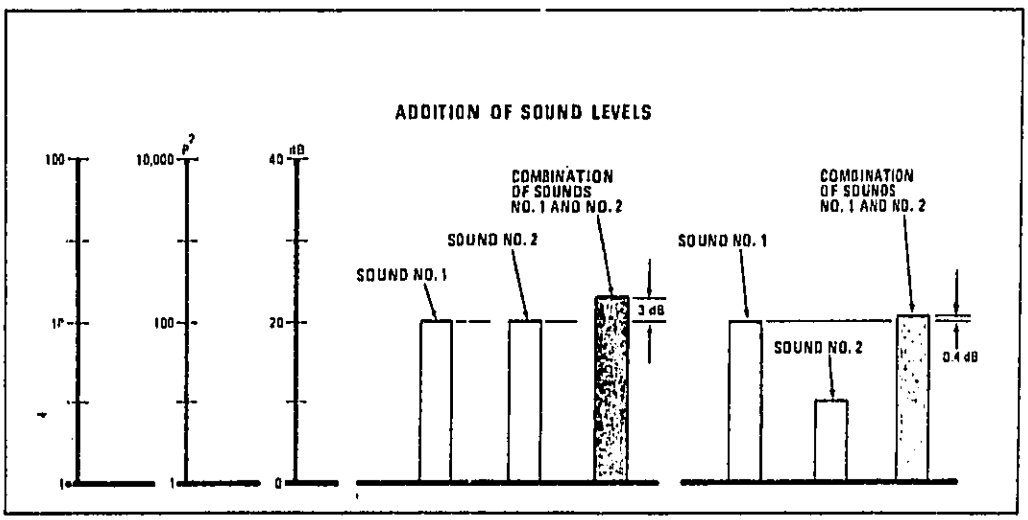


Figure 7

Figure 8. Doubling the number of identical sources results in a 3 dB increase in sound pressure level.

cover most of the audible frequency range are 31.5, 6, 3, 125, 250, 500, 1000, 2000, 4000, 8000, and 16000. This technique measures the decibel level for each octave band. It is very useful in describing the frequency content and locating the specific source of a sound. For more specialized needs requiring better resolution, each octave band is subdivided into three equal portions called "one-third octave bands".

An example of a typical octave-band analysis is shown in figure 9.

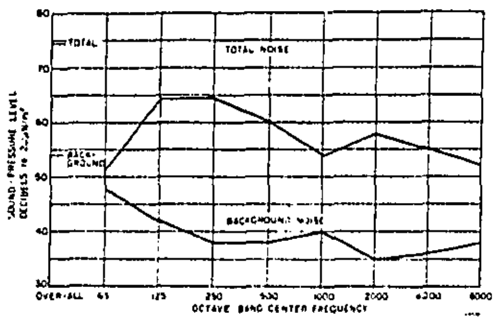


Figure 9. A plot of the octave-band analysis of noise from a calculating machine.

WEIGHTED SOUND LEVEL MEASUREMENTS

The most widely used technique of sound measurement is to describe the levels at each frequency with a single composite number. The levels are automatically summed by using an electronic circuit. In addition to this a number of systems have been developed for "weighting" the levels at each frequency. The most common are the A, B and C weightings. As illustrated in figure 10, each discriminates against the lower frequencies to varying degrees. The C-scale has relatively little weighting and is very nearly a flat response. The A-scale has considerable weighting against the low frequencies. These two levels (the A and C) are often used to provide a feel for the energy content of the total spectrum. For example, if the difference between the C-scale and the A level is large, one would know that the noise contained considerable energy in the low frequencies. As the difference in these levels is reduced the energy will be shifted to higher frequencies.

It is known that the human auditory response to noise incorporates a weighting system which is most closely described by the A-weighted scale. In fact, the A-scale was developed from surveys of people's subjective determination of equal loudness. To illustrate this, a sound at 100 Hz must be 20 dB higher than a sound at 1000 Hz for the two to be perceived as equally loud.

Because of the close correlation between human response and the A-weighting, most of the current noise emission standards and hearing risk criteria are expressed in A-weighted decibels (dBA).

ENVIRONMENTAL NOISE DESCRIPTORS

To go one step further, it is necessary to describe all of the sounds present in a given period of time in some convenient manner. Attempts to accomplish this and to correlate the results to human response have been numerous. The majority of these techniques are described in references 3, 4, 5, and 6. Most fall into two general categories:

1. Statistical measures
2. Cumulative measures.

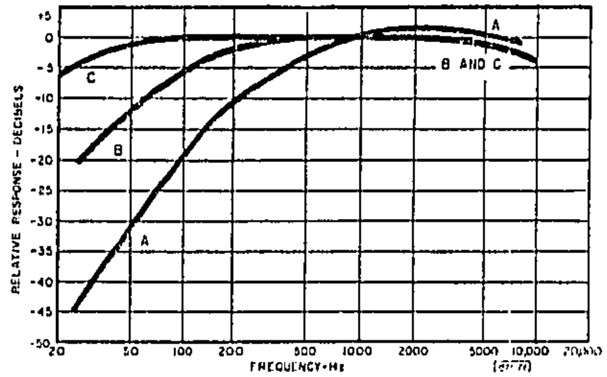


Figure 10. Frequency responses for SLM weighting characteristics

Statistical Measures

To obtain statistical descriptors, it is first necessary to continuously record the sound pressure levels present at a specific location for a given period of time. From this data, the sound pressure level exceeded a certain percentage of time may be calculated. The most common percentages used are 10, 50, and 90 and are expressed as L_{10}, L_{50} and L_{90}, respectively. For example, an L_{50} of 75 dBA means that over the specified period of time the level of 75 dB(A) was exceeded 50% of the time. An L_{10} of 90 dBA would mean that a level of 90 dB(A) was exceeded 10% of the time. The L_{10} gives an approximate measure of the higher level and short duration noise, the L_{50} is a measure of the median sound level, and the L_{90} is a measure of the residual sound level. It is also useful to report the total range of sound levels observed since maximum and minimum are not otherwise indicated.

Cumulative Measures

The basic quantity used in these measures is the energy mean noise level (L_{eq}). By definition it is the A-weighted level of steady state continuous noise having the same energy as the actual time-varying noise. It is analagous to making equal monthly utility payments, to pay the actual costs, which vary from month to month. The numerous methods in use, generally provide corrections to this to account for different factors. For example, corrections are made for sounds of unusual characteristics (pure tone, for example) and for the time it occurs. In recommending levels of safe noise exposure, the Environmental Protection Agency has recommended using L_{eq} and L_{dn}. The latter simply applies a 10 dBA penalty to the noise emitted during 10 pm to 7 am. Reference 5 appendix describes these measures in considerable detail.

NOISE MEASUREMENT INSTRUMENTATION

There is a large variety of noise measurement instrumentation to meet the many needs that arise. This is emphasized by Appendix IX Reference 5. By far, the most widely used instrument is the Sound Level Meter. The accuracy of this instrument is currently specified by American National Standards Institute S1.4-1971, "Specification for Sound Level Meters". This standard identifies three levels of accuracy. Depending on a meter's performance, it is designated Type I, II, or III.

All sound level meters are designed to measure some or all of the weighted sound levels previously described. Invariably a meter will measure the A-weighted sound level and must include the B and C-weightings.

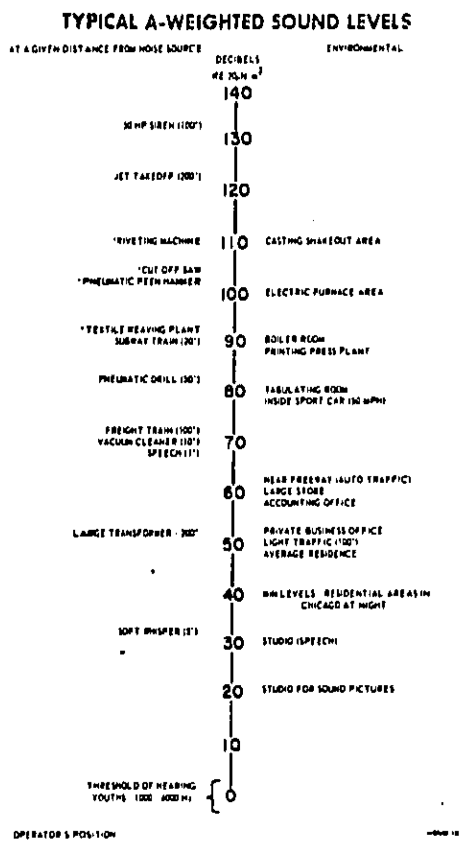


Figure 11. Typical A-weighted sound levels measured with a sound-level meter. These values are taken from the literature. Sound-level measurements give only part of the information usually necessary to handle noise problems, and are often supplemented by analysis of the noise spectra.

Type I meters have the highest precision and often are designed to mate with an octave band filter attachment. This permits the measurement of octave band sound pressure levels.

For the most, these meters are portable lightweight and battery operated. The basic components of a sound level meter are:

1. A transducer,

2. An electronic amplifier and calibrated attenuator for gain-control (1)

3. A readout device.

These components are illustrated in figure 12 along with illustrations of typical sound level meters, figures 13 and 14.

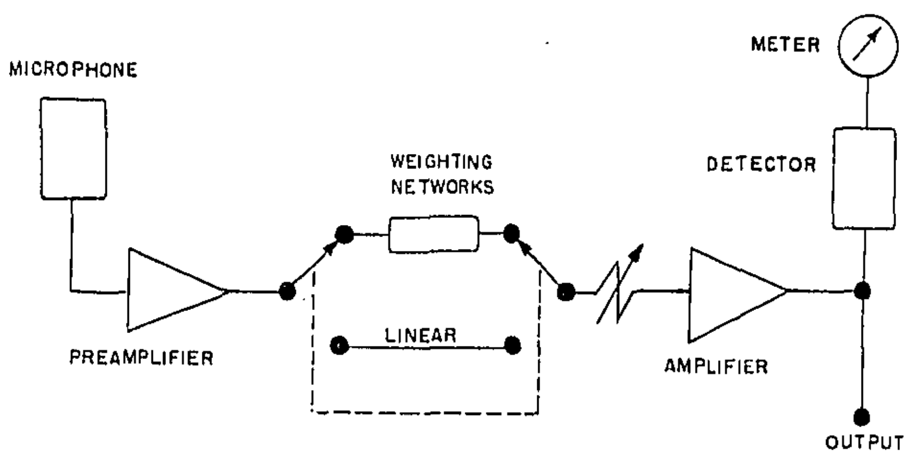
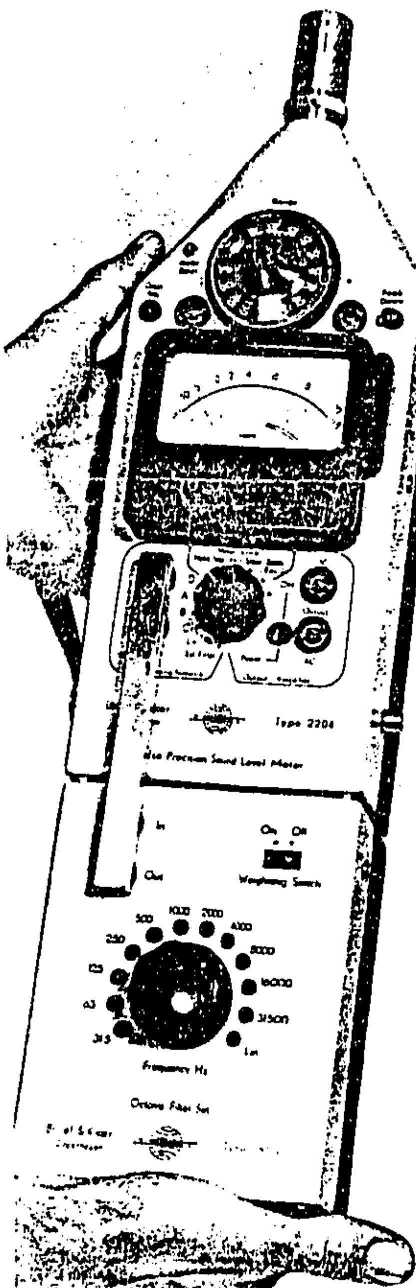


Figure 12. Block diagram indicating the typical internal arrangement of a sound level meter.



General Radio Co., Concord, Massachusetts.

Figure 14. A standard sound level meter.

B&K Instruments, Inc., Cleveland, Ohio.

Figure 13. A precision sound level meter with an octave band filter attached to the base.

WHAT ARE THE MAJOR SOURCES OF NOISE TODAY?

The main contributors to noise today may be classified into the following broad areas:

- Transportation systems
- Construction equipment
- Devices powered by internal combustion engines
- Electrical appliances

In EPA's *Report to the President and Congress on Noise* (March 1975 (7) the major sources of noise are described in detail. Subsequent to the Noise Control Act of 1972, more detailed studies of specific sources have been conducted in preparation for product standards. This section will present a cursory description of these sources and the levels of noise they emit.

TRANSPORTATION SYSTEMS

For the purpose of this document, transportation systems include:

- Aircraft
- Highway vehicles
- Recreational vehicles
- Railroad vehicles.

The principal causes of *aircraft* noise are:

- The high velocity mixing of gases from the jet engine,
- Aerodynamic noise generated by propeller and aircraft body.

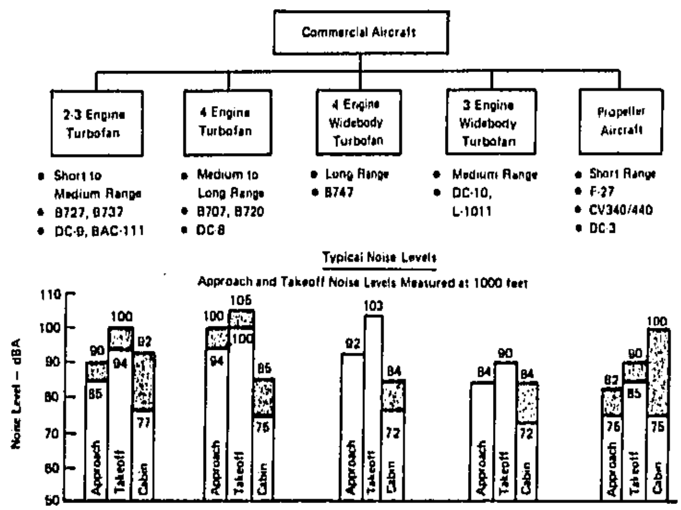


Figure 15. Characteristics of commerical aircraft

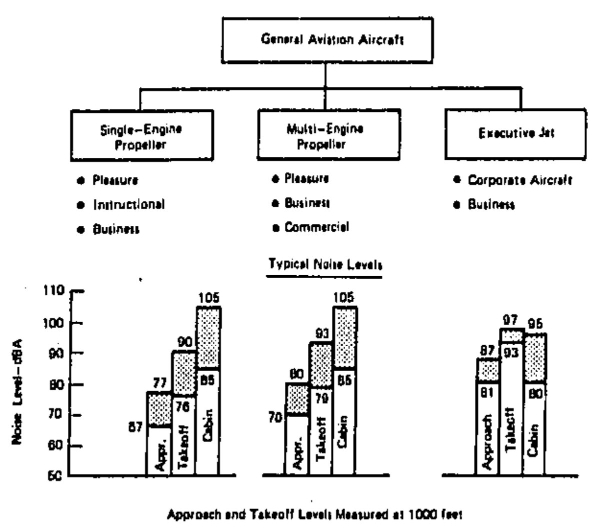


Figure 16. Characteristics of general aviation aircraft

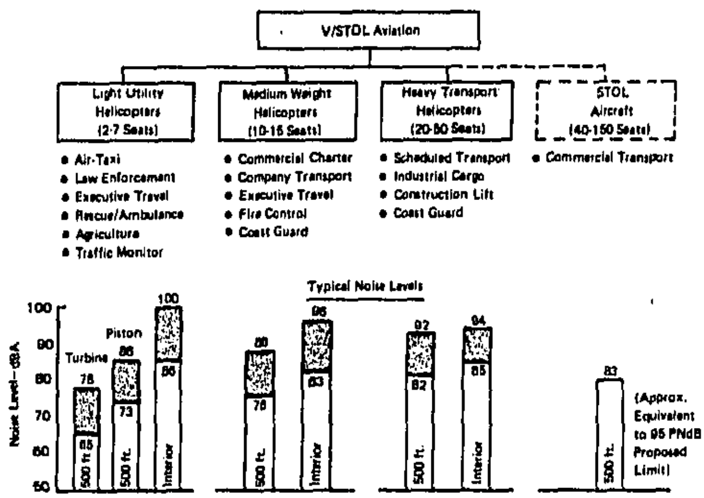


Figure 17. Characteristics of V/STOL aircraft

The noise produced by *highway vehicles* can be attributed to three major causes:

1. Tires and gearing
2. Engine and related accessories
3. Aerodynamic and body noise.

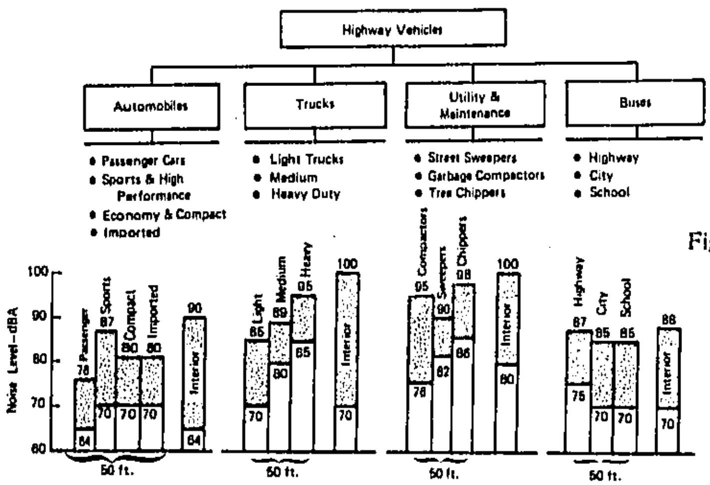


Figure 18. Characteristics of Highway Vehicles

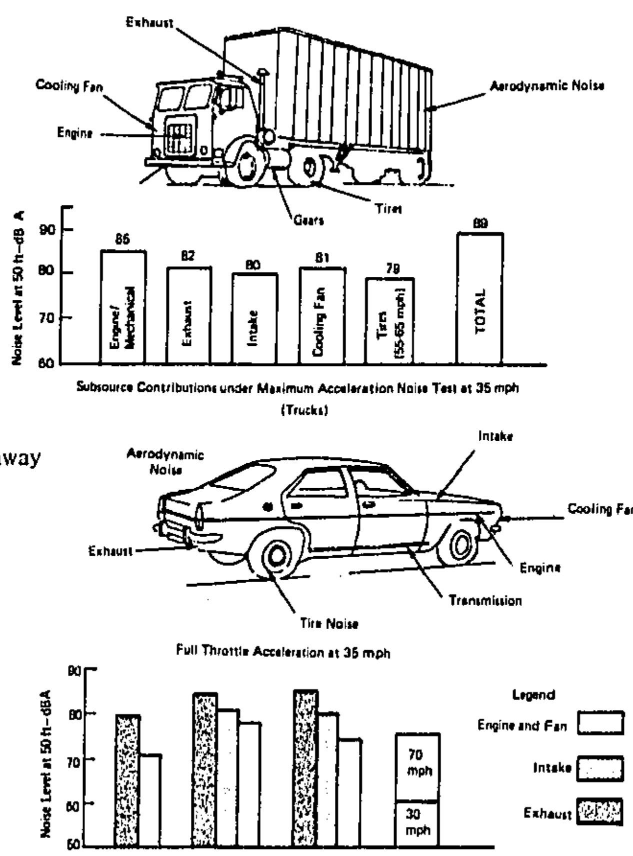


Figure 19. Noise Sources for Highway Vehicles

Recreational vehicles are defined here to include motocycles, snowmobiles, all-terrain vehicles and pleasure boats. The growth in availability and use of these vehicles has been remarkable in the past 10 to 20 years. The noise output, though dependent upon speed, is primarily a function of their mode of operation. The major contributing source of noise from these vehicles is the exhaust system. Of secondary significance is the noise radiated from the intakes and engine walls.

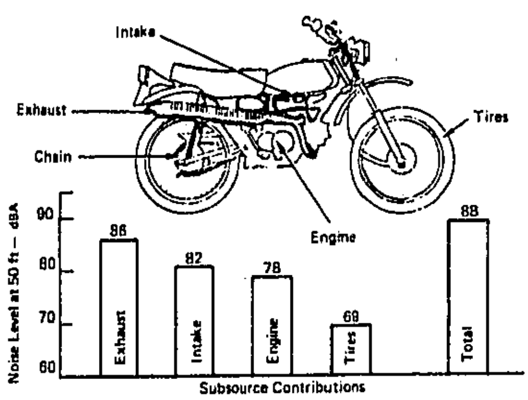


Figure 20. Motorcycle noise sources

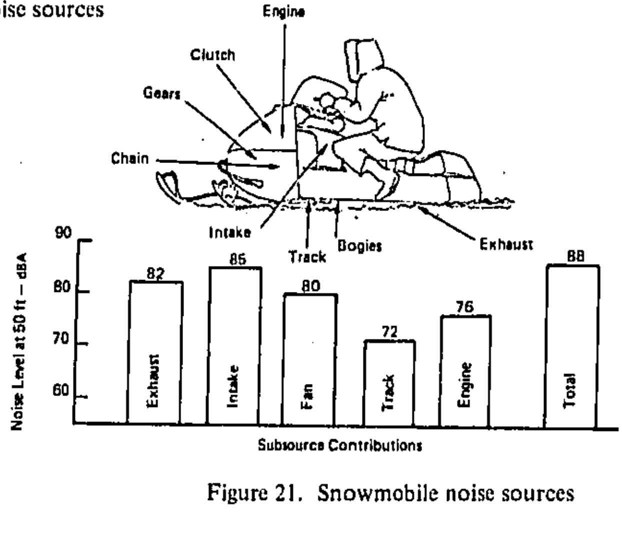


Figure 21. Snowmobile noise sources

The maximum noise levels measured for pleasure boats (both inboard- outboard-powered) range from 65 to 105 dBA at a distance of 50 feet The lower limits of this range are created by small craft (with 6- to 10-horsepower engines). The highest levels, exceeding 105 dBA at 50 feet, are produced by inboard-powered ski boats with unmuffled exhausts.

Engine exhausts are the main source of noise for the boats exhibiting the highest noise levels. On the ski boats, which have large exposed engines, intake and engine mechanical noise also provide a significant contribution. The noise levels of smaller engine and intake, though acoustically shielded, produce almost as much noise as the exhaust.

The typical noise exposures for operators of outboard boats are also high. These exposures range from 84 dBA for 6-horsepower units to 105 dBA for 125-horsepower units measured at the driver position under accelerating conditions. At cruising speeds, operator levels on all boat types (inboard and outboard) range from 73 to 96 dBA.

Railroad vehicles include:

- Locomotives
- Frieght cars
- Passenger cars

The main sources of locomotive noise contributing to the overall levels are:

- Diesel exhaust
- Diesel engine, surrounding casing, intake and turbocharger
- Cooling fans
- Wheel/rail interaction
- Electrical generator.

Rail car noise is composed of wheel/rail noise and vibration of the car body.

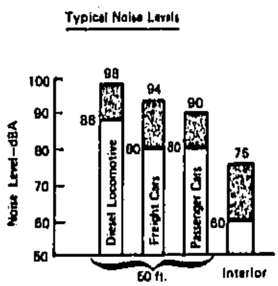


Figure 22. Characteristics of rail systems

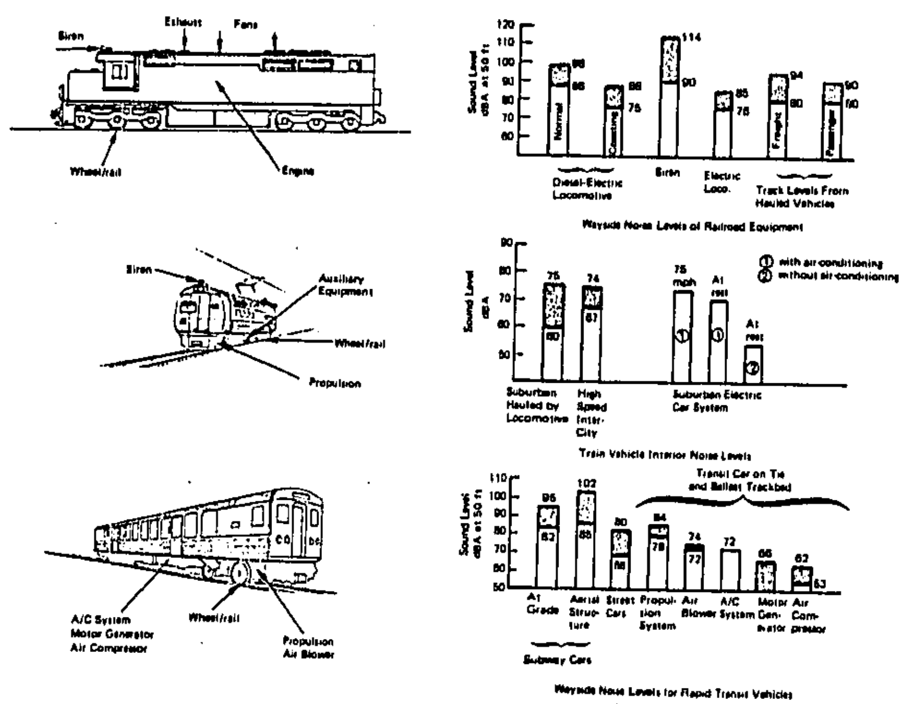


Figure 23. Rail vehicle noise sources

Table 2 provides a summary of the sources of noise comprising the transportation system noise.

Table 2
Rank Ordering of Surface Transportation System According to A-Weighted Noise Level

	Typical A-Weighted Noise Levels at 50 ft(1) dB re: 20μN/m^2	Estimated Vehicle-Miles in Urban Areas Billions
HIGHWAY		
Medium and Heavy Trucks	84 (88)	19
Motorcycles	82 (88)	NA(2)
Garbage Trucks	82 (88)	0.5
Highway Buses	82 (86)	0.1
Automobiles (Sport, etc.	75 (86)	21
City Buses	73 (85)	2.2
Light Trucks	72 (86)	77
Automobiles (Standard)	69 (84)	335
RAIL		
Freight and Passenger Trains	94	NA(2)
Rapid Transit	86	0.33
Trolley Cars*	80	0.33
Trolley Cars**	68	0.33
RECREATIONAL VEHICLES		
Off-Road Motorcycles	85	
Snowmobiles	85	
Inboard Motorboats	80	
Outboard Motorboats	80	

(1) Values inside parentheses are typical for maximum acceleration. All other values are for normal cruising speeds. Variations of 5 dB can be expected.

(2) Not available.

*Pre-WWII
**Post-WWII

CONSTRUCTION EQUIPMENT AND OPERATIONS

Although there is a great variety in the types and sizes of construction equipment there are similarities in the mechanisms producing the dominant noise. This allows construction equipment to be grouped in the following general categories:

- Equipment powered by internal combustion engines
- Impact equipment and tools
- Other equipment and tools

The equipment included in these categories and their typical noise levels are illustrated below:

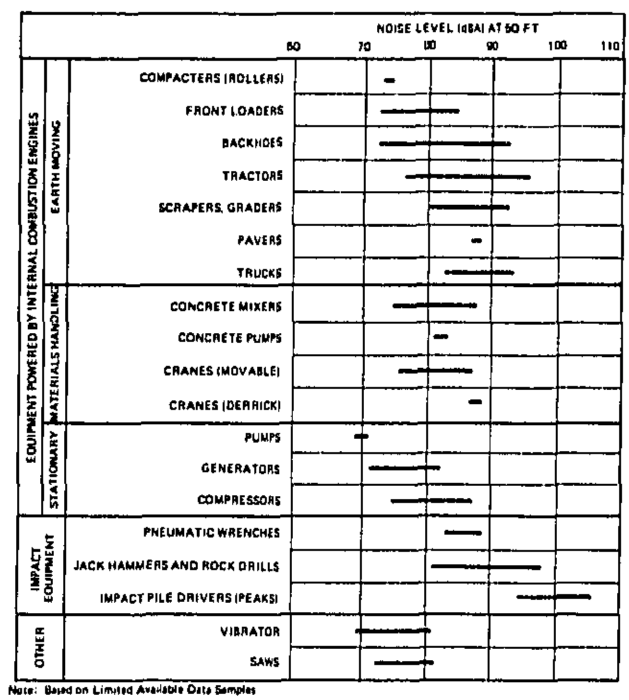


Figure 24. Construction equipment noise ranges

DEVICES POWERED BY INTERNAL COMBUSTION ENGINES

The devices considered in this category of noise are listed in figures 25 and 26 along with typical value of the noise levels emitted.

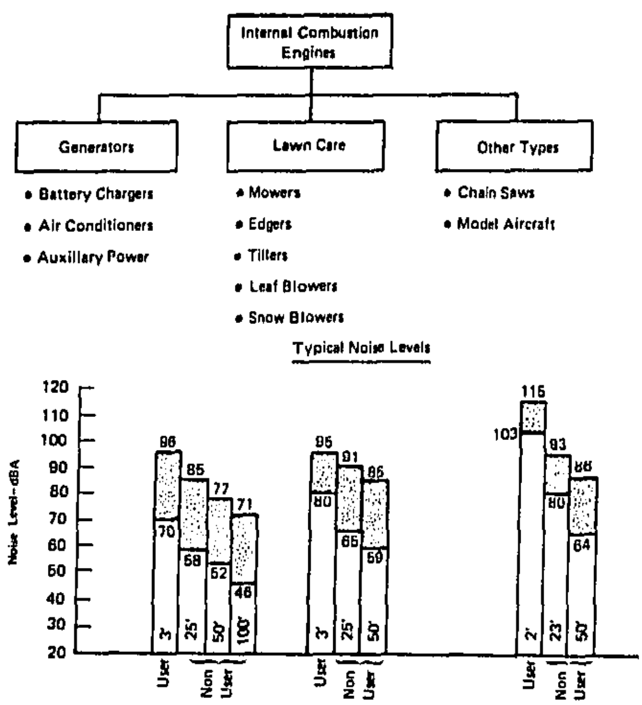


Figure 25. Characteristics of devices powered by internal combustion engines

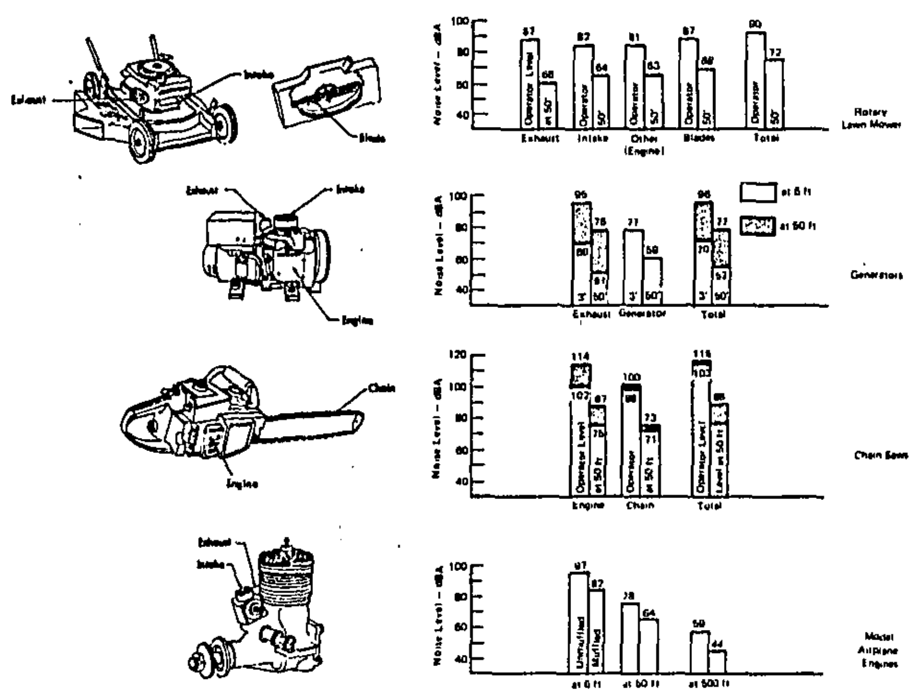


Figure 26. Noise source characteristics of internal combustion engine devices

ELECTRICAL APPLIANCES

In recent years there has been a proliferation of small electrical appliances that emit significant levels of noise. Figure 27 lists a number of these devices and typical noise levels.

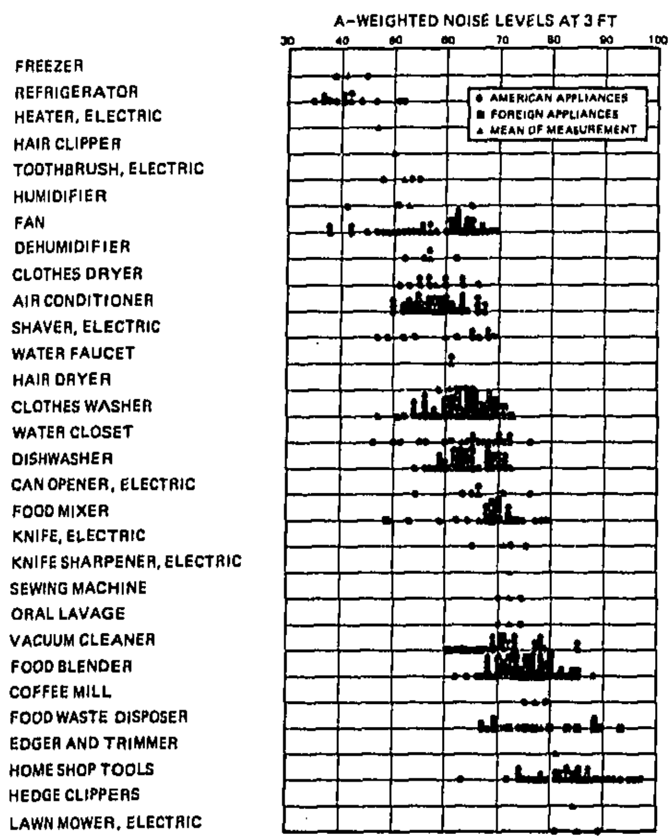


Figure 27. A summary of noise levels for appliances measured at a distance of 3 feet

WHAT ARE THE BASIC PRINCIPLES OF NOISE CONTROL? (3)

The general approach to noise reduction can be divided into two major parts as follows:

1. Reduction of noise at its source.

2. Reduction of noise level at the ear of the listener by changes in the path from the source.

NOISE CONTROL AT THE SOURCE

It is usually wise to determine first whether the noise can be reduced at the source. A different type of source might be selected. For example, a process might be changed so that parts are welded instead of riveted together. A source of different basic construction but of a similar type might be used. For example, a slower fan of many blades can sometimes be substituted for a high-speed two-bladed fan. Or, the construction of the particular source at hand might be modified, and this procedure will be discussed briefly.

When modification of a source is attempted, a decrease in the radiated power is usually the most important change that can be made. This usually means a reduction of vibration amplitudes and of the radiation of sound produced by the vibration. We can separate this problem into three sections:

1. Decrease the energy available for driving the vibrating system.

2. Change the coupling between this energy and the acoustical radiating system.

3. Change the structure that radiates the sound so that less is radiated.

In each of these sections it is usually helpful to track down the important sources of noise and the path of transmission by using frequency analysis of the sound and vibration. The effects of changes in the source (for example, speed, structure, and mounting) on the spectrum should also help in finding the important elements. The reduction of the vibration that produces noise is discussed later. Change in the coupling system frequently means the use of vibration isolation mounts. It may also mean decreased or even increased stiffness in some members transmitting the vibration. Or it may mean better fastening of some parts to massive, rigid members. Resonant structures are often troublesome coupling members. The resonance may be in the mechanical structure or in an air chamber. In either situation, it is usually possible to shift the resonance by changes in the structure or to damp the resonance by adding absorbing material. Mufflers may be needed on exhaust or intake systems. Changing the radiating structure often means nothing more than reducing the external surface areas of the vibrating parts as much as possible. It may be possible to put holes in the radiating member to reduce the efficiency of radiation. Less stiffness of the part may help to reduce radiated sound by permitting sections to vibrate in different time patterns. Large surfaces near the vibrating parts should also be avoided, since these surfaces may increase the radiating efficiency of the vibrating parts.

Another possible way of modifying the source to improve the noise situation is to change the directivity pattern of the radiated sound. When streams of air or other gases come out of an opening, they radiate sound that may be highly directional at high frequencies. Changing the direction of flow can shift this pattern. It may be possible to direct it in such a way that noise in certain directions is considerably reduced.

CONTROL OF THE PATH OF SOUND

The control of the noise by changes in the path of the sound can be analyzed into three sections:

1. Change in relative position of source and listener.

2. Change in acoustic environment.

3. Introduction of attenuating structures between source and listener.

Increasing the distance between the noise source and the listener is often a practical method of noise control. Furthermore, merely rotating the source of noise may permit one to decrease the level if a change to a direction of low directivity factor is achieved. Both these procedures are effective only in the region where approximately free-field conditions exist (that is, little reflection of noise).

The most obvious change that can be made in a room to reduce the noise level is to add acoustical absorbing material. A wide variety of commercial acoustical materials is available. These materials are often of great value in a noise reduction program, but the limitations of this treatment should be realized. These materials are mainly useful in the room where the noise originates, and there they help mainly to reduce the noise level at some distance from the source. But at the same time not much reduction is obtained at a distance of 2 ft., say, which is a common distance between a machine and the operator's ear.

A number of different types of attenuating structures are used for reducing the noise level for the listener. One of these is an ear defender, which may be an ear plug or earmuffs. Others are walls, barriers, and total enclosures. Almost any degree of reduction of airborne sound can be achieved by a total enclosure or a combination of several enclosures. But as the required attenuation increases, so does the complexity, weight, and cost. In addition, great care must be taken that the attenuation gained by the enclosure is not lost by sound transmission through a ventilating duct or by solid-borne vibration. Because of this possible flanking transmission in ventilating systems, total enclosures frequently require carefully designed ventilating systems with ducts lined with absorbing material. These lined ducts are essentially mufflers for the air stream.

When a door is required in a total enclosure, it should be built with air-tight seals at all joints. A refrigerator-type door is usually satisfactory when it can be used. A total enclosure should also be lined at least on part of the inside walls with absorbing material. This lining helps to keep the noise at the walls of the enclosure at the lowest practical level.

A barrier is not as effective as a total enclosure, but it does help to shield high-frequency sound. Little attenuation of low-frequency sound is obtained unless the barriers are very large, and the attenuation of high-frequency sound is usually only a few decibels unless the opening that remains is relatively small. Here, too, absorbing material should cover the barrier to avoid exaggerating the level by reflections from the barrier.

The approach to a noise reduction problem can be summed up as follows:

- Consider the source.

  Can a quieter machine be substituted?

  Can the noise energy be reduced?

  Can a useful change be made in the directivity pattern?

  Are resilient mounts of any use here?

- Consider the path from the source to the listener.

  Can the source or the listener be readily moved?

  Is acoustic treatment a useful solution?

WHAT ARE THE EFFECTS OF NOISE?

Noise causes numerous detrimental and undesirable effects on man. They may be broadly classified as:

- Physiological
- Psychological

The types of physiological effects are

- Auditory (affecting the hearing mechanism)
- Non-auditory

PHYSIOLOGICAL EFFECTS

Auditory Effects

The effect of excessive noise on the ear is to raise the threshold of hearing at certain frequencies. This hearing loss may be temporary or permanent depending upon the severity of the exposure experienced. These are termed noise-induced temporary threshold shift (NITTS) and noise-induced permanent threshold shift (NIPTS), respectively. It is generally agreed that repeated exposures causing temporary shifts (NITTS) will eventually result in permanent hearing loss (NIPTS). Temporary hearing shifts may occur after brief exposures to high level noise and many last from a few seconds to a few days. Permanent hearing loss generally requires repeated exposure over a long period of time.

Hearing loss is usually described in terms of the amount of shift (in decibels) at each audiometric test frequency (500, 1000, 2000, 3000, 6000 Hz). Also, since certain frequencies are believed to be more important than others it is common to average the hearing loss at these frequencies. The most common averages used are at 500, 1000 and 2000 Hz; and 1000, 2000 and 3000 Hz. The purpose of this is to relate the amount of hearing loss to an individual's understanding of speech. This topic is the subject of considerable controversy today. Figures 28 and 29 show the expected hearing loss "due to noise" after 10 years and

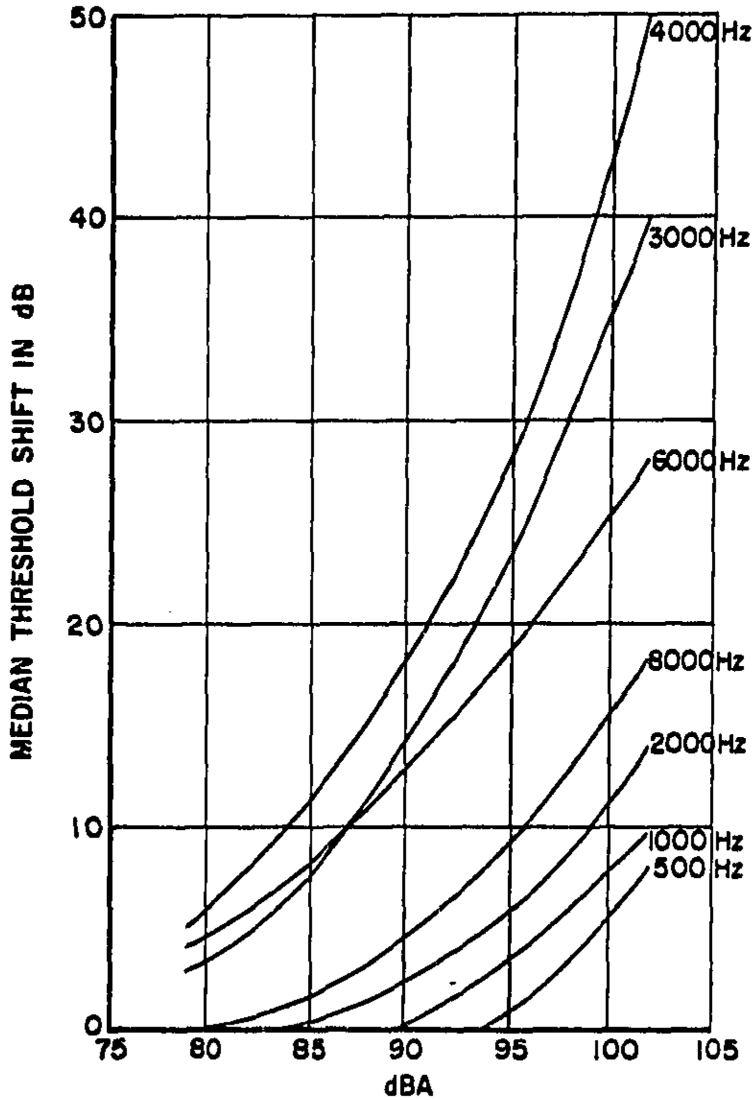


Figure 28. Median Noise-Induced Permanent Threshold Shift in dB as a Function of Exposure Level 8 Hours a Day for a Period of 10 Years.

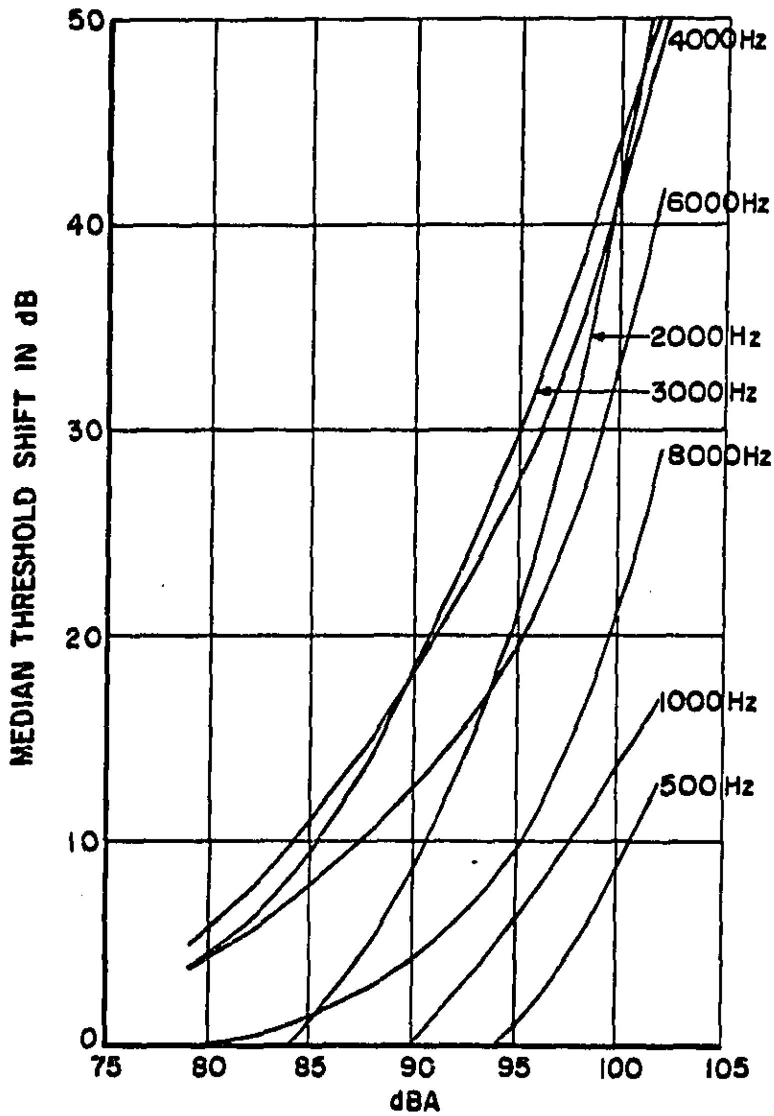


Figure 29. Median Noise-Induced Permanent Threshold Shift in dB as a Function of Noise Exposure Level 8 Hours per Day for a Period of 40 Years.

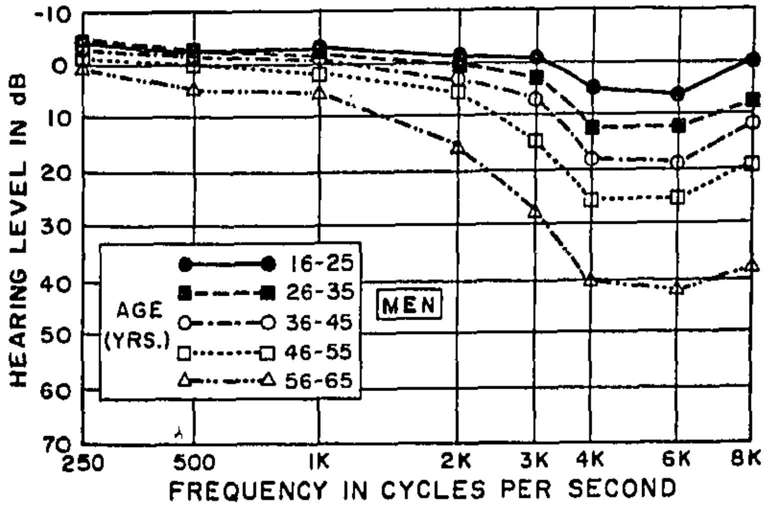
40 years of repeated 8 hour exposure to various levels. (10) It should be apparent that permanent hearing loss due to noise requires extended exposures to high level noise. It is important to realize that the loss caused by noise should be added to the loss that occurs normally during aging called "presbyacusis" (see figure 30).

Noise affects hearing by attacking the hair-cells in the inner ear that transmit receptive nerve impulses to the brain. Moderate noise exposure that fatigues these cells causes temporary shifts, from which they recover. Severe exposure causes permanent damage to these cells and permanent hearing loss. Since the nerve is affected, this type of damage is called a sensory-neural disorder. The other type of ear damage is called conductive describing a malfunction of the mechanical transmission of sound to the inner ear. These disorders cause different hearing difficulties. The sensory-neural loss causes distortion so that a signal may not be clear regardless how loud it is presented. The conductive loss usually causes a reduction in perceived loudness while maintaining the clarity. The former is much more difficult to deal with since simply amplifying sound does not help. In fact it can cause greater distortion. This is the problem associated with noise-induced hearing loss. This concept is illustrated in figure 31. It should be pointed out that it is possible to have a measurable hearing impairment and not be subjectively aware of any subsequent difficulty. Such a loss, however, is often an indication of susceptibility to further loss.

Because the susceptibility to noise-induced effects varies considerably throughout the population, they must be dealt with in a statistical manner. The term used to describe the amount of hearing loss to be expected from different exposures is called damage risk criteria. (1) Two big areas of controversy exist in attempting to develop damage risk criteria. First is the quantity of hearing loss that will occur for a given exposure; and second is how the hearing loss affects an individual's life. It is generally agreed that the prime importance of hearing is to understand speech. Therefore, the effect is usually dealt with in terms of how speech communication is impaired for a given loss. Both of these areas are the subject of considerable controversy by noted experts in the field.

Damage risk criteria can be very confusing, and it is important to realize the parameters that must be defined to present a complete criteria:

- Noise exposure (usually stated as a time-weighted average exposure, which is like the Leq)
- Duration of exposure (usually expressed in years)
- Quantities used to account for hearing loss due to aging



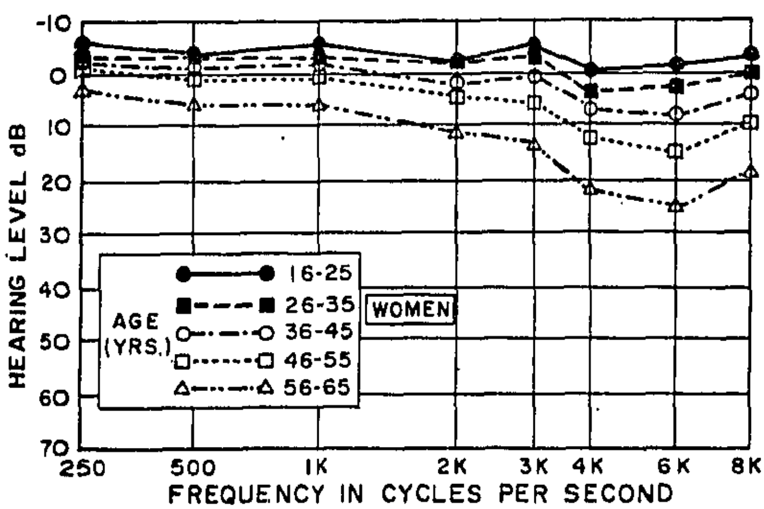


Figure 30. Mean hearing levels as a function of age and sex for persons having minimal exposure to noise and no otological impairments. Data replotted from Riley et al. (28)

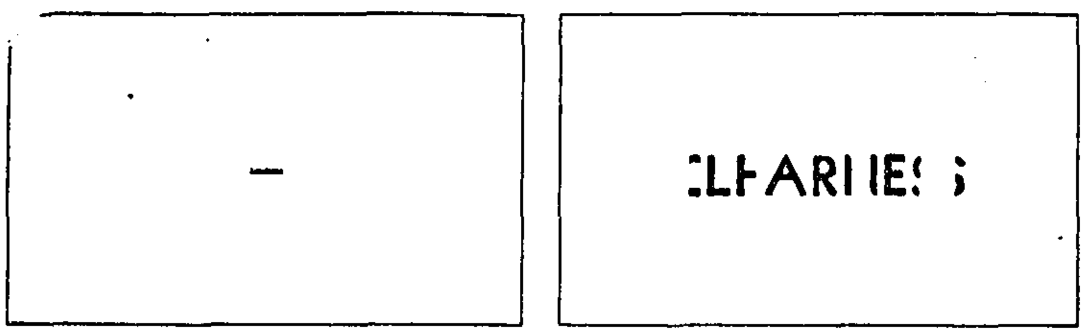


Figure 31. Represent, by analogy, two important dimensions of normal hearing–the ability to hear sounds as loud as they truly are and the ability to hear sounds with complete clarity. Hold Figure on the left at an arm's length, and look at the writing. If you have difficulty reading the word "LOUDNESS," at this distance, it is similar to missing faint sounds. Moving the figure closer makes it easier to read just as increasing volume makes it easier to hear. On the other hand, no matter how close you hold right Figure there is difficulty figuring out what it says. The word is unclear, because there are some important parts of the letters missing. This illustrates a hearing difficulty caused by a loss in the ability to distinguish between various sounds. (The word, incidentally, is "CLEARNESS.")

- Amount of hearing loss attributed to noise
- Rationale for how the hearing loss will affect one's life.

Damage risk criteria is stated in many different ways. It is important to know exactly what is meant by a given criteria. Common ways that it is found stated are:

- After "X" years of exposure to "Y" level, "Z" percent of the people will have a hearing handicap.
- After "X" years of exposure to "Y" levels "Z" percent will lose more than "W" decibels average at 500, 1000, and 1000 Hz.

Sometimes a risk is stated for a certain percentile of the population; for instance, 2% or 10%. This simply means that the figures given are for the 2% most susceptible individuals. The more popular hearing risk criteria are presented in Table 3, which is based on exposures to noise 8 hours/day, 40 hours/week for 40 years.

Table 3
Percentage of the Population at Risk (Exceeding 25 dB Hearing Loss) as a Result of Various Noise Exposure Levels

Item	Noise Exposure Level (dBA)	Risk (Percent)
a. Averaged frequencies 500 Hz, 1000 Hz, and 2000 Hz:		
ISO	90	21
	85	10
	80	0
EPA	90	22.3
	85	12
	80	5
NIOSH	90	29
	83	15
	80	3
b. Hearing risk for 4000 Hz:		
BAUGHN	90	52
	85	30
	80	6

Since exposures are not usually at any one noise level, it becomes necessary to account for varying levels of exposure. The fluctuations of noise with time is accounted for in the determination of the time-weighted average noise exposure. For example, 4 hours at 80 dBA and 4 hours at 90 dBA would be equivalent to an 8-hour time-weighted average exposure of 85 dBA.

Also, given a safe level of noise for a certain exposure duration, it is necessary to adjust the allowable duration for higher levels of noise. This is known as a time-intensity tradeoff. The proper tradeoff is currently the subject of much controversy. The discussion is primarily between 3 dBA and 5 dBA increase in exposure level for a halving of duration. Therefore (using 3 dBA, if the safe exposure is a time weighted average of 83 dBA for hours, then if the level were 87 dBA the safe exposure duration would be 4 hours. If it were 90 dBA it would be 2 hours, and so on.

Non-auditory Effects:

It has been found that noise can elicit many different physiological responses. However, it is presently not conclusive that continued activation of these responses leads to irreversible changes and permanent health effects. (2) These alterations in biological function are dependent upon the characteristics of the noise and the exposure duration, age and activity of the persons exposed. Although current investigations are not conclusive, they suggest that health may be endangered by long-time exposure to noise even before modification in hearing is seen. (9) Effects which have been observed include: (9)

- Alterations in the cardiovascular system (heart rate, blood pressure, white blood cell count).
- Neurological dysfunction.
- Digestive dysfunction.
- Endocrine dysfunction.
- Biochemical dysfunction.
- Electroencephalographic changes.

Since insufficient evidence exists, it is often assumed that noise exposures which are low enough to protect the hearing will most likely not directly induce non-auditory disease. This entire area is one in which more intense investigation is necessary.

PSYCHOLOGICAL EFFECTS

Many effects have been reported and observed that fall into this category. It is reasonable to assume that there is a certain degree of overlap between the physiological and psychological effects of noise. Some of the effects are very difficult to assess, since intensive noise exposure is often associated with circumstances that may have similar effects, even without the noise.

The two most common effects of this nature are:

- Masking of speech
- Interference with sleep

A number of other effects which have been attributed to noise exposure are: (2)

- Nausea
- Headaches
- Irritability
- Instability
- Argumentativeness
- Anxiety
- Nervousness
- Loss of appetite
- Reduction in sexual drive

There is little quantitative data available regarding these effects.

High levels of noise are believed to have a profound effect on the performance of tasks. This would be of prime importance with regard to occupational noise and the influence on production. Also, absenteeism from work has been found to be higher in noisy occupations.

LEVELS OF NOISE RECOMMENDED BY EPA TO PROTECT PUBLIC HEALTH AND WELFARE (5)

Pursuant to Section 5a(2) of the Noise Control Act, EPA was charged with publishing information on levels of noise which are requisite to protect the public health and welfare, with an adequate margin of safety. For the case of hearing loss, EPA has provided a level that would protect against any permanent shift in hearing.

Levels for hearing loss, as well as annoyance, are presented in table 4 along with an explanation.

Table 4
Summary of Noise Levels Identified as Requisite to Protect Public Health and Welfare with an Adequate Margin of Safety

Effect	Level	Area
Hearing Loss	$L_{eq(24)} \leq 70$ dB	All areas
Outdoor activity interference and annoyance	$L_{dn} \leq 55$ dB	Outdoors in residential areas and farms and other outdoor areas where people spend widely varying amounts of time and other places in which quiet is a basis for use.
	$L_{eq(24)} \leq 55$ dB	Outdoor areas where people spend limited amounts of time, such as school yards, playgrounds, etc.
Indoor activity interference and annoyance	$L_{dn} \leq 45$ dB	Indoor residential areas
	$L_{eq(24)} \leq 45$ dB	Other indoor areas with human activities such as schools, etc.

Explanation of Table 4

1. Detailed discussions of the terms L_{dn}, $L_{eq(8)}$ and L_{eq} (24) appear later in the document. Briefly, $L_{eq(8)}$ represents the sound energy averaged over an 8-hour period while $L_{eq(24)}$ energy averages over a 24-hour period. L_{dn} represents the L_{eq} with a 10 dB nighttime weighting.

2. The hearing loss level identified here represents annual averages of the daily level over a period of forty years. (These are energy averages, not to be confused with arithmetic averages.)

3. Relationship of an $L_{eq(24)}$ of 70 dB to higher exposure levels.

EPA has determined that for purposes of hearing conservation alone, a level which is protective of that segment of the population at or below the 96th percentile will protect virtually the entire population. This level has been calculated to be an L_{eq} of 70 dB over a 24-hour day.

Given this quantity, it is possible to calculate levels which, when averaged over given durations shorter than 24 hours, result in equivalent amounts of energy. For example, the energy contained in a 8-hour exposure to 75 dB is equivalent to the energy contained in a 24-hour exposure to 70 dB. For practical purposes, the former exposure is only equivalent to the latter when the average level of the remaining 16 hours per day is negligible (i.e., no more than about 60 dB for this case).

WHAT IS BEING DONE TO CONTROL NOISE?

Over the past two centuries, industrial development has resulted in a steady increase in the extent of noise impact. It is the addition of new noise sources in already noisy situations and the proliferation of noise sources of increased output into previously quieter areas that has greatly stimulated increased public concern and has created the need for increased governmental costs.

The state and local governments have the primary responsibilities in most respects, for the actions necessary to provide a quieter environment. This includes land-use planning and zoning, building codes, use regulations, and the necessary enforcement programs. However, as stated in section 2(3) of the Noise Control Act of 1972, "Federal action is essential to deal with major noise sources in commerce, control of which require national uniformity of treatment."

FEDERAL LEADERSHIP IN NOISE ABATEMENT AND CONTROL

The Noise Control Act of 1972 states as its ultimate purpose "to promote an environment for all Americans free from noise that jeopardizes their health or welfare." For this reason, the Act provides for: the establishment of means for the effective coordination of Federal research and activities in noise control; the directing of Federal agencies to carry out noise control programs consistent with their authorities; the authorization of the establishment of Federal noise emission standards in the areas of interstate motor carriers, railroads and new products distributed in commerce; and the providing of information to the public about noise emission sources and reduction techniques.

The Act granted the Environmental Protection Agency broad authority in the area of interagency coordination for noise programs. Section 4 of the Act directs EPA to coordinate all Federal agency noise standards and regulations and to develop a report on the status of the Federal government's overall efforts to control noise. The "First Report on Federal Agencies Noise Control and Noise Research Activities" covers the current noise activities of 38 Federal agencies in the following areas: standards and regulations, hearing conservation programs, noise abatement programs, and research and development. The report was prepared by EPA and includes the Agency's planning strategy.

On December 17, 1972, the President signed Executive Order 11752: "Prevention, Control, and Abatement of Environmental Pollution at Federal Facilities." This order provides a strong management role by the EPA in ensuring compliance by Federal facilities with environmental pollution standards.

The Office of Noise Abatement and Control (ONAC) was established within the EPA in 1971. Following the statutory mandate of the Noise Control Act – to protect public health and welfare — ONAC has developed and published noise exposure criteria and identified levels of environmental noise.

The *Criteria* document was published on July 27, 1973. Pursuant to section 5(A) of the Act, this document reflects "the scientific knowledge most useful in indicating the kind and extent of all identifiable effects of noise on the public health and welfare which may be expected from differing quantities and qualities of noise." This document served as a basis for the establishment of the recommended environmental noise level goals. The *Levels* document of March 1974, provides information on levels of environmental noise requisite to public health and welfare with an adequate margin of safety.

ONAC has taken further actions to implement the Noise Control Act by:

1. Publishing a Report to the Congress on aircraft and aviation noise and recommending to FAA regulations for aircraft noise emissions.

2. Promulgating interstate motor carrier regulations for vehicles used in interstate commerce.

3. Proposing regulations for new medium and heavy duty truck noise control.

4. Proposing regulations to control noise from interstate rail carriers.

5. Proposing regulations for portable air compressors.

6. Initiating actions for further noise emission regulations.

The above represent some of the steps EPA is taking to curb noise pollution at the Federal level. In addition to the EPA, departments with significant involvement in noise include: Department of Defense, Health, Education and Welfare, Housing and Urban Department, Department of Labor, NASA and the Department of Transportation.

Noise abatement efforts by DOD have been both considerable and long standing. The armed services particularly are involved in research on noise and noise abatement procedures. The primary DOD thrusts are concentrated in the areas of: occupation noise control and hearing conservation, operational aircraft noise abatement, noise elimination in weapon systems and construction specifications for noise control.

The Occupational Safety and Health Act (OSHA) provides authority for the National Institute for Occupational Safety and Health of HEW to undertake research with the objectives of: defining occupational noise limits for hearing conservation, assessing industrial noise effects on overall health, safety, and performance capability, considering different diagnoses of noise-induced hearing loss cases, and training projects bearing on industrial noise control and hearing conservation. HEW conducts a hearing conservation program for its own employees as part of its occupational health activities.

The Department of Labor emphasis on noise is in two areas: The Walsh Healy Contracts Act, which covered health standards for employees engaged in Federal contract work exceeding $10,000 and the 1970 Occupational Safety and Health Act, extending coverage to all businesses engaged in interstate commerce. Worker exposure standards under the two are identical. Hearing loss due to noise is one of the health considerations covered under the 1970 legislation.

NASA has been deeply involved in aircraft noise research for many years. At the Langley Research Center a new aircraft noise reduction laboratory was completed late in 1972. In addition to research activities, NASA provides noise protection for its employees through work site surveillance and audiometric testing, supplemented by general medical protection.

The Department of Transportation is engaged in research and development relating to transportation noise, particularly aircraft noise. A separate office of noise abatement administers the noise program at DOT.

STATE AND LOCAL LEADERSHIP IN NOISE ABATEMENT AND CONTROL

States and cities are entering the noise control field zealously, as demonstrated by the growing number of recently enacted or proposed regulations in this area since 1970. In 1974, 440 municipalities possessed noise laws as compared to 288 during 1973. Presently, it is estimated that more than 600 municipalities have enacted noise regulations. This is a significant increase from the 10 noise programs of 1970.

The trend in these regulations is toward more comprehensive, objective laws covering noise sources and enforced by environmental agencies.

In April 1973, the Council of State Governments adopted a model bill for noise control legislation at the state level. The bill attempts to give maximum authority to the states to regulate noise pollution consistent with the preemptive provisions of the Federal Noise Control Act of 1972. ONAC will update the document shortly.

EPA regional offices were instituted by the Office of Noise Abatement and Control in 1971. The regions were involved in initiating projects to bring the noise problem to the attention of both public and private groups in their area. They have performed noise related tasks which include: EIS review, collection of data pertaining to the particular region, workshops, and consultations with state and local officials regarding noise ordinance development and noise programs.

ONAC provides guidance and support to the regions, and to State and local governments. This technical assistance to implement noise control programs takes the form of:

- Program development by developing a Model Community Noise Ordinance which would serve as a guide to communities in the preparation of noise control regulations suited to their local needs and conditions.

- Resource development by providing advice on the selection of personnel, aiding in the selection and operation of noise monitoring equipment, and providing lists of sound level meter manufacturers. ONAC has also developed a low cost sound level meter for general regulatory use, under contract with the Air Force Academy.

- Collecting, reviewing, and evaluating State and local noise regulations.

The foregoing provides an overview of present efforts to abate and control noise at the Federal, State and local levels. It is important to point out that participation by the public is essential to all of these efforts.

AFTER NOISE IS CONTROLLED TO THE EXTENT FEASIBLE–THEN WHAT?

There is no doubt that after all feasible measures to control noise are taken, people will still be exposed to unwanted sound.

The alternative that remains is to use some sort of personal hearing protection device. There is a large variety of these devices currently available. To obtain effective performance, the proper selection, use and care of hearing protectors is most important. The major categories of these devices are the (1) insert, (2) semi-insert, and (3) muffs, which are illustrated in figure 32:

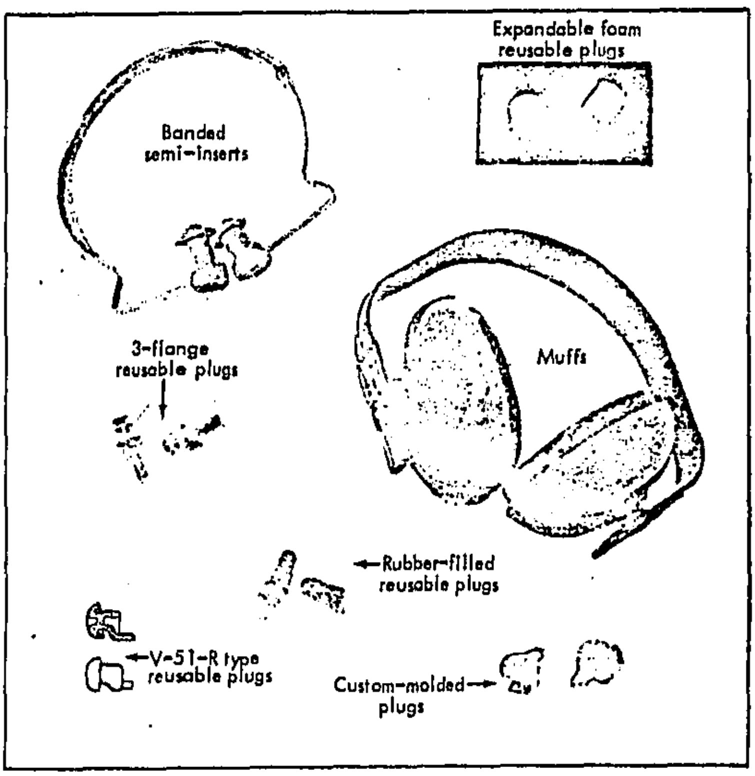


Figure 32

The insert-type earplug is designed to provide an airtight seal between the air within the external ear canal and the ambient atmosphere where noise or sound is propagated. There are three common forms of the insert: (1) pre-molded, (2) moldable, and (3) custom molded. The semi-insert does not fit into the ear canal but covers the opening to the canal. The muffs fit over the entire external ear and forms a seal with the head.

The performance of hearing protectors is currently evaluated by determining the threshold of hearing first without the device, and then with the device in place. The standard test procedure is designated by American National Standards Institute S3.19-1975, "Method for the Measurement of Real-Ear Protection of Hearing Protectors and Physical Attenuation of Earmuffs".

Some of the more important factors that must be considered in selecting the proper device are:

- Nature of the noise exposure
- Conditions under which protection will be worn
- Proper fit
- Comfort
- Ease of caring for device

There is no doubt that hearing protectors are effective when used properly and conscientiously. However, there are certain negative factors that should be identified regarding the use of hearing protectors:

- Discomfort
- Not hearing important sounds
- Possible feeling of isolation when in place

Under the labeling authority of section 8 of the Noise Control Act of 1972, the Environmental Protection Agency is developing a regulation that will require that hearing protectors be labeled. Such a label will provide the user with information as to the effectiveness and proper use of the device.

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