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Consumer Product Noise: A Basis for Regulation

Pearl G. Weissler, Gerald A. Zerdy and Sally G. Revoile

Sound Section
Mechanics Division
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ABSTRACT

The Consumer Product Safety Commission is charged with the responsibility for promulgating safety standards to protect the public against unreasonable risks of injury associated with consumer products. There is a risk of injury from noisy products, directly by damage to hearing and indirectly by degradation of essential speech communication. This report develops criteria relevant to the specification of Safety Standards for noisy consumer products. Consumer product noise is discussed in relation to the existing body of knowledge regarding noise induced hearing loss and speech communication. From the EPA Levels Document, levels of product noise are identified that should protect against hearing impairment and against speech communication degradation. Methods of measurement for consumer product noise are described and a bibliography of standards relevant to the regulation of noisy consumer products is provided. A list of products that are potentially hazardous to the hearing of the operator is included with typical levels and usage patterns. The list is based upon reported data and some measurements made at NBS. Possible discrepancies among noise regulations established by different governmental agencies are discussed with suggestions for obtaining uniformity.

Key Words: Consumer products; criteria for safety standards; federal regulations; hearing impairment; hearing survey; noise emission; speech communication interference.

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INTRODUCTION

The focus of this study at its inception was to obviate conflicts in regulating sound emissions of consumer products by the Consumer Product Safety Commission and other agencies of the Federal Government concerned with noise. To do this, a basis for such regulation had to be established. Thus the literature on the effects of noise on man was surveyed. It was not the intent, however, to write just another report on this subject, since in recent years there has been a proliferation of such publications on this subject. Rather, it was decided to extract those effects of noise of greatest relevance to the safety of consumer products. The two major effects considered are noise-induced hearing loss and the impairment of speech communication in the presence of noise.

Another important factor in the regulation of consumer products is the use of proper test methods; i.e., measurement of sound output and measurement of intelligibility of speech in noise. Some basic physical and psychophysical principles involved in such tests and specific test procedures are discussed in this report, again with emphasis on consumer products. A list of relevant published standards is also included.

A third factor considered as a basis for regulation is a knowledge of the consumer products themselves their sound output and impact (i.e., total number of people using the product and their usage patterns). For this, use was made of published data as well as measurements made at the National Bureau of Standards.

With this scientific basis for regulating noise emissions of consumer products for safety, one can resolve the problems of formulating unified Federal Noise Regulations more intelligently. Suggestions toward this end are also included in this report. Two important factors, economic and technological feasibility, were not treated in this report.

CHAPTER I

THE HEARING MECHANISM AND NOISE-INDUCED HEARING DAMAGE

Some Dimensions of Audition

The sense of hearing enables one to perceive sounds of different frequencies and intensities. The maximum range of frequencies that can be heard by the human ear varies from about 16 to 20,000 Hz. Within this range, however, the ear is not equally sensitive to all frequencies (see Fig. I-1[1]). Among the frequencies, different intensities are required to achieve the threshold of audibility for a sound, i.e., the minimum intensity that renders it just barely detectable. For sounds of very high intensity the ear responds similarly, irrespective of frequency. The threshold of pain for sound occurs at around 140 dB re 20 micropascals, while the thresholds of feeling and discomfort, respectively, occur about 10 and 20 dB lower.[2]

The Hearing Structure

Anatomical descriptions of the ear differentiate among three sections: the outer ear, the middle ear, and the inner ear (see Fig. I-2). The outer ear includes the parts of the ear that are externally visible: the pinna and the ear canal. The ear canal is terminated internally by the eardrum that separates the outer and middle ears. The middle ear is a small air-filled chamber that contains the ossicles - three very small bones connected in a lever-like formation. Two small muscles partially support the ossicles in the middle ear. The ossicle formation is attached to the eardrum at one end and to the oval window at the other end. The oval window is a small opening in one wall of the middle ear that leads to the inner ear. The fluid-filled inner ear contains the sensory structure for hearing, the organ of Corti, as well as the mechanisms for maintaining equillibrium. The organ of Corti is located in the cochlea of the inner ear in a fluid- filled, membranous channel (see Fig. I-3). The specialized structures of the organ of Corti include numerous cells with projections of hair at the top. Overhead, the hairs are embedded in a gelatinous structure, the tectorial membrane.

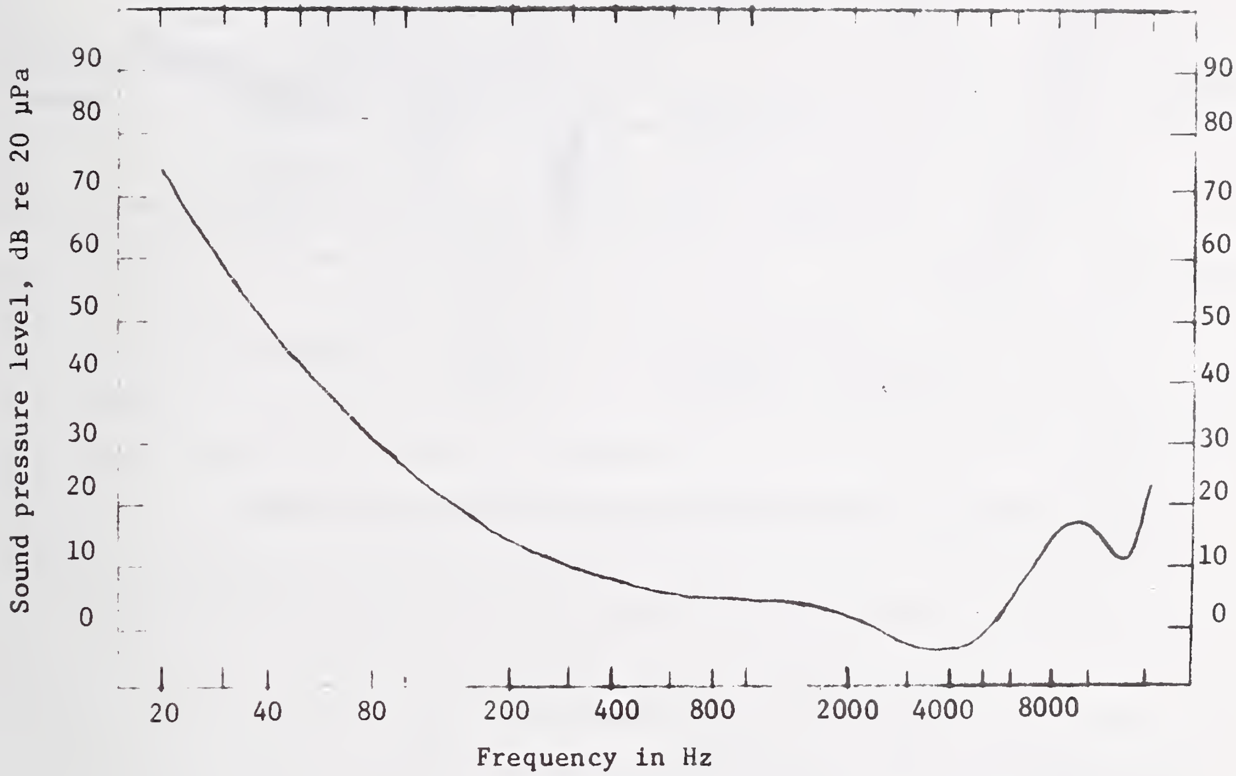

Figure I-1. Threshold of hearing for binaural, free-field listening.[1]

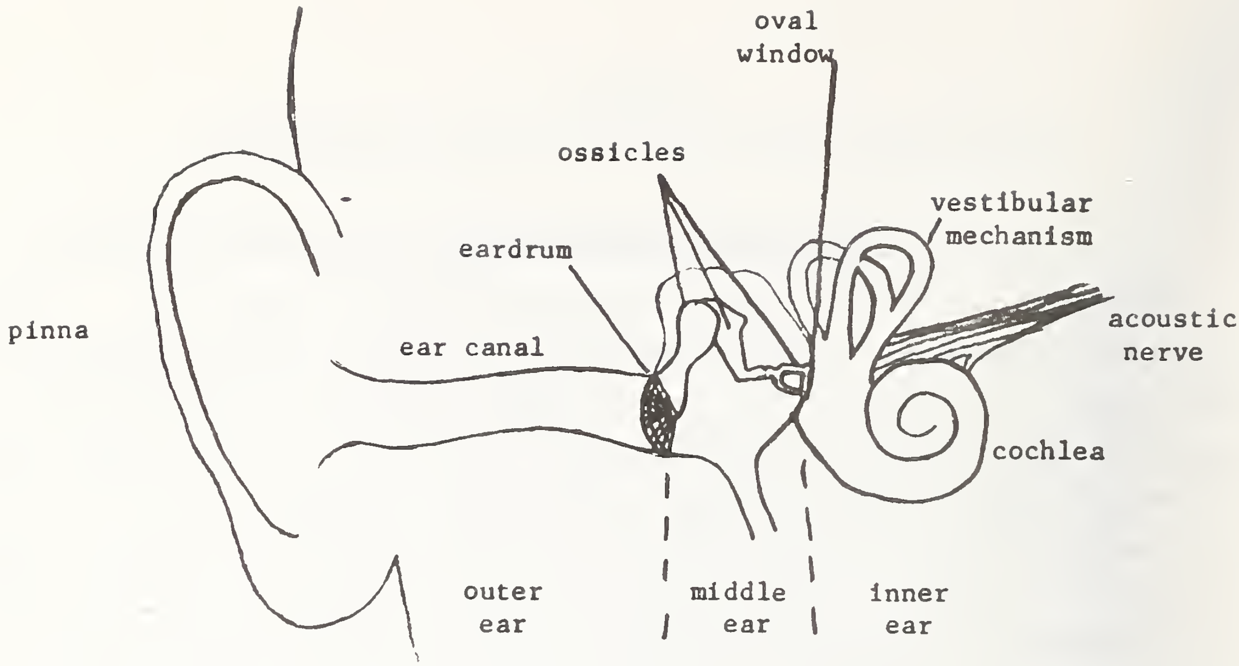

Figure I-2. A schematic drawing of the hearing mechanism.

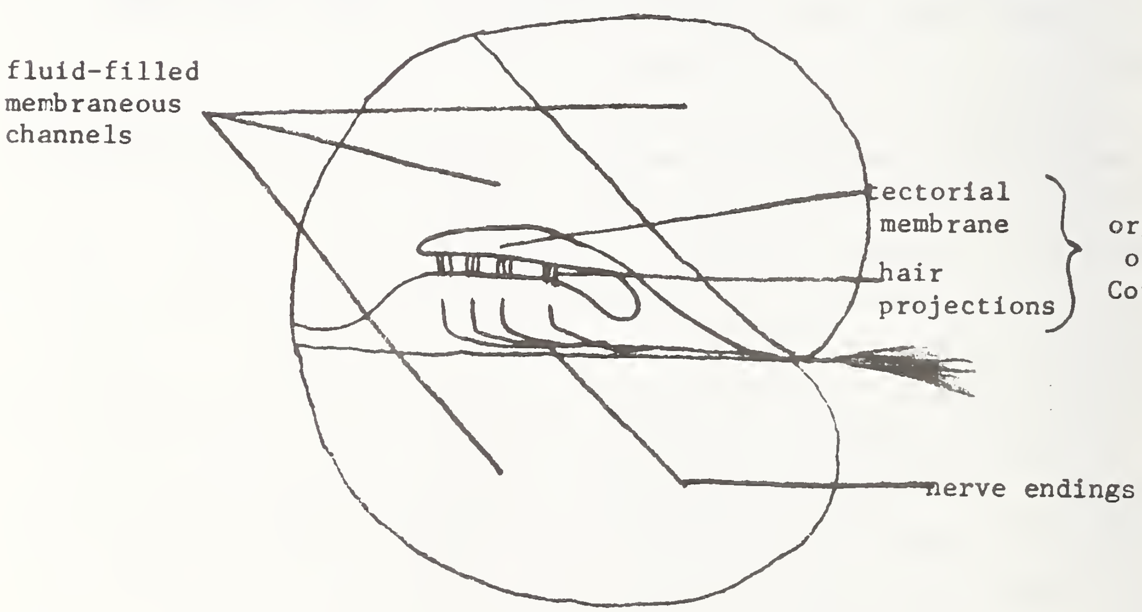

Figure I-3. A schematic drawing of a cross section of a spiral of the cochlea showing the organ of Corti.

The hair cells make functional contact with nerve endings that comprise part of the eighth cranial nerve of the central nervous system.

Transmission of Sound to the Inner Ear

Sound is perceived when a listener receives an auditory sensation. The auditory sensation results from a series of functions in the ear that normally begin mechanically at the eardrum. The eardrum is pressure sensitive and vibrates in response to certain air pressure changes, namely, sound waves caused by a vibrating surface or air turbulences. Vibrations of the eardrum cause the ossicles to move in turn, thus transmitting the vibrations to the fluid of the inner ear. (Vibrations may also be transmitted to the inner ear through the bones of the skull.) Pressure variations then occur in the inner ear fluid causing a shearing motion between the tectorial membrane and the hair cells. The mechanical movement of the hairs is transformed into electrical impulses where the hair cells contact the neurons of the acoustic nerve. The impulses are then transmitted along the acoustic nerve to the brain.

Injury to the Ear Structure from Loud Noise

When a very loud sound (at least 80 dB above threshold of audibility[3]) produces excessive vibration at the eardrum the muscles that support the ossicles act involuntarily to restrict the movement of the eardrum and ossicles. This protective action, called the acoustic reflex, serves to reduce the vibratory force reaching the inner ear from the loud sound. However, the reflex action reduces the vibratory force only to a limited degree and for a limited time. The effective reduction in sound level is on the order of five to ten decibels.[4] After about 15 minutes, the reflex action seems to decrease in magnitude[2] even though the intensity of the sound is unchanged. Thus, the acoustic reflex provides only limited protection to the inner ear and damage can be caused by the excessive vibratory force from intense sound.

The damage in the inner ear from excessive vibratory force occurs to the organ of Corti. In the presence of extremely intense sound, such as that from an explosion, immediate structural damage can occur to the organ of Corti with concurrent hearing impairment. From less intense sound the hair cells and other structures of the organ of Corti seem to degenerate gradually when the ear is intermittently exposed over prolonged periods of time. The actual cause of this degeneration is not known definitely. It has been theorized that mechanical destruction or metabolic changes within the inner ear may be responsible for the hair cell degeneration. In any case, the destruction is irreversible, since the specialized cells of the organ of Corti do not regenerate. Consequently, hearing impairments are irreversible when caused by permanent damage to the organ of Corti.

Noise-Induced Hearing Impairments

Most hearing impairments that are caused by noise occur gradually. The initial exposures to a damaging noise may produce only a temporary loss of hearing that disappears following cessation of the noise. From repeated exposures, however, the ear seems to lose the ability to recover from the temporary loss and a permanent impairment results. At first, the permanent impairment may not be fully realized because the hearing damage is usually minor and affects only a limited frequency range. There may be no more than a slight reduction in hearing sensitivity at frequencies around 4000 to 6000 Hz (see Fig. I-4). Even the warning sensations of hearing damage that may accompany the noise, such as ringing or tickling in the ear, may not seem particularly significant since they are usually transient. At this point, however, the individual has already lost some hearing for bird songs, music, and certain speech sounds. Among the sounds of speech, those often affected earliest are the "s", "f", and "th" as in <u>th</u>ink. These sounds are comprised of frequencies around 4000 to 6000 Hz and contain relatively little speech energy as well.[5] With additional exposure to injurious noise the hearing damage increases in severity and involves a broader frequency range (see Fig. I-4). Generally, the impairment becomes more and more apparent as the individual has increasing difficulty understanding speech.

People vary in susceptibility to hearing damage from noise. Evidence of the differences in susceptibility is found in studies of occupational hearing losses. In one study, large differences were shown

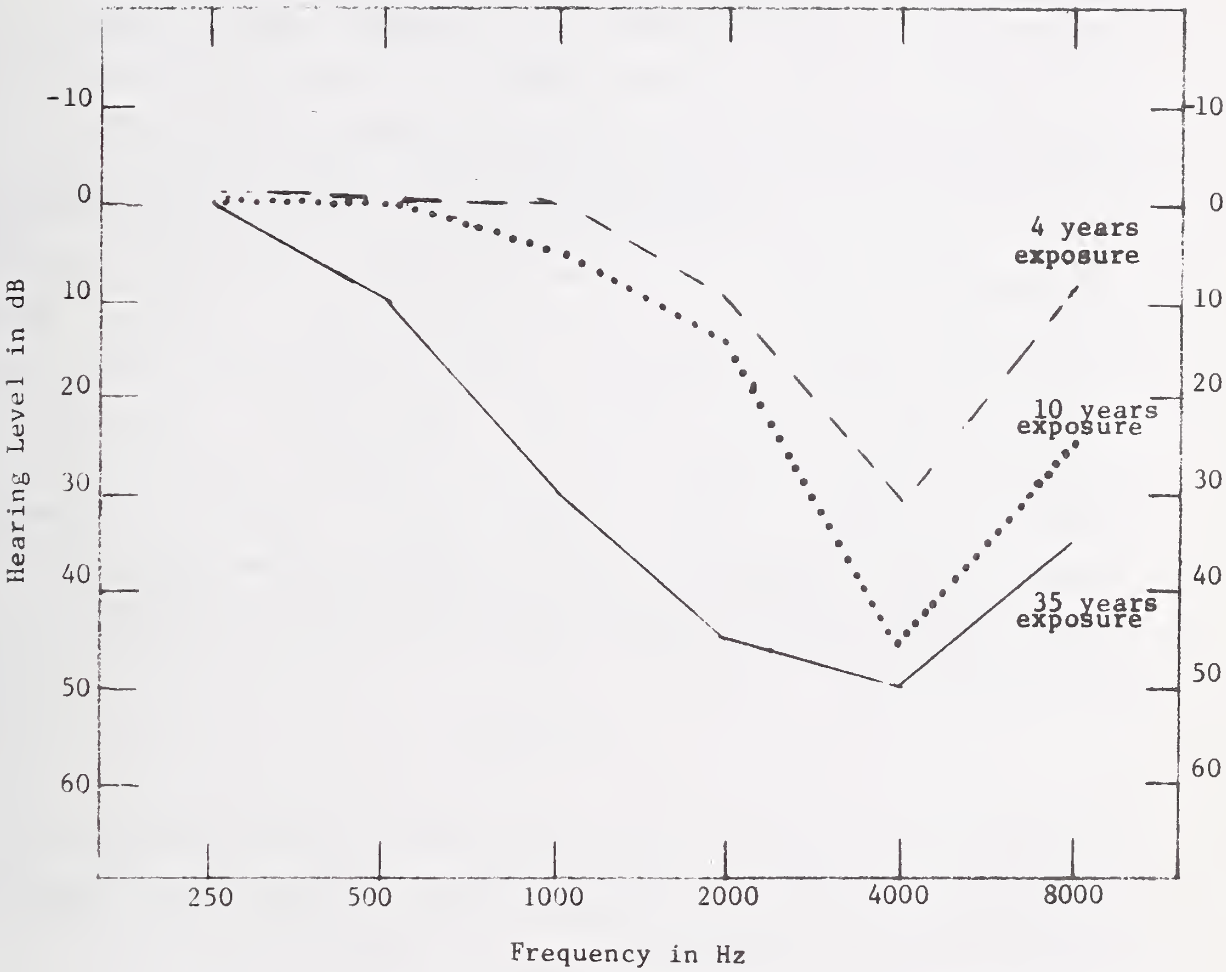

Figure I-4. Typical audiometric configurations for noise-induced hearing impairments representing various durations of occupational noise exposure.

in the severities of hearing impairments among workers exposed to the same occupational noises for similar periods of time, with little accompanying exposure to non-occupational noise.[6] Non-occupational noise exposures are of importance, since the combinations of noises that workers experience away from the job may increase their total amount of hearing damage. Non-occupational noises may also be of significance for people without the hazard of occupational noise exposure. There is growing concern that the noises encountered in everyday living over a lifetime may be a partial contributory cause to the hearing impairments seen among the elderly.[7] The noise from consumer products may comprise a considerable portion of the noises encountered daily. There is a need to evaluate the hazard to hearing from noisy consumer products as well as their possible interference with speech communication. Other effects from noise, such as annoyance and sleep disturbance, may also be of concern with respect to noisy consumer products. However, if consumer product noise is limited for protection against hearing damage and impaired speech communication, it is unlikely that other serious physiological effects will be induced.

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CHAPTER II

SPEECH COMMUNICATION AND CONSUMER PRODUCT NOISE

Many consumer products are operated in situations where people communicate. In the presence of a noisy consumer product any conversation that takes place may be disrupted because of the noise. The disruption or interference in communication from noise is technically called masking. Masking from the noise of a consumer product can affect speech communication by changing its message or rendering it partially or completely inaudible.

Experimental Procedures for Measuring the Effect of Noise on Intelligibility

Information is lacking concerning the effects of noise from consumer products, in particular, on speech communication. It is possible, however, to deduce these effects from existing information on the masking of speech in general. Most of our knowledge of the masking of speech by noise has been obtained experimentally. Investigations have been conducted in which listeners write or repeat the speech signals they hear in the presence of masking noise. Generally, in such an experiment, several different noises are studied individually under controlled test conditions, using the same listeners to determine the masking effects for all noises being tested. Because the same listeners participate, different speech signals have to be presented for each noise under study. The speech signals used are standardized lists of materials that have been shown to yield similar results when presented without masking to normal hearing listeners.

Speech Intelligibility Tests

Different types of speech materials have been developed to determine the effects of masking noise on speech. These materials include sentences or phrases, individual words out of context (e.g. Say the word <u>HILL</u>), and nonsense syllables (meaningless fragments of speech or combinations of speech sounds). Tests are available that are composed of one or the other of these types of speech material. The tests include different lists containing equal numbers of the particular speech items of interest. The intelligibility index for a list is usually reported in terms of a percentage score computed on the basis of the number of items identified correctly out of the total number in the list. Tests consisting of nonsense syllables are called articulation tests. Tests comprised of single words or sentences are called intelligibility tests.

Some Factors Affecting the Intelligibility of Speech

The intelligibility of speech materials. If different intelligibility tests are spoken by the same talker in the presence of a given masking noise, the masking effect will vary in relation to the intelligibility of the speech materials comprising the tests. A fundamental factor contributing to the intelligibility of different types of speech materials is the verbal context of the materials. Verbal context is related to the structure and constraints of language, called redundancy, that allow us to infer what will be said on the basis of what we have already heard. The greater the verbal context in a speech signal, the more likely it will be understood. Consequently, a speech test comprised of sentences is more intelligible than a test containing isolated words, when both tests are administered in the same amount of noise.

There are other factors inherent in speech materials, themselves, that will affect their intelligibility when spoken. Some speech sounds are easier to recognize than others. Consequently, the intelligibility of a word will be influenced by the sounds comprising that word. Among one- and two-syllable words, intelligibility increases with the number of speech sounds. Two-syllable words are more intelligible than one-syllable words. Also, familiar words are more intelligible than unfamiliar words.

The intelligibility of talkers. If the same intelligibility test is spoken by different talkers in the presence of a given masking noise, the masking effect will vary in relation to the intelligibility of the talkers. People may differ widely in the intelligibility of their speech. In one study, the same intelligibility test was spoken by 12 different talkers under the same noise conditions.[1] The scores that resulted ranged from 44 percent to 85 percent. In a related investigation, the speech characteristics of talkers were studied to determine the aspects important for intelligibility.[2] Other than acoustical characteristics, aspects shown to contribute to speech intelligibility in noise were the strength and precision of the consonants and the dialect.

Intelligibility in relation to the acoustical characteristics of speech. In the presence of noise, the intensity level of speech is generally the most important acoustical characteristic contributing to intelligibility. The intensity of speech varies in relation to vocal effort and the distance of the listener from the speaker. From a loud shout to normal conversational speech, intensity level varies about 18 dB.[3] Approximately three feet from the speaker a shout is around 85 dB sound pressure level (SPL), quiet speech is about 45 dB SPL, and average conversational speech is approximately 65 dB SPL.[4] Among people there are rather large differences in conversational levels. Conversational speech varied from 55 to 75 dB SPL when measured at the location of a telephone microphone for a large number of talkers.[4] Outdoors, the intensity of speech at different distances from talkers can be estimated on the basis of the inverse square law. As the distance from the talker doubles, the level of speech decreases by about 6 dB.

In a quiet environment, speech can be understood at about 25 dB SPL[5] and remains intelligible when amplified through an intensity range up to and including 130 dB SPL.[6] When speech intensity changes with different amounts of vocal effort in the presence of noise, intelligibility is greater at speech intensities representing normal or loud speech (about 50 to 80 dB SPL) than for speech spoken with less or more force, as in a weak voice (≈40 dB SPL) or maximum shouting (90-105 dB SPL).[7] Additional acoustical characteristics of speech found important for intelligibility in noise are the fundamental frequency and the peak pressures of the voice.[2] These characteristics in combination with intensity were shown to contribute to the "noise-penetrating quality" of speech.

The spectrum of speech can be varied significantly without decreasing intelligibility. Measurements of the normal speech spectrum over a period of time show that speech energy occurs between 50 and 10,000 Hz. Most of the long-term speech energy occurs at frequencies below 1000 Hz. The area of the spectrum between 200 and 7000 Hz is of greatest importance for speech-intelligibility in noise.[8] In quiet, it is possible to eliminate frequencies of the speech spectrum either above or below 1900 Hz without reducing the intelligibility of ordinary conversation.[9]

Speech Intelligibility in Relation to the Acoustical Characteristics of Noise

The acoustical characteristics of noise that affect speech intelligibility are intensity, spectrum, and temporal continuity. By far, however, the most important characteristic is intensity. Other characteristics of noise are irrelevant to speech intelligibility if there are large differences between the intensity of the noise and the speech.

Extensive investigations have been conducted to determine the masking effects of different noise intensities on speech intelligibility. Most of these studies were concerned with the interference of noise with speech over communications systems. The results reported often identified the minimum speech-to-noise ratios (S/N) that permitted accurate speech perception under certain conditions. In a study using white noise, listeners understood connected discourse with reasonable accuracy at a S/N of +6 dB for a wide range of conditions.[10] However, speech can be detected in the presence of white noise at a S/N of -18 dB.[11]

The effect of the spectrum of noise on speech intelligibility has also been studied. The effects of a broad-band noise and narrow bands of noise at different levels were compared in one study.[10] Over a frequency range from 135 to 4000 Hz, eight different noise bands of varying levels were tested. The three bands of noise below 1000 Hz were found to be more effective maskers than those above 1000 Hz at S/N of $\geq$ -6 dB with the speech at 95 dB SPL. However, a 20-4000 Hz broad-band noise produced more masking than any of the narrow bands. These findings led to the conclusion that a wide band noise from about 20 to 4000 Hz, with most of its energy concentrated at frequencies below 1000 Hz, should be more deleterious to speech intelligibility than narrower bands of noise within the frequency range of the wide band. In general, however, the spectrum of the noise is of little concern for speech intelligibility, if the S/N is 20-30 dB.[10]

The effect of the temporal continuity of noise on speech intelligibility has been shown in experiments with intermittent noises. Noises at different S/N were interrupted from 0.1 to 10,000 times per second at a noise-time fraction of 0.5.[12] At a S/N of +9 dB one-syllable words at 90 dB were $\geq$90% intelligible for all interruption rates. At a 0 dB S/N, intelligibility ranged between 65 and 90 percent for all interruptions. For -9 and -18 dB S/N, interruption rates between 2 and 30 per second yielded the highest intelligibility - from about 65 to 80 percent. Noises interrupted at rates $\geq$ 100 times per second produced a masking effect similar to that of continuous noise.

Speech Intelligibility in the Presence of Consumer Product Noise

How is the information above relevant to speech interference from consumer product noise? The same factors affecting speech intelligibility under experimental conditions will be operative also in practical situations. For consumer products, the practical situation of greatest concern is, perhaps, the communication of a warning in the presence of a noisy product. To generalize for just a few factors of speech intelligibility, we can predict that a phrase of warning will be more intelligible than a word of warning. A shouted warning will be less intelligible than a warning in a loud voice. Irrespective of the vocal effort, the warning will probably not be detected if the product noise level is 18 dB greater than the level of the warning.[11]

Many other examples of the effect of product noise on speech could be generalized. It would be more meaningful, however, to evaluate directly the expected effect of a given product noise on speech intelligibility. There are at least three means of approach for evaluating the effects on speech communication of the noise from a consumer product. (1) The product noise level may be compared to one of various nomographs or tables (see Fig. II-1 and Table II-1) that show the estimated quality of communication expected for different levels of noise (p. 18). (2) Procedures may be used for calculating the effects of a given noise on speech communication (p. 18). (3) Intelligibility tests may be conducted in the presence of a product noise (p. 19). Among these approaches there are differences in complexity as well as differences in the accuracy with which each approach predicts interference with speech communication. Moreover, one approach may be more appropriate than another for use with a particular noise measurement, or in relation to a particular communication situation that may occur in the presence of a noisy consumer product. However, these approaches are not mutually exclusive for estimating the effects of a consumer product noise on speech communication. Rather, they may be considered as successive steps in a process that seeks to identify noisy consumer products for which speech interference is highly probable. In this process the essential first step is the measurement of the product noise.

Noise Measurements

The noise level of the consumer product should be known relative to the ear of the operator, or at that point closest to the product where a conversation might logically be heard by a listener. At these locations the measurements of product noise should be obtained in a controlled environment (see Chapter III) that simulates the usual situation encountered during normal product use.

Product noises should be measured in A-weighted sound pressure or sound pressure at contiguous frequency bands since A-weighted noise measurements can be used with nomographs (see Fig. II-1) that show the effects of noise on speech. Also, measurements of noise at certain frequency bands across the spectrum are necessary for procedures that calculate the speech interference of the noise. Measurements of spectrum are important also for noises that are unusual, particularly those that have greater energy in the low frequencies. A-weighted measurements are less appropriate for noises that have a preponderance of low frequency energy. The A-weighted frequency network of a sound level meter approximates the sensitivity of the human ear to different frequencies. The ear is less sensitive to frequencies below 1000 Hz than above. Consequently, A- weighted noise measurements do not fully represent the contribution of frequencies below 1000 Hz to the measured noise level. This characteristic of A-weighted measurements is of concern in relation to the masking effectiveness of noises of different frequencies. As discussed earlier, noises with greater energy below 1000 Hz are more effective speech maskers than noises with greater energy above 1000 Hz.[10] The noise emissions of nearly all of the consumer products measured at NBS seemed to have most of their sound energy in the middle and high frequency range (see Chapter V).

Maximum product noise levels for no speech interference. In the Environmental Protection Agency (EPA) "Levels" document,[13] levels of background noise are discussed that should cause no interference with speech communication.[13] These levels may be appropriate as maximum levels for consumer product noise that will not interfere with speech communication. An A-weighted steady sound level of 45 dB was indicated as the maximum level indoors that would permit 100% intelligibility of sentences spoken with a normal voice when the talker and listener were separated by >1.1 meters in a room with a reverberant field. For outdoors a level of 66 dB was cited as the maximum A-weighted sound level that would allow 95% sentence intelligibility with a normal voice when the talker and listener were separated by one meter. Consumer products emitting noises at or below these levels when used in the environments specified should not interfere with speech communication. Products with noise emissions above these levels should be evaluated next relative to the probability of speech communication occuring during the operation of the product.

Conditions of Product Use

It is reasonable to assume that speech communication might be attempted in the presence of any noisy consumer product. Communication may be a necessity in situations where two people work together using a noisy product. In the use of a bench saw, for example, one person may operate the saw while another holds the article being sawed. Communication may also occur between two people who are uninvolved with the operation of a product but are in the noise vicinity of the product. For example, a conversation might take place in a kitchen where a dishwasher is operating. To evaluate the communication probability in the presence of a noisy consumer product considerations of importance are: (1) the expected duration of use for the product, (b) the necessity of an operator for product use, and (c) the likelihood of a two-person team using the product.

In addition to communication probability the product should be evaluated in relation to the possibility of an injury occurring during its use. The operations of some products render them potentially hazardous. An injury could more easily occur from an interference in the communication of a warning during the operation of a noisy product that is also hazardous. Both injury and communication probabilities should be considered in deciding how extensively to evaluate the effects on speech interference from the noise of a consumer product.

Communication Situations

When communication occurs in the presence of a noisy product there are three possible situations that can exist among the talker, the listener, and the product noise. (1) The listener and talker may be the same distance from the product, hence the noise level is likely to be the same for both. (2) The talker may be closer to the product, thus the noise will be greater for the talker than the listener. (3) The listener may be closer to the product, therefore the noise will be greater for the listener than the talker. In each of these situations communication could be disrupted from a product noise of sufficient intensity. However, the latter situation seems to have the greatest potential for interference with communication. When the noise is less intense for the talker than the listener, the talker may raise his voice only in relation to the noise level at his location. Although ostensibly intelligible to the talker, the speech signal is masked at the location of the listener where the noise level is greater. These communication situations are discussed below in relation to the approaches for evaluating the effects of a product noise on speech communication.

Nomographs and Tables for Estimating the Effect of Noise on Speech Communication

Recent information for estimating the speech interference from noise appears in documents published by the EPA.[13,14] As part of that information, nomographs and tables (see Fig. II-1 and Table II-1 for examples) are presented from which it is possible to estimate for a given level of noise either: (a) percent intelligibility, (b) the distance between the talker and listener that allows at least 95% intelligibility, or (c) the quality of communication at various distances between the talker and the listener. However, certain characteristics of this information limit its applicability for estimating speech interference from consumer product noises. First, the noise levels specified are based on A-weighted sound pressure. For this reason, the information is most appropriately used to estimate speech interference for product noise levels measured in A-weighted sound pressure. Second, the information was developed, for the most part, from extrapolations of experimental data on face to face communications in noise during which talkers and listeners were surrounded by ambient noise.[15] For estimating speech interference from product noise, then, it would seem that the EPA information best lends itself to the communication situation in which the product noise is the same level for both the talker and the listener. However, other communication situations may be compared to nomographs to obtain rough estimates of the expected interference from a given noise level.

Procedures for Calculating the Effect of Consumer Product Noise on Speech Communication

For any communication situation, irrespective of the relative product noise levels for the talker and listener, procedures may be used to calculate the expected amount of speech interference. These procedures require sound pressure measurements of noise at particular frequency bands, hence they are particularly applicable to product noises for which spectrum measurements are important. The procedures yield a more accurate prediction of the noise effect on speech than estimates obtained from information based on A-weighted noise measurements.

Articulation Index (AI). Although somewhat complicated to derive, the AI generally provides the most accurate prediction of the effect of noise on speech. Indirectly, the AI represents the percent intelligibility that may be expected for given noise and speech levels. Briefly, the AI is computed from the difference between the average known or estimated speech level and the average measured noise level of interest for 20 frequency bands throughout the spectrum of speech. The AI can be calculated for both steady and intermittent noises. A description of the method for computing the AI is presented in a standard[16] and additional discussions of the AI are available elsewhere.[15,17] Other less complicated but also less precise methods for deriving the AI are based on one-third octave or octave band measurements.[18]

Speech Interference Level (SIL). A simpler though generally less accurate procedure for calculating the effects of noise on speech is the SIL.[3,15,17,18] The derived SIL value is an average of the levels of the noise measured in either three or four octave bands across the lower-mid speech spectrum. The derived SIL value must be compared to a table of speech interference levels to determine the voice level required for barely reliable conversation at various distances between the listener and talker.

Intelligibility Tests for Estimating the Effects of Consumer Product Noise on Speech Communication

If conducted under carefully controlled and relevant conditions, speech intelligibility tests should provide the most accurate information concerning the effects of consumer product noise on speech communication. A standard has been written for the measurement of word intelligibility[19] and a plethora of literature is available concerning speech intelligibility and its measurement.[20-24]

In measuring the effect of a product noise on speech, probably the most reliable results will be obtained through the use of commercially available recorded speech intelligibility tests comprised of lists equated in difficulty. Various intelligibility tests have been recorded for experimental purposes and for clinical use in hearing testing. One of the earliest tests, the Phonetically Balanced (PB) 50 Word Lists, developed at Harvard, is comprised of 20 different lists of 50 words each. All of the lists appear in the American National Standard on word intelligibility.[18] Eight of these lists have been recorded and are distributed by Technisonic Studios, 1201 South Brentwood Bldg., Richmond Heights, Missouri. Another intelligibility test prepared by this firm is the CID Auditory Test W-22 that includes six randomizations of four different lists of 50 words each. A more recent recording of an intelligibility word test is the Northwestern University Auditory Test No. 6 (Northwestern University, 2299 Sheridan Road, Auditory Research Lab., Evanston, Illinois 60201). It is composed of four randomizations of four different lists of 50 words each.

For the three tests mentioned above, a listener receiving the tests is required only to repeat or write each stimulus word he hears. A different type of response is required in another recorded intelligibility test. A listener receiving the Modified Rhyme Test must circle the stimulus word he hears from a group of six printed words. The test includes six different lists of 50 words each and was developed at the Stanford Research Institute, Menlo Park, California.

Recently, a revised version of the CID Sentence Lists were recorded at the Biocommunications Laboratory, University of Maryland, College Park, Maryland. The test is composed of ten different lists of sentences that were originally developed at the Central Institute for the Deaf. Each list consists of 10 sentences that the listener repeats during presentation of the test.

Discussions of the relative merits and shortcomings of these tests may be found in the literature.[25-29]

Summary

Consumer products with A-weighted noise levels greater than 45 dB indoors and 66 dB outdoors may interfere with speech communication. The amount of speech interference from a given product noise level may be (1) estimated from a nomograph, (2) calculated using the Articulation Index or Speech Interference procedures, or (3) determined from the results of intelligibility tests presented in the presence of the product noise.

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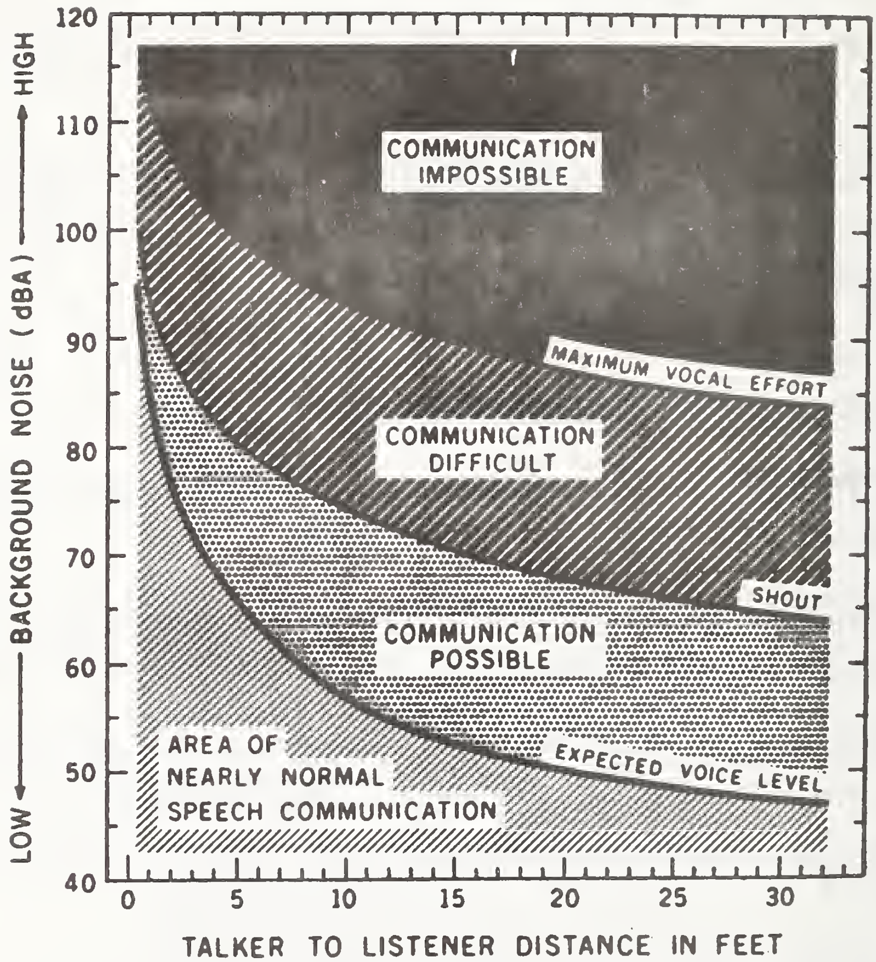

Figure II-1. Speech communication quality in relation to the A-weighted sound level of noise (dBA) and the distance between the talker and the listener.[14]

TABLE II-1. Steady A-weighted noise levels that allow communication with 95 percent sentence intelligibility over various distances outdoors for different voice levels[13]

Voice Level	Communication Distance (meters)					
	0.5	1	2	3	4	5
Normal Voice (dB)	72	66	60	56	54	52
Raised Voice (dB)	78	72	66	62	60	58

CHAPTER III

MEASUREMENT PROCEDURES FOR SOUND OUTPUT OF CONSUMER PRODUCTS

Introduction; Purpose for Measuring Sound Output

There are many considerations that affect the measurement of the output of a sound source. One has to know what characteristics of sound to measure, the proper conditions for such a measurement and the type of equipment to use. The purpose for making the measurement, as well as knowledge of the science of acoustics and electronics, are all relevant to good measurement.

For consumer products, measurement of sound output for the purpose of insuring safety is of prime importance. Exposure to loud noise can cause permanent hearing damage and affect one's physiological well-being. Also, noise can mask other signals, making it difficult for the operator of a noisy product to communicate with another person. Effective communication is essential in a dangerous task such as cutting a tree where one person operates a power saw and another guides the tree with a rope. Good communication may not be possible because of the noise output of the saw. These effects of sound on man are discussed in more detail in Chapters I and II.

Considerations of safety help specify which characteristics of sound should be measured. Not only is the overall sound level of importance, but also other characteristics such as frequency composition and whether the noise is on-going or impulsive have to be considered.

For hearing damage from on-going noise, the A-weighted sound level should be measured, while for impulsive noise, measurement of the peak pressure level is appropriate. For speech communication, both the A-weighted sound level and the frequency composition of the interfering noise are important although it might be more direct to perform specific articulation tests such as described in Chapter II.

There are many other reasons for making a measurement of the sound output of a consumer product. A manufacturer might be interested in quality control or in comparison of the noise output of a product with one of a new design or in rating a product with respect to noisiness. One might wish to obtain information on the exposure of the users to sound in order to develop a regulation or to check for compliance with an existing regulation or acoustical criterion.

As with safety, all of these objectives determine which qualities of sound should be measured. To some degree they also determine the measurement strategy. That is, the objectives determine whether a standard measurement procedure for a large class of sound sources should be used or whether a procedure specific for the product in question is more suitable.

Some Principles of Measurement of Sound Output and Their Relation to Standard Procedures

The sound output of a source is a function of its environment. In general, the sound pressure level one would measure from a sound source depends upon the location of the microphone and its relation to the source and the environment. Not only is the distance from the source a factor, but reflections from all nearby surfaces (ground, buildings, etc., when outdoors, and walls, furniture, etc., when indoors) as well as the total volume enclosing the source, affect the resultant sound pressure level. Thus in order to make repeatable and meaningful measurements of sound level the environment must be specified.

One standard environment used for determining the sound power radiated by small sources of steady noise is the reverberation room. This is a room designed to have special acoustical properties. It has hard, reflecting walls, floor and ceiling, with low absorption of sound in the frequency range of interest. There is a means, such as rotating vanes, to break up the sound pattern. The room is large enough to permit measurement of sound level in the reverberant sound field, beyond the direct sound field of the noise source. These and other properties and a procedure for qualifying a reverberation room are described in ANS S1.21-1972, "Methods for the determination of sound power levels of small sources in reverberation rooms." This test procedure could be used for quality control of product noise emissions and for information regarding the new design of a product for reduced noise output. The directionality of the signal is lost, however, in a reverberant room.

Another standard environment used for the determination of the sound power radiated by a source of sound is the anechoic chamber. This is a room designed to approximate the conditions of a free field where sound from a source radiates outward and is never reflected back. The surfaces of the room are highly absorbent to sound in the frequency range of interest. The room is large enough so that the microphones can be placed in the far radiation field of the sound source without being too close to the room surfaces. The properties of the anechoic room and the determination of sound power in a free field are described in section 3.3 of ANS S1.2-1962, "Physical Measurement of Sound."

In an anechoic chamber, an array of 20 microphones are distributed uniformly over the surface of a sphere enclosing the sound source. From the sound pressure levels at each microphone position, Lp, the mean-square sound pressure level in decibels, $\bar{L}p$, and the sound power level can be calculated. As with the reverberation room measurement, the determination of sound power in an anechoic room is useful in design of low-noise products. In addition the directivity index (DI) of the source can be calculated.

$$DI = Lp - \bar{L}p.$$

The directivity index of a sound source is a measure of how much the actual sound pressure level in a given direction and distance from the source exceeds that sound pressure level that would have emanated from the same source radiating the same total sound energy equally in all directions. A knowledge of the directionality of the sound output of a product with respect to the operator position is of value in assessing the hazards of its noise emissions.

However, if the purpose for measuring the sound output of a product is to determine exposure to the operator then the actual sound levels produced in its "natural" environment are of paramount importance. It is possible to utilize the sound power output of a source to predict the sound pressure at a particular location in a particular environment; however, there are instances where it is preferable to express noise emission in terms of sound pressure under specified measurement conditions rather than in terms of sound power. In general, sound pressure is appropriate if the operator's (listener's) location is well defined and the transmission to the operator (listener) does not differ much among typical applications.

Also for many sources, including mobile sources and stationary sources powered by internal combustion engines, a confined space is not a suitable test environment due to the difficulty in providing for operating loads, heat loads and exhaust emissions. Domestic and international standards exist which define test environments for such sources. For example, ISO Recommendation R362, Measurement of Noise Emitted by Vehicles, describes a test site and procedure suitable for moving vehicles. Acoustical considerations of the site such as area, reflections from objects, sound absorption by ground, etc. are discussed. This is necessary so that the sound level emitted by a product at one test site will be the same as at another test site. The more closely the acoustical requirements are specified and met, the greater the test data will agree. For the test procedure the mode of operation of the vehicle (load, speed and acceleration, etc.) are specified.

Developing a Test Procedure for a Specific Product

In developing a test procedure for a specific product, insofar as practical, an existing ANSI or ISO procedure should be used or adapted. The acoustical properties of a typical or standard environment should be specified. Tests should be performed under varying conditions of use including one producing maximum noise. If installation is required, the mounting should be specified. Directionality of the source should be checked. Sound levels at the operator's ear position should be measured and if good communication is essential, at the ear of the second operator or co-worker.

The quality of the measuring equipment and its calibration affects the accuracy of the sound measurement. Here again, as far as possible equipment that meets ANSI and/or ISO-IEC requirements should be used. The overall accuracy of the measurements should be specified. Particularly helpful is ISO Recommendation R495 "General Requirements for the Preparation of Test Codes for Measuring the Noise Emitted by Machines".

The appendix at the end of this report contains a list of standards relevant to the measurement of sound output of consumer products.

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CHAPTER IV

NOISE EMISSIONS FROM PRODUCTS: INTENSITY AND CONSUMER USAGE

Dr. Vern O. Knudsen, an eminent acoustician, has claimed that "the loudest noises to which we are exposed have increased some 20 decibels in the past 20 years."[1] A growing population has expressed its demands in the marketplace for more and more powerful appliances, tools, and vehicles. The increasing number of noisy consumer products in use has contributed to the overall growth in the level of environmental noise to which most of us have been exposed.

In accord with its mission to protect consumers against unreasonable risk of injury from hazardous products, the Consumer Product Safety Commission has undertaken the evaluation of the potential hazards associated with the noise emissions of consumer products. Product noise emissions could prove to be hazardous to the user in a variety of ways. The noise from a device could prevent the user from hearing (i.e., mask) an auditory warning signal such as a shout or a horn or siren. Likewise, a noisy product may prevent the user from detecting a mechanical malfunction. A noisy device might distract the operator from the demands of the task which he is performing or it may, with time, increase the operator's level of fatigue or irritability. Any of the above conditions may predispose the operator to respond inappropriately if a crisis situation should arise and an accident could follow. Furthermore, the use of products emitting intense levels of noise may lead to temporary or even permanent loss of hearing. The debilitating effects of such hearing losses may, in turn, increase even further the users' susceptibility to accidents resulting from auditory failure.

The specific hazards of noisy products are discussed in greater detail elsewhere in this report. The present chapter will examine the general scope of the problem of noisy products in terms of their impact upon the population of consumers. The noise impact of a product can be considered a joint function of the intensity level of its noise emissions and the extent to which the user population is exposed to it. Extent of usage is determined from the usage pattern associated with a given product. At a minimum, a usage pattern describes how many people on the average use a particular product, how frequently and for how long. Although there is controversy about how intensity level and amount of usage should be combined mathematically in order to express noise impact on the individual (the measure, L_{eq} seems to be in current favor - see Chapter VI), it is clear that the hazards associated with a product increase as both intensity and amount of usage increase. The magnitude of noise-induced hearing loss becomes greater as the intensity level of the noise to which the ear has been habitually exposed increases and also as the duration of exposure to the noise increases.[2] Furthermore, the capability of a noise to mask a warning signal increases directly with its intensity.[3] Finally, the number of people risking either hearing damage or an accident from a noisy product is likely to increase in direct proportion to the number of people who own or use the product.

In order to assess noise impact on the consumer, an extensive list of potentially noisy products was compiled. This list of products was developed using an updated version of the categories and products listed in the Consumer Product Safety Index of the National Commission on Product Safety.[4] The selection procedure was editorial; that is, the investigators simply included any item which we felt produced substantial amounts of noise. In the case of many of these products, data on noise emissions were not available. This compilation is presented in Tables IV-1a & b. Concurrently, the technical literature was searched for reported levels of noise emissions from consumer products. The outcome of this literature search is presented with the list of products given in Table IV-1a. The range of reported A-weighted sound pressure levels measured at the operator's approximate ear position is given in Table IV-1a for those products for which data were available. The average of the reported levels is also given along with the sample size if these were determinable. In some cases the product noise measurements were reported in octave-band sound pressure levels and the A-weighted level was calculated. A bibliography listing the sources of the reported product noise measurements is appended at the end of the chapter.

Noise levels for consumer products reported in the literature tend to concentrate on about a dozen common household items (e.g., air conditioners, dishwashers, vacuum cleaners, garbage disposals). Reported levels on the more esoteric items (e.g., staple-guns, shredder-baggers, electric ice crushers) are much less common. The most extensive lists of product noise levels were found in a report prepared by Bolt Beranek and Newman for the Environmental Protection Agency ("Noise from Construction Equipment and Operations, Building Equipment, and Home Appliances"[5]), and in a report prepared by the Environmental Design Department of the University of Wisconsin for the Koss Corporation ("The Auditory Environment in the Home."[6]). The Bolt Beranek and Newman (BB&N) report presents average A-weighted sound levels for thirty different appliances and eleven shop tools obtained from the literature and from their own measurements. The Koss report gives A-weighted sound levels which the investigators measured for 41 products (presumably, only a single item was measured in each product category in the Koss study). It is interesting to note that the noise levels for those 21 products appearing in both of the above reports differed on the average by about 10 dB.

It is difficult to get a clear and consistent picture of product noise levels by examining those reported in the literature. As stated previously, most studies deal with only a handful of the most common products. Furthermore, measurements from the different studies are hard to compare since few of the studies provide enough information to evaluate the measured levels properly. Such information should ideally specify the number of products sampled, power ratings of the sampled products, mode of product installation and operation, exact distance at which measurements were made along with other details of the test procedure and the acoustic environment.

The BB&N report cited above was perhaps the most useful single source of information about product noise levels. The authors of this report also emphasized the scarcity of reliable product noise data in the open literature. Consequently, they chose to supplement their tabulation of noise levels from the literature with noise measurements which they themselves conducted. The authors of the BB&N report describe their test procedures in greater detail than is generally the case in other studies. They also provide octave or 1/3 octave-band sound pressure levels for some of the products whose A-weighted sound level was measured. Brief descriptions of the sound generating characteristics of some products are also provided.

The data on product noise levels tabulated in the BB&N report have been updated by us and are incorporated in Table IV-1a (see p. 39). Product noise levels reported in those studies from our literature search which were not cited in the BB&N report (which was completed in 1971) were added to the tabulation. In addition the A-weighted sound levels for 16 different products which were measured by us at the National Bureau of Standards are also included in the updated tabulation. Our product noise measurements are presented and discussed more fully in Chapter V of the present report.

Although published information on product noise levels is scarce, limited in extent, and often difficult to compare and interpret, data on product usage patterns which would allow precise assessment of noise impact were not found. To our knowledge, the BB&N report is the only survey or article on product noise which utilizes statistics on consumer product usage. About the best that could be done was to follow up the sources of information cited in their report for more recent statistics of greater relevance to product usage patterns. None of interest were found. Other pertinent sources of statistical information were also queried without success.

Since we could not improve upon the usage statistics provided by the BB&N report, our discussion of the noise impact of consumer products is based entirely on the BB&N usage data. They cite the following as sources of information:

New York State College of Human Ecology, Cornell University (both published and unpublished data gathered as part of a 1296-household survey of Syracuse, New York).

Department of Agriculture information based on studies of home activities (a long-term interest, which is now being continued under the Agriculture Research Service Division of the Department of Agriculture).

Potomac Electric Power Company (an informal survey conducted by their Home Services Department; note: a representative of the company told us that the original source of the data was probably the Electrical Energy Institute in New York.)

Manufacturer's industry information.

In addition to the sources of information on product usage cited in the BB&N report, we found the following sources potentially valuable although we did not incorporate them in our own analysis:

The 1970 U.S. Census of Population and Housing; series HC S1-6 June, 1972 (provides information on the availability of appliances in a 5% sample of 66 million households).

Merchandising Week Magazine (supplies market penetration data for many products - it is more up-to-date than the census information but is biased in ways that can be misleading).

To supplement the data from the sources which they used, the investigators of the BB&N report conducted their own survey based on 20 households (unfortunately, little information is given on the details of how the survey was conducted). Information from these sources was condensed into two composite statistics to describe the usage pattern for a variety of products:

(1) the estimated number of people (in millions) in the united States exposed to a product's noise emissions, and

(2) the estimated average duration of exposure (in hours) to a product in a household for one week.

Admittedly, such statistics are gross overgeneralizations; there is no such thing as a "typical" household. Households vary greatly in the number of their members, the number of appliances owned, and in the personal habits of the members. Thus, any analysis of product noise impact which is based on such generalized statistics should be interpreted cautiously as an "order-of-magnitude" type of estimate.

Unfortunately, given the quality of information on product noise levels and usage statistics currently available, such estimates are about the best that can be achieved in assessing the impact of product noise emissions.

A list of products which we considered as having a high level of noise impact upon the consumer is presented in Table IV-2. An A-weighted sound pressure level of 70 dB was chosen as a tentative and somewhat arbitrary lower limit or criterion level. Only products whose reported range of A-weighted sound levels exceeded 70 dB were considered as potential high- impact products. A cutoff level of 70 dB was felt to be reasonably conservative with respect to protection of hearing (see Chapter VI). Other information suggests that with an A-weighted sound level not exceeding 70 dB (outdoors), communication is possible with a very loud voice up to a distance of about 7 ft and that a shout can be recognized up to a distance of about 15 ft.[3] Thus, within a limit of 70 dB, disruption of auditory warning signals would probably not be excessively severe. This projection, however, is a generalization and should, of course, be put to empirical test for particular products used in specific situations (see Chapter II).

If a product whose range of noise levels exceeded 70 dB also appeared to have a substantial amount of consumer usage associated with it, then it was included in Table IV-2. Two features of the data in Table IV-2 are especially notable. The first is that the range of reported noise levels within a given product category can be quite wide. This might suggest the possibility that a few of the many manufacturers of a certain product may be responsible for most of the noisy models. It also implies that a product category generally considered as "quiet" may nonetheless harbor some models having hazardous noise emissions. Finally, reported noise levels are representative only of products in their normal condition. The noise from some products can be totally innocuous when operating normally, yet hazardous when the product malfunctions.

A second important feature of the data in Table IV-2 is that very few of the products for which usage statistics are given and which have reported noise levels exceeding 70 dB are also in use for more than an hour per week in the average household. This might lead to the conclusion that the noise impact from most products is inconsequential for the typical consumer. However, many noisy products are often used in atypical patterns. Household appliances and tools are frequently used for occupational purposes. A home seamstress or a gardener or a handyman would generally use such tools and appliances far in excess of the amount of time which is representative for the average householder. Since these individuals are self-employed, they would not be subject to the noise-safety regulations of the Occupational Safety and Health Administration (OSHA). A similar case can be drawn for products which can be used for hobbies and recreational purposes such as workshop tools, sewing machines, snowmobiles, motorcycles and the like. Thus, many of the products found in Table IV-2 are items which can be used for recreational and occupational purposes.

In summary, it should be recognized that generalized usage statistics such as those presented above are inherently misleading and any evaluation of noise impact which is based upon them will not fully insure adequate protection for all consumers.

A few closing comments are in order regarding usage patterns for consumer products. The discussion thus far has assumed that a particular product is used by itself. This assumption is patently unrealistic for most products. Any complete analysis of product noise impact would ideally include joint product usage patterns as well as combined noise spectra. Of more importance, however, is the fact that although the duration of exposure to the noise from products may be relatively small for most consumers, it must be combined in some manner with the exposure to noise which is incurred through one's occupation and the general environment. This matter will be discussed more thoroughly in Chapter VI.

References

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[5]Bolt, Beranek and Newman, "Noise from Construction Equipment and Operations, Building Equipment, and Home Appliances," (prepared for the U.S. Environmental Protection Agency) EPA Document No. NTID300.1 (U.S. Government Printing Office, 1972).

[6]"The Auditory Environment in the Home," a report by the Environmental Design Department, University of Wisconsin, for Koss Electronics, Inc., Milwaukee, Wisconsin.

Table IV-1a. Consumer products having substantial noise emissions with statistics for reported A-weighted sound pressure levels.

Standard Industrial Classification Number[a]	Product	References[b]	A-Weighted Sound Pressure Level, dB		Sample Size
			Range	Average	
0823	Air Compressor	10	-	94	1
0321	Air Conditioner	1,4,10,11,15	50-70	57	55
0629	Alarm Clock, Electric	4,10,11	60-80	68	3
0215	Blender, Electric	1,4,11	62-93	77	69
0213	Can Opener, Electric	1,11	54-78	68	7
0127	Clothes Dryer	1,11	52-66	58	12
0126	Clothes Washing Machine	1,4,11	47-78	64	61
0217	Coffee Grinder	1,11	66-79	75	3
0511	Desk Calculator	12	-	94	1
0306	Dehumidifier	1	52-62	57	4
0214	Dishwasher	1,4,11,17	54-85	66	46
0802	Drill, Electric	1,11,18	70-89	80	7
1404	Edger and Trimmer, Lawn	1	-	81	1
0116	Electric Broom	18	-	82	1
1637	Electric Comb	18	78-80	79	2
0806	Electric Grinder	1	87-97	-	3
0218	Electric Knife	1	65-75	71	3
1608	Electric Toothbrush	1	48-55	52	3
0111	Fan	1,11	38-70	58	42
0648	Faucet	1	-	61	1

Table IV-1a (Cont'd)

Standard Industrial Classification Number[a]	Product	References[b]	A-Weighted Sound Pressure Level, dB Range	Average	Sample Size
0231	Food Mixer	1,4,11	49-82	68	27
0113	Floor Buffer/ Waxer	18	-	67	1
0208	Freezer	1	39-45	41	3
0327	Furnace	11	-	100	1
0237	Garbage Disposal	1,4,11,17	67-93	79	22
1602	Hair Dryer	1,11,18	59-80	66	7
1601	Hair Clipper	1	-	50	1
0323	Heater, Electric	1	-	47	1
1427	Hedge Clipper	1	-	84	1
0304	Humidifier	1	41-65	53	3
0516	Infant Incubator	5	54-62	58	6
0240	Knife Sharpener	1,11	72-78	75	2
0805	Lathe	11,18	76-80	78	2
1401	Lawn Mower, Electric	1	81-89	85	2
1401	Lawn Mower, Gasoline	2,4,10	81-98	90	6
1263	Minibike	14	92-96	-	17
1236	Motorcycle	6	85-110	93	10
1608	Oral Lavage	1	70-74	72	2
0208	Refrigerator	1,11	35-52	43	13
0804	Router	1,18	88-103	95	3
0803	Sander, Belt	1,11,18	86-104	94	4
0803	Sander, Disk	11	-	93	1
0803	Sander, Orbital	11,18	70-82	76	2
0801	Saw, Band	18	-	105	1

Table IV-la (Cont'd)

Standard Industrial Classification Number[a]	Product	References[b]	A-Weighted Sound Pressure Level, dB		Sample Size
			Range	Average	
0801	Saw, Chain	4	96-111	-	-
0801	Saw, Circular	9,18	95-98	97	3
0801	Saw, Jig	11	-	68	1
0801	Saw, Radial	11	-	92	1
0801	Saw, Sabre	18	91-110	101	2
0801	Saw, Skill	11,18	100-104	102	2
0112	Sewing Machine	1,11	64-74	69	3
0808	Shaper, Electric	18	-	90	1
1601	Shaver, Electric	1	47-69	60	11
0611	Shower	11	-	78	1
1433	Shredder (Power Mulcher)	18	103-104	104	2
1619	Siren/Horn,	18	-	118	1
1218	Snowmobile	8	103-117	109	4
0649	Toilet (Flushing)	1,11	46-76	65	21
0511	Typewriter, Electric	12	65-74	-	14
0115	Vacuum Cleaner	1,4,10,11,17	62-85	72	30

[a]See reference 4 cited in text.

[b]Numbers entered in this column correspond to the references appended to this Table.

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12. R. Martin, "Noise measurements on desk calculators and typewriters," J. Acoust. Soc. Am. 51, 143 (1972).

13. E. E. Mikeska, "Noise in the modern home," Noise Control 4, 38 (1958).

14. R. P. Oppenheimer, Noise Control Report 2, No. 23, 226 (1973).

15. J. R. Schreiner, talk presented before Air-Conditioning-Heating-Refrigeration Exposition of the Air Conditioning and Refrigeration Institute, Los Angeles, 1974.

16. W. M. Shearer and G. H. Stevens, "Acoustic threshold shift from power lawnmower noise," Sound and Vibration, p. 29 (October, 1968).

17. M.C.C. Tsao and R. S. Musa, "Noise control in home appliances," Sound and Vibration, p. 31 (March, 1973).

18. Measurements conducted by Pearl G. Weissler and Gerald A. Zerdy of the Sound Section, National Bureau of Standards, and Thomas Cooper of the Consumer Product Safety Commission at the National Bureau of Standards, Wash., D.C.

Table IV-1b. Consumer products having substantial noise emissions for which data were not found.

Standard Industrial Classification Number	Product
1202	Bicycle Horn
0606	Electric Generator
0225	Electric Ice Cream Maker
0226	Electric Ice Crusher
0228	Electric Juicer
1611	Electric Manicure
0819	Electric Motor (Separate)
0232	Electric Scissors
1613	Electric Shoe Polisher
0701	Fire Extinguisher
1405	Garden Tractor
0820	Gasoline Engine (Separate)
0811	Gas Torch
1306	Gasoline Powered Toys
1213	Golf Cart
1237	Guns, Gas, Air, Spring Powered
0108	Ironing Machine
0807	Jointer
1610	Massage Devices, Vibrators
0230	Meat Grinder, Electric
1236	Motor Scooter, Unlicensed
0822	Paint Sprayer
1412	Pump
0114	Rug Cleaner/Shampooer
1406	Snow Thrower, Plow
0834	Stapler, Powered
1408	Tiller, Cultivator
1330	Toys, Powered Riding
0252	Trash Compactor

Table IV-2. Consumer products having high noise impact.

Product	Range of Reported A-Weighted Sound Pressure Levels (in dB)[a]	Weekly Exposure: Number of Persons (in millions)[b]	Weekly Exposure: Average Duration (in hours)[c]
Air Conditioner	50-70	60	3.00
Blender, Electric	62-93	63	0.02
Clothes Washing Machine	47-78	183	0.50
Dishwasher	54-85	47	5.00
Drill, Electric	70-89	?	?
Fan	38-70	160	10.00
Food Mixer	49-82	163	0.15
Garbage Disposal	67-93	46	0.10
Hair Dryer	59-80	?	?
Lathe	76-80	?	?
Lawn Mower	81-98	?	0.5
Minibike	92-96	?	?
Motorcycle	85-110	?	?
Sander, Powered	70-104	?	?
Saw, Powered	91-110	?	?
Sewing Machine	64-74	100	0.25
Shredder	103-104	?	?
Snowmobile	103-117	7.5[d]	?
Typewriter, Electric	65-74	?	?
Vacuum Cleaner	62-85	181	1.5

[a]From Table la.

[b]Source: Bolt Beranek and Newman report cited in text, p. 107.

[c]Source: Bolt Beranek and Newman report cited in text, p. 110.

[d]Source: International Snowmobile Industry Association.

CHAPTER V

NBS MEASUREMENTS OF THE SOUND OUTPUT OF SOME CONSUMER PRODUCTS

Introduction

During the search for reported levels of noise emissions from consumer products, described in Chapter IV, the sparsity of available data became apparent. It was decided to try to fill in some of the gaps with our own measurements. We were more interested in the order-of-magnitude of the noise emissions of a variety of product categories rather than the complete range of sound output of one category of product. Also, measurements were made in convenient locations rather than in standard environments such as an anechoic or reverberation room (see Chapter III). The measurements were made by Pearl G. Weissler and Gerald A. Zerdy of NBS and Thomas Cooper, a Guest Worker from the Consumer Product Safety Commission.

Apparatus and Procedure for Indoor Measurements

The measurements were made with a sound level meter whose specifications meet those of ANSI S1.4-1971 for a Type I sound level meter. A commercial acoustic calibrator was used to check the sound level meter at 125, 250, 500, 1000 and 2000 Hz. In addition, the sound output of a sabre saw was measured with this sound level meter and another sound level meter from a different manufacturer, also a Type I. The results agreed within 2 dB.

Measurements on all products except the shredders were made in several different indoor environments; (A) a sound-insulated laboratory with acoustic tile on walls and ceiling, (B) a small general-purpose shop with hard walls and high ceiling, (C) a large wood construction shop, also with hard walls and high ceiling, (D) a small anechoic chamber, (E) a home basement workshop, and (F) in a home bedroom. At E and F the measurements were taken by Frank R. Breckenridge, at (D) by Edwin D. Burnett.

The ambient noise was measured in each room. With the product turned on, the sound pressure level was measured near the operator's ear and sometimes in an additional location, except for the freon siren where no measurements were made at the operator's ear position. Where applicable, the measurements were made under conditions of load and no load. Both the flat and A-weighting networks were used, and both fast and slow meter characteristics were used.

Results of Indoor Measurements

The results can be seen in Table V-1. Sound levels for most of these products, measured with the A-weighting setting are the same as when measured with a linear or "flat" setting. This means most of the sound energy is in the middle and high frequency range. The lathe, however, has relatively more low frequency energy.

Outdoor Measurements

The noise outputs of two shredders, 4 and 5 HP, were measured outdoors in two locations with the same sound level meter described above. The first location (see Figure V-1) was in a driveway leading to a loading platform. With the shredders turned off, the background noise in the area was measured. Then each shredder in turn was placed just north of the loading platform near an industrial disposal with the muffler facing east and then turned on. Sound level measurements were recorded near the position of the operator's ear, (with the operator present), at a distance of 7.6 m north of the shredder, (position 1), and at a distance 7.6 m east of the shredder (position 2). The sound level was measured under conditions of no load and loaded with twigs and thin tree branches. The sound level meter was alternately set to read the unweighted sound pressure level ("flat" scale) and the "A"-weighted sound pressure level ("A" scale). The A-scale weights the sound pressure level as a function of frequency somewhat as the ear does. This attenuates frequencies below 1000 Hz. The meter was set to "fast" response.

Some measurements were also made at a second location (see Figure V-2) which was in the center of a grass area north of a large building. The shredders were oriented with the muffler facing the building. Here position 2 is 7.6 m south of the shredder, between the shredder and the building.

Results are summarized in Table VI-2. There is no significant difference between the A-weighted sound level measured with the fast or slow meter response for the no-load condition. Sound levels were slightly lower in location 2, probably due to sound abosrption by the grass and the elimination of a large reflecting surface (the industrial disposal) just behind the sound source.

Table V-1. NBS measurements of noise emissions from certain consumer products.

Sound Source	Room	SPL, dB A-Weight	SPL, dB Flat	Meter Response
Sabre Saw:				
at operator's ear, no load	A	110		Impulse
hanging by string, rear, near switch	A	124		Fast
at operator's ear, load	B	100		Fast
Sabre Saw (different brand):				
at operator's ear, no load	C	91	91	Fast
		91		Slow
Electric Hand Drill, 1/4", 1800 rpm:				
at operator's ear, no load	A	84	84	Impulse
Electric Hand Drill (different brand):				
at operator's ear, no load	C	89-90	89-90	Fast
		89		Slow
Circular Saw:				
at operator's ear, under load	B	95-98	95-98	Slow
Circular Saw (different brand, 9"):				
at operator's ear, no load	E	95	95	
Electric Band Saw, 7":				
right ear, no load	B	100	100	Fast
right ear, wood load	B	101-105	101-105	Fast
Drill Press:				
at operator's ear, under load	B	72		Fast
Belt Sander:				
at operator's ear, no load	C	98	98	Fast
		98		Slow
at operator's left ear, wood load	C	94	95	Fast
		97		Slow
at operator's right ear, wood load	C	94-96	94-96	Fast
Belt Sander (another type):				
at operator's ear, no load	B	102-104	102-104	Fast
at operator's ear, wood load	B	97-101		
Orbital Sander:				
at operator's ear, wood load	C	80-82	81-83	Fast
Router:				
at operator's ear, no load	C	89	89	Fast
at operator's ear, wood load	C	90-95	93	Fast
		93		Slow

Table V-1 (Cont'd)

Sound Source	Room	SPL, dB A-Weight	SPL, dB Flat	Meter Response
Router (another type):				
at operator's ear, to side, no load	B	97	98	Fast
at operator's ear, above, no load	B	99-100	99-100	Fast
at operator's ear, to side, wood load	B	100-103	100-103	Fast
at operator's ear, 15" above, wood load	B	102-104	102-104	Fast
Skilsaw (8-1/2 in.):				
at operator's ear, no load	C	93	93	Fast
		93		Slow
at operator's ear, wood load	C	98-104	98-104	Fast
Shaper (with 1-1/4" bit):				
at operator's left ear, no load	C	85	86	Fast
		85		Slow
at operator's right ear, wood load	C	90	91	Fast
		90		Slow
at operator's right ear, no load	C	89	89	Fast
Lathe:				
at operator's ear, no load	C	73-76	80-81	Fast
Floor Buffer:				
at operator's ear	A	65-67	65-66	Fast
Electric Broom:				
at operator's ear, slow speed	A	76-77	76-77	Fast
at operator's ear, high speed	A	81-82	81-82	Fast
Electric Comb:				
at operator's ear, while combing	A	78	78	Fast
Electric Comb (different brand):				
at operator's ear, while combing	F	80	80	
Hair Dryer:				
near ear, under cap	A	78-80	83-85	Fast
Freon Siren:				
45" in front of source	B	118	117	Fast
1 m from source	D		114	Fast
Ambient Noise:	A	25	61	Slow
	B	43-46	63-71	Fast
	C	54	68	Fast
	D	25	63	Slow

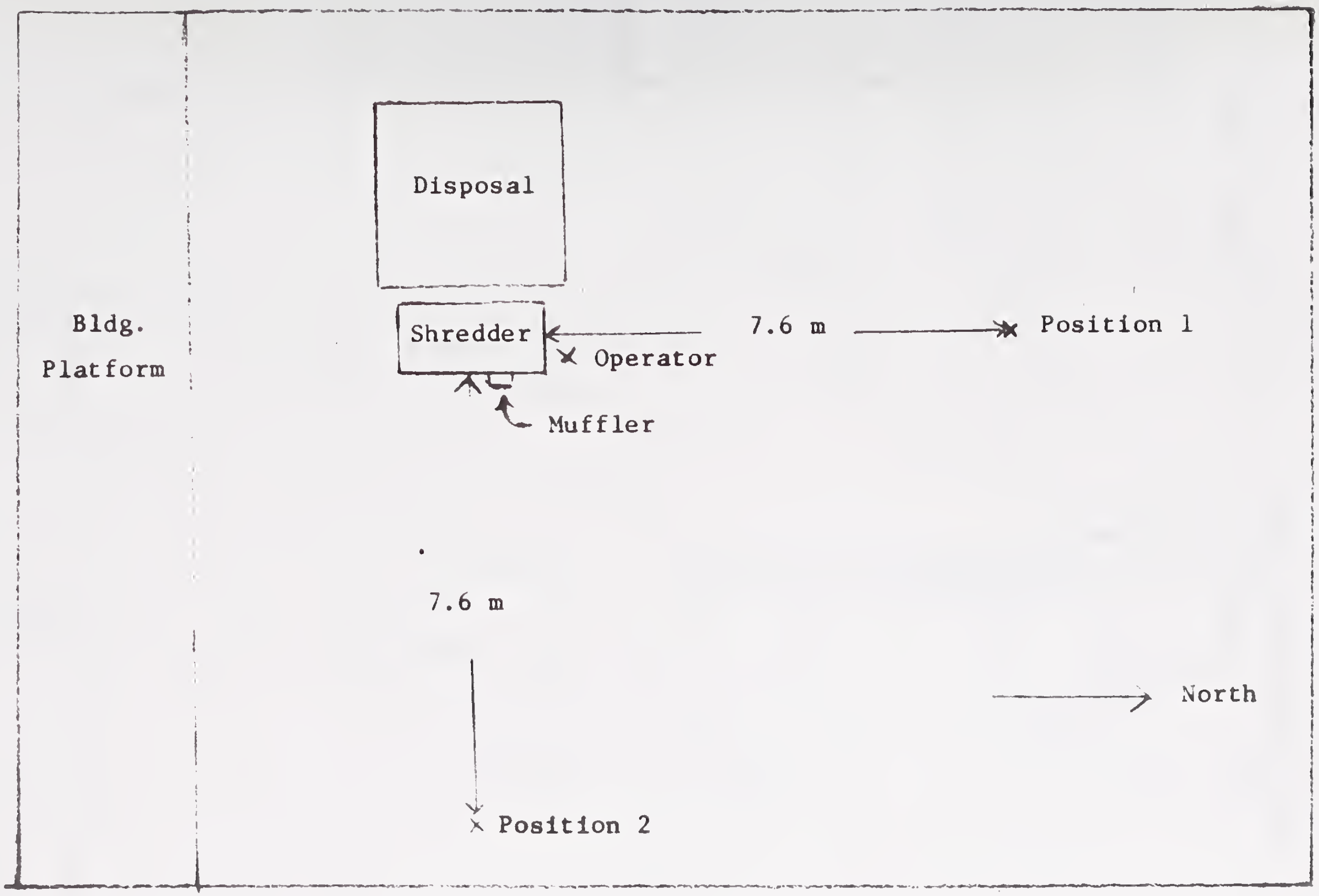

Figure V-1. Orientation of equipment for measurement of noise output of shredders in location 1.

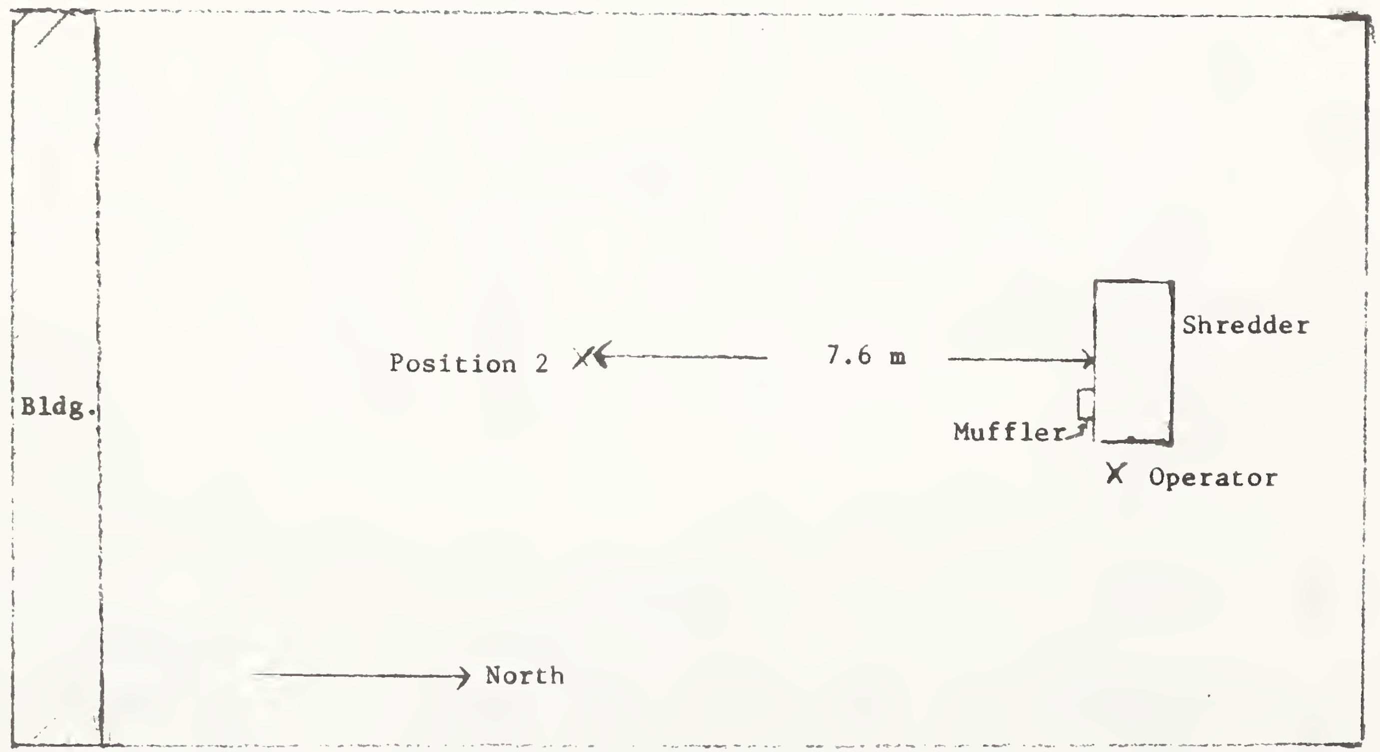

Figure V-2. Orientation of equipment for measurement of noise output of shredders in location 2.

Table V-2. NBS measurements of shredder noise emissions.

Sound Source	Sound Pressure Level, dB A-Weighted	Sound Pressure Level, dB Flat	Meter Response
Location 1			
Background noise	48-50	70-75	Fast
Shredder, 4 HP:			
at operator's ear, no load	94	99	Fast
at operator's ear, load	98	103	Fast
position 1, no load	78	84	Fast
position 1, load	80-82	85	Fast
position 2, load	87	88	Fast
Shredder, 5 HP:			
at operator's ear, no load	98	102	Fast
at operator's ear, load	100	104	Fast
position 1, no load	81-82	89	Fast
position 1, load	89	88-91	Fast
position 2, no load	83	90	Fast
position 2, load	87-91	93	Fast
Location 2			
Shredder, 5 HP:			
at operator's ear, no load	96	98-100	Fast
	96	-	Slow
position 2, no load	78	88	Fast
	80	-	Slow

CHAPTER VI

IDENTIFYING SOUND LEVELS FOR CONSUMER PRODUCTS WITH RESPECT TO HEARING DAMAGE

During the course of a day an individual is exposed to many different sources of noise. His noise exposure pattern depends upon whether he lives in a city or on a farm, whether he travels to work by subway, bus or car, whether he works in a factory, office or at home, and whether after work he mows the lawn, retires to his basement workshop to refinish an old desk or reads a book. If his daily noise exposure is sufficiently high, then after a number of years he may begin to lose his hearing. Noisy consumer products play a part in this complicated pattern. It is important for the Consumer Product Safety Commission to know whether or not a product is contributing significantly to the degradation of hearing.

In order to gain some insight into the problem of determining which consumer products could be considered safe or unsafe with respect to noise-induced hearing loss, use was made of the March 1974 EPA Levels Document[1] and some of its principles were applied to the consumer products listed in Chapter IV. This EPA Document identifies levels requisite to protect public health and welfare with an adequate margin of safety for both activity interference and hearing loss. To define a level which protects the public health, with respect to hearing conservation, some observations and assumptions had to be made about the nature of noise and its measurement with respect to its effect on hearing. Some of these EPA assumptions follow.

The A-weighted sound level is widely accepted as an adequate way to assess noise with respect to its potential for causing hearing loss. A characteristic of much environmental noise is that it is not steady, making it difficult to say that a person at a given location is exposed to so many decibels of noise. In addition, as a person moves from place to place he is exposed to different levels of noise. His total noise exposure is related to the whole time-varying pattern of sound levels.

Accordingly, an Equivalent Sound Level, L_{eq}, was defined in terms of that equivalent steady noise level which, in a given period of time, would contain the same noise energy as the time-varying noise during the same period.

$$L_{eq} = 10 \log \left[\frac{1}{t_2 - t_1} \int_{t_1}^{t_2} \frac{p^2(t)}{p_o^2} \, dt \right] \qquad \text{VI-1}$$

where p(t) is the time varying sound pressure and p_o is a reference pressure equal to 20 micropascals.

This is a particularly useful concept when combined with the Equal Energy Hypothesis which states that equal amounts of sound energy will cause equal amounts of noise-induced permanent threshold shift regardless of the distribution of the energy across time.

An early symptom of noise-induced hearing damage is a change in hearing level at 4000 Hz, the typical noise-sensitive frequency. A change in hearing level of less than 5 dB is not considered significant. Thus, if a noise exposure level could be identified which causes less than a 5-dB change in hearing level at 4000 Hz in a large percentage of the exposed population, then the public health would be protected. In order to do this a considerable amount of data on hearing losses of people with known histories of noise exposure were examined. By comparing groups of such individuals with similar non-noise exposed populations, evidence for noise-induced permanent threshold shift could be inferred.

Much of these data came from industrial environments and thus initially an eight-hour exposure level was identified which was protective of a large proportion of the population. By application of the Equal Energy Hypothesis, corrections were made for yearly and daily (24 hour) dosages. Another correction (+5 dB) was made to allow for the intermittency of environmental noise and the final result was rounded down by 1.4 dB to allow for uncertainties.

Thus available data suggested that for hearing conservation, a level less than or equal to an equivalent sound level of 70 dB over a 24-hour day [$L_{eq(24)} \leq 70$ dB] protects virtually the entire population against a change in hearing level greater than 5 dB at 4000 Hz. $L_{eq(24)}$ represents the sound energy averaged over a 24-hour period and the level identified represents annual averages of the daily level over a period of forty years.

Similarly, for more than 99 percent of the people studied the data suggested that an $L_{eq(24)}$ of 81 dB will cause no more than a 5-dB shift in hearing level averaged for the frequencies 500, 1000 and 2000 Hz, and an $L_{eq(24)}$ of 86 dB will cause no more than a 10-dB shift averaged for the frequencies 500, 1000, and 2000 Hz. However, an average 10-dB shift in the low and middle frequencies is accompanied by a greater hearing loss in the high frequencies (see Fig. I-4). Also, although the data cover a 40-year span, a large part of the damage due to noise occurs in the first ten years.

According to the Occupational Safety and Health Act of 1970, protection against the effects of noise exposure for workers is not mandatory unless the sound level is greater than 90 dB, A-weighted for 8 hours a day. The criterion[2] of 90 dB, A-weighted, comes from data showing the dependence of hearing impairment on age, experience and noise exposure. OSHA considered a handicap for speech as a requirement for its definition of hearing impairment, specifically, a hearing level averaged for the three frequencies 500, 1000, and 2000 Hz, that is greater than 25 dB. If this level of 90 dB were adjusted to environmental levels, by correcting for intermittency and by summing energy on a 24 hours/day and a yearly basis, it would be equivalent to $L_{eq(24)} = 88.4$ dB. This is close to the EPA identified level of $L_{eq(24)} = 86$ dB described above.

Thus one can infer from the EPA Levels Document that for determining which consumer products could be considered safe or unsafe with respect to noise-induced hearing loss, the criterion $L_{eq(24)} \leq 70$ dB is indicative of safe products and $L_{eq(24)} \geq 86$ dB is indicative of those products whose safety may be in question. For all products contributing to an $L_{eq(24)} > 70$ dB, total noise impact must also be considered (see Chapter V).

To calculate equivalent sound levels for consumer products according to the Levels Document, Eq. VI-1 can be employed. If we consider an exposure period consisting of two constant sound levels, L_b and L_x, where x is the fraction of the time L_x is on and (1-x) is the fraction of the time L_b is on, then Eq. VI-1 can be written

$$L_{eq} = L_b + 10 \log \left[(1-x) + x \cdot 10^{\frac{(L_x - L_b)}{10}} \right]. \qquad \text{VI-2}$$

To calculate $L_{eq(24)}$ for a person who drives a snowmobile for an hour a day and who is exposed for the remainder of the day to an equivalent sound level of 40 dB we substitute

L_b = 40 dB,

L_x = 117 dB, and

x = 1/24

into Eq VI-2.

$L_{eq(24)}$ = 103 dB is the result.

This means that a noise exposure of one hour at 117 dB (e.g. from a snowmobile) and 23 hours at 40 dB is equivalent to a noise exposure of 103 dB for 24 hours. This is true for all background noise levels $L_b \leq 91$ dB. For $L_b > 91$ dB, $L_{eq(24)}$ increases. Similarly if one were to operate a power tool producing a sound level of 100 dB (L_x = 100) for two hours, the equivalent noise exposure, $L_{eq(24)}$ would be 89 dB for $L_b \leq 77$ dB. A convenient solution to Eq. VI-2 for low values of L_b can be found in Table VI-1.

To utilize the EPA identified levels of $L_{eq(24)}$ = 70 and $L_{eq(24)}$ = 86 we solve Eq. VI-2 for L_x.

$$L_x = L_b + 10 \log \left[\frac{10^{\frac{(L_{eq}-L_b)}{10}} - (1-x)}{x} \right]. \qquad \text{VI-3}$$

Now with $L_{eq(24)} = 70$ dB and with exposure times, x, corresponding to consumer usage patterns we can identify levels of exposure, L_x, for consumer products that would be safe for use within a limited range of noise exposure during the rest of the day. Table VI-2 gives examples of such exposures.

Similarly, with $L_{eq(24)} = 86$ dB we can identify exposures to sound output of consumer products that, with daily use over many years, for a large percentage of the population would cause no more than a 10-dB increase in hearing level averaged for 500, 1000 and 2000 Hz, provided the equivalent sound level for the rest of the day ≤ 74 dB. These exposures are shown in Table VI-3.

The EPA levels document states "In planning community noise abatement, local governments should bear in mind the special needs of those residents who experience levels higher than $L_{eq(8)}$ at 70 on their jobs." The $L_{eq(24)}$ for a worker exposed to 90 dB for 8 hours, and one of the exposures listed in Table VI-3, equals 88.8 dB.

The effect of noise on hearing is cumulative over the years. To decide whether a particular product is a potential hazard, its sound level, usage pattern and additional noise exposure of the person using the product have to be considered. As an example, in the winter a person may drive a snowmobile regularly and have an $L_{eq(24)}$ of 100 dB. In the summer he may sleep near a noisy air conditioner (70 dB), mow his lawn or use a powered tool for one hour (90 dB), and work in a factory (90 dB). His resulting exposure would thus be $L_{eq(24)} = 86$ dB. This is mainly due to the exposure at work. However, if the sound level at work is low, his $L_{eq(24)}$ would be 77 dB, with the main contributions coming from the air conditioner and lawn mower.

From Table IV-2, one could find products having noise levels $\geq$ 100 dB that could conceivably be used nearly every day for an hour. These products are obviously, by themselves, hazardous (e.g., many powered tools). There are more noisy products that are not hazards in themselves. It is the general level of noisiness of many consumer products and their variety, prevalence, and impact that constitute the danger to the hearing of the population. Any product whose sound level and usage exceed that in Table VI-2 could contribute to degradation of the hearing of its users. Any product whose sound level and usage exceeds those specified in Table VI-3 contributes more seriously to the degradation of hearing of its users. However, any product whose sound level is greater than 70 dB has the potential to impair hearing if used over a period of sufficient length. These conclusions are inferred from the EPA Levels Document.

References

1. U.S. Environmental Protection Agency, "Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare with an Adequate Margin of Safety," 550/9-74-004, March 1974.
2. U.S. Department of Health, Education and Welfare, "Criteria for a Recommended Standard...Occupational Exposure to Noise," 1972.

Table VI-1. Factors to convert the sound level of a consumer product (L_x) to the equivalent sound level for 24 hours [$L_{eq(24)}$] provided that the equivalent exposure for the remainder of the day, L_b, is at least 12 dB below the derived $L_{eq(24)}$.

Duration of L_x, hours	$L_x - L_{eq(24)}$, dB
0.5	17
1	14
2	11
4	8

Table VI-2. Product noise exposures that do not exceed those protective of the public health and welfare, provided the equivalent sound level for the remainder of the day $\leq$ 58 dB. Increased exposure could cause hearing loss.

Exposure Duration, hours	Exposure Sound Level, dB
0.5	87
1	84
2	81
4	78

Table VI-3. Product noise exposures that, with daily use over many years for a large percentage of the population, would cause no more than a 10-dB increase in hearing level averaged for 500, 1000 and 2000 Hz provided the equivalent sound level for the rest of the day $\leq$ 74 dB. Increased exposure could cause more hearing loss.

Exposure Duration, hours	Exposure Sound Level, dB
0.5	103
1	100
2	97
4	94

CHAPTER VII

TOWARD A UNIFIED SET OF NOISE REGULATIONS

In the Introduction it was pointed out that conflict in the regulation of the sound output of consumer products could arise because of different mandates from Congress to the agencies of the Federal Government concerned with noise. A brief summary of the pertinent parts of these mandates would serve to clarify the issue.

The purposes of the Consumer Product Safety Act[1] are:

(1) to protect the public against unreasonable risks of injury associated with consumer products;

(2) to assist consumers in evaluating the comparative safety of consumer products;

(3) to develop uniform safety standards for consumer products and to minimize conflicting state and local regulations; and

(4) to promote research and investigation into the causes and prevention of product-related deaths, illnesses, and injuries.

In Sec. 31 of this Act it says "The Commission shall have no authority under this Act to regulate any risk of injury associated with a consumer product if such risk could be eliminated or reduced to a sufficient extent by actions taken under the Occupational Safety and Health Act of 1970."

The purpose of the Occupational Safety and Health Act of 1970[2] is ".. to assure as far as possible every working man and woman in the nation safe and healthful working conditions."

As expressed in the Noise Control Act of 1972,[3] it is the policy of the United States to promote an environment for all Americans free from noise that jeopardizes their health and welfare. This is to be done by coordinating Federal effort in noise control, establishing noise emission standards for products distributed in commerce; and providing information to the public respecting the noise emission and noise reduction characteristics of such products. The Environmental Protection Agency has the main responsibility for implementing this act.

Many products used by consumers could also be used in industry; e.g., lawn mowers, power tools, snowmobiles. Their noise emissions affect not only the operator but also the outdoor environment. The noise emission of these and other products could be regulated by EPA, OSHA and CPSC, all from somewhat different points of view. For mobile sources, EPA at present is primarily concerned with the environment and emphasizes measurements of noise levels at 50 ft from the source. However, noise levels which protect the community at a criterion of 50 ft may still be unsafe at the operator's ear. The present OSHA regulations deal with noise exposure in a working environment, usually the result of many noise sources in the same room. Usually consumers are exposed to one noise source at a time. Thus, three incompatible standards for a single product could result from the differing regulatory interests of these agencies.

Another type of problem could occur as a result of differing priorities. Recently, the EPA identified products as major sources of noise.[4] Highest priority was given to sources that contribute to community noise exposure. So far only two products have been identified; medium and heavy-duty trucks and portable air compressors. It appears as though CPSC will be in a position to set standards for products of mutual interest to EPA, much before EPA will be ready to consider them.

Another problem is the procedure for summing noise exposures. The OSHA Act uses a 5-dB rule for relating exposure level and time. That is, an exposure of 90 dB (A-weighted) for 8 hours is considered equivalent to 95 dB, A-weighted, for 4 hours or 100 dB, A-weighted, for 2 hours. This is in contrast to the Equal Energy Hypothesis which is equivalent to a 3-dB rule for relating exposure level and time. That is, 90 dB, A-weighted, for 8 hours is considered equivalent to 93 dB, A-weighted, for 4 hours.

Resolution of these conflicts requires legal, administrative, and scientific judgments.

In order to begin the necessary communication between EPA and CPSC, a letter was written to the Deputy Assistant Administrator for Noise Control Programs, Office of Noise Abatement and Control, Environmental

Protection Agency. This letter stated the interest which the Consumer Product Safety Commission has in establishing safe noise levels for consumer products, and the Commission's concern about a uniform set of noise standards for the Federal Government, particularly with respect to those products that both EPA and CPSC would regulate.

As a result, communication at the working technical level was immediately established. This enabled us to keep informed of ONAC's program and latest publications. A significant portion of this report is based on information from ONAC's technical publications.

Also, a meeting between CPSC and EPA representatives was recently held. The areas of standard setting, labeling and state/local interface were identified as ones for high level discussions for the purpose of developing agreements. Similar future meetings with CPSC, OSHA and EPA could resolve any OSHA-CPSC overlap.

Of equal importance would be the establishment of a formal procedure for the regular exchange of information among EPA, OSHA, NIOSH and CPSC regarding their activities in noise control. This could take the form of periodically circulating lists of publications, grants and contracts proposed and awarded, standards under consideration, etc. Duplication would be avoided and each agency would have the benefit of the others' resources. For example, the EPA has recently awarded a grant for developing improved criteria for verbal communication in noise. This procedure has been followed successfully by the Office of Naval Research, Army Ordnance Research Office, and Air Force Office of Scientific Research and others in the area of research and development grants and contracts.

On a scientific basis both EPA and CPSC could be in fundamental agreement since the critical levels of human exposure to noise reported here (see Chapters II and VI) come from those published by ONAC.[5] In regulating a mobile source that is used outdoors, measurements should be made of the sound levels at the operator's ear and at a reference distance to the side of the vehicle, so that one standard could satisfy both community and consumer needs.

References

1. Consumer Product Safety Act, Public Law 92-573, 1972.

2. Occupational Safety and Health Act of 1970, Public Law 91-596.

3. Noise Control Act of 1972, Public Law 92-574.

4. Identification of Products as Major Sources of Noise, Federal Register 39, 22297-22299, June 21, 1974.

5. Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare with an Adequate Margin of Safety, U.S. Environmental Protection Agency, Office of Noise Abatement and Control, March, 1974.

APPENDIX

PUBLISHED STANDARDS RELEVANT TO REGULATION OF SOUND OUTPUT OF CONSUMER PRODUCTS

These standards fall into one or more of the following categories:

1. Principles of measurement of noise,

2. Procedure for determining sound power output of stationary sources,

3. Principles for preparation of test codes for measurement of noise emitted by machines,

4. Industrial procedures for determining sound levels produced by specific types of sound sources,

5. Specifications for acoustical measuring equipment, and

6. Procedures for measuring speech intelligibility.

Addresses of the organizations from which these standards can be obtained appear at the end of the list of standards.

International Organization for Standardization (ISO)

ISO Recommendation R362. Measurement of Noise Emitted by Vehicles (1964).

ISO Recommendation R495. General Requirements for the Preparation of Test Codes for Measuring the Noise Emitted by Machines (1966).

ISO Recommendation R2204. Guide to the Measurement of Acoustical Noise and Evaluation of Its Effect on Man.

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Air Moving and Conditioning Association (AMCA)
30 West University Drive
Arlington Heights, Illinois 60004

Association of Home Appliance Manufacturers (AHAM)
20 North Wacker Drive
Chicago, Illinois 60606

National Machine Tool Builders Association (NMTBA)
7901 West Park Drive
McLean, Virginia 22101

Power Saw Manufacturers Association (PSMA)
734 15th Street, N.W.
Washington, D.C. 20005

Military Specifications
Commanding Officer
Naval Publications and Forms Center
5801 Tabor Avenue
Philadelphia, Pennsylvania 19120

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5205 Leesburg Pike
Falls Church, Virginia 22041

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San Dimas, California 91773

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GLOSSARY

A-WEIGHTED SOUND LEVEL. See SOUND LEVEL.

ACOUSTIC REFLEX. The involuntary contraction of the muscles (stapedius and/or tensor tympani) of the middle ear in response to acoustic or mechanical stimuli.

AMBIENT NOISE. The all-encompassing noise associated with a given environment, being usually a composite of sounds from many sources near and far.

ARTICULATION INDEX (AI). A numerically calculated measure of the intelligibility of transmitted or processed speech. It takes into account the limitations of the transmission path and the background noise. The articulation index can range in magnitude between 0 and 1.0. If the AI is less than 0.1, speech intelligibility is generally low. If it is above 0.6, speech intelligibility is generally high. See ANSI S3.5-1969.

BROAD-BAND NOISE. Noise whose energy is distributed over a broad range of frequency (generally speaking, more than one octave).

BACKGROUND NOISE. The total of all noise interference in a system used for the production, detection, measurement, or recording of a signal, independent of the presence of the signal.

CONNECTED (CONTINUOUS) DISCOURSE. Continuous speech usually spoken with little variation in intensity (or rapidity) and generally presented by one speaker reading from several paragraphs of written material having little emotional appeal or interest value.

DECIBEL. One tenth of a bel. Thus, the decibel is a unit of level when the base of the logarithm is the tenth root of ten, and the quantities concerned are proportional to power.

Note 1: Examples of quantities that qualify are power (any form), sound pressure squared, particle velocity squared, sound intensity, sound-energy density, voltage squared. Thus the decibel is a unit of sound-pressure-squared level; it is common practice, however, to shorten this to sound pressure level because ordinarily no ambiguity results from so doing.

Note 2: The logarithm to the base the tenth root of 10 is the same as ten times the logarithm to the base 10: e.g., for a number X^2, $\log_{10^{1/10}} X^2 = 10 \log_{10} X^2 = 20 \log_{10}$. This last relationship is the one ordinarily used to simplify the language in definitions of sound pressure level, etc.

DOSE. The summed exposure (to sound) over a period of time.

EQUAL ENERGY HYPOTHESIS. Equal amounts of sound energy will cause equal amounts of noise induced permanent threshold shift regardless of the distribution of energy across time.

EQUIVALENT SOUND LEVEL. The level of a constant sound which, in a given situation and time period, has the same sound energy as does a time-varying sound. Technically, equivalent sound level is the level of the time-weighted, mean square, A-weighted sound pressure. The time interval over which the measurement is taken should always be specified.

HEARING CONSERVATION. Those measures which are taken to reduce the risk of noise-induced hearing loss.

HEARING LEVEL (HEARING LOSS, HEARING-THRESHOLD LEVEL). The amount, in decibels, at a specified frequency by which the threshold of audibility for that ear exceeds a standard audiometric threshold.

INVERSE SQUARE LAW. In a free field (no reflections) the intensity of a point source of sound decreases inversely with the square of the distance from the source.

LEVEL. The logarithm of the ratio of a quantity to a reference quantity of the same kind. The base of the logarithm, the reference quantity, and the kind of level must be specified.

MASKING. The process by which the threshold of audibility for one sound is raised by the presence of another (masking) sound. Masking as a generic term refers to the reduction in performance to one sound as a result of the introduction of a second sound. Reduction in performance may be expressed as a shift in threshold acuity but also, by extension, as reduced speech reception...and so forth, whenever the signal to be responded to is admixed with some other sound in a more or less favorable ratio.

NARROW-BAND NOISE. A relative term describing the pass-band of a filter or the spectral distribution of a noise. Note: The term frequently implies a bandwidth of 1/3 octave or less (cf. Broad-band noise).

NOISE. Any undesired sound. By extension, noise is any unwanted disturbance within a useful frequency band, such as undesired electric waves in a transmission channel or device. Noise is an erratic, intermittent, or statistically random oscillation.

Note 1: If ambiguity exists as to the nature of the noise, a phrase such as "acoustic noise" or "electric noise" should be used.

Note 2: Since the above definitions are not mutually exclusive, it is usually necessary to depend upon context for the distinction.

NOISE EXPOSURE. The cumulative acoustic stimulation reaching the ear of the person over a specified period of time (e.g., a work shift, a day, a working life, or a lifetime).

NOISE EXPOSURE PATTERN. The various sound intensities and their durations that may be encountered throughout daily living.

NOISE-INDUCED HEARING LOSS. (Noise-Induced Permanent Threshold Shift.) The cumulative permanent hearing loss that is due to repeated exposure to intense noise.

NOISE-TIME FRACTION. The fraction of time that a noise is presented during a given time period.

OCTAVE. The interval between two sounds having a basic frequency ratio of two. Note: The interval in octaves, between any two frequencies, is the logarithm to the base 2 of the frequency ratio.

PEAK SOUND PRESSURE. The maximum absolute value of the instantaneous sound pressure in that interval. Note: In the case of a periodic wave, if the time interval considered is a complete period, the peak sound pressure becomes identical with the maximum sound pressure.

PHONETICALLY BALANCED WORD LIST. A list that includes words containing a distribution of speech sounds that approximates the distribution of the same sounds as they occur in conversational American English.

RANDOM NOISE. An oscillation whose instantaneous magnitude is not specified for any given instant of time. The instantaneous magnitudes of a random noise are specified only by probability distribution functions giving the fraction of the total time that the magnitude, or some sequence of magnitudes, lies within a specified range. Note: A random noise whose instantaneous magnitudes occur according to the Gaussian distribution is called "Gaussian random noise."

REVERBERANT FIELD. In an average enclosed room close to the sound source the sound-pressure level tends to vary with the distance from the source as it does under free-field conditions. This region is sometimes called the near field. Far from the source the sound-pressure level becomes independent of the directivity and the distance to the source. This region is called the reverberant or far field. Here the level is determined by the acoustic power radiated by the source and the acoustic characteristics of the room. The region over which the transition between the free-field behavior and the reverberant field occurs is determined by the directivity factor and the room constant.

SOUND. An oscillation in pressure, stress, particle displacement, particle velocity, etc., in a medium with internal forces (e.g., elastic, viscous), or the superposition of such propagated oscillations. Sound is an auditory sensation evoked by the oscillation described above.

SOUND INTENSITY (SOUND-ENERGY FLUX DENSITY) (SOUND-POWER DENSITY). In a specified direction at a particular point, the average rate of sound energy transmitted in the specified direction through a unit area normal to this direction at the point considered.

Note 1: The sound intensity in any specified direction, a, of a sound field is the sound-energy flux through a unit area normal to that direction. This is given by the expression

$$I_a = \frac{1}{T} \int_0^T p v_a \, dt$$

where

T = an integral number of periods or a time long compared to a period

p = the instantaneous sound pressure

v_a = the component of the instantaneous particle velocity in the direction a

t = time.

Note 2: In the case of a free plane or spherical wave having the effective sound pressure, p, the velocity of propagation, c, in a medium of density, ρ, the intensity in the direction of propagation is given by:

$$I = \frac{p^2}{\rho c} .$$

SOUND LEVEL. A weighted sound pressure level, obtained by the use of metering characteristics specified in ANS Standard Specification for General Purpose Sound Level Meters, S1.4-1961. In this report only A-weighted sound level is used. The ear does not respond equally to frequencies, but is less sensitive at low and high frequencies than it is at middle or speech-range frequencies. The A-weighted network weights the sound frequencies approximately as the ear does at medium sound pressure levels.

SOUND PRESSURE LEVEL. Sound pressure level, in decibels, of a sound is 20 times the logarithm to the base 10 of the ratio of the pressure of this sound to the reference pressure. The reference pressure should be explicitly stated.

Note 1: The standard reference pressure is 20 micropascals per square meter for sound in gases and is the reference pressure used in this report.

Note 2: Unless otherwise explicitly stated, it is to be understood that the sound pressure is the effective (root-mean-square) sound pressure.

SPECTRUM. A description of the resolution of a function of time into components, each of different frequency and (usually) different amplitude and phase. "Spectrum" is also used to signify a continuous range of components, usually wide in extent, within which waves have some specified common characteristic; e.g., "audio-frequency spectrum."

THRESHOLD OF AUDIBILITY. The minimum effective sound pressure level of a signal that evokes an auditory sensation in a specified fraction of the trials.

THRESHOLD OF FEELING (or Tickle). The minimum sound pressure level at the entrance to the external auditory canal which, in a specified fraction of the trials, will stimulate the ear to a point at which there is a sensation of feeling that is different from the sensation of hearing.

THRESHOLD OF DISCOMFORT. The minimum effective sound pressure level of that signal which, in a specified fraction of the trials, will stimulate the ear to a point at which the sensation of feeling becomes uncomfortable.

THRESHOLD OF PAIN. The minimum effective sound pressure level of that signal which, in a specified fraction of the trials, will stimulate the ear to a point at which the discomfort gives way to definite pain that is distinct from mere non-noxious feeling of discomfort.

WHITE NOISE. A noise whose spectrum density (or spectrum level) is substantially independent of frequency over a specified range. Note: White noise need not be random.

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16. ABSTRACT *(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.)*

The Consumer Product Safety Commission is charged with the responsibility for promulgating safety standards to protect the public against unreasonable risks of injury associated with consumer products. There is a risk of injury from noisy products, directly by damage to hearing and indirectly by degradation of essential speech communication. This report develops criteria relevant to the specification of Safety Standards for noisy consumer products. Consumer product noise is discussed in relation to the existing body of knowledge regarding noise induced hearing loss and speech communication. Levels of product noise are identified that should protect against hearing impairment and against speech communication degradation. Methods of measurement for consumer product noise are described and a bibliography of standards relevant to the regulation of noisy consumer products is provided. A list of products that are potentially hazardous to the hearing of the operator is included with typical levels and usage patterns. The list is based upon reported data and some measurements made at NBS. Possible discrepancies among noise regulations established by different governmental agencies are discussed with suggestions for obtaining uniformity.

17. KEY WORDS *(six to twelve entries; alphabetical order; capitalize only the first letter of the first key word unless a proper name; separated by semicolons)*

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