Information Circular 8564

Hearing Conservation for the Mineral Industry

By Raymond Derzay
Denver Technical Support Center, Denver, Colo.

UNITED STATES DEPARTMENT OF THE INTERIOR
Rogers C. B. Morton, Secretary

BUREAU OF MINES
Elburt F. Osborn, Director

This publication has been cataloged as follows:

Derzay, Raymond C

Hearing conservation for the mineral industry. [Washington] U.S. Dept. of the Interior, Bureau of Mines [1972]

42p. illus., tables. (U.S. Bureau of Mines. Information circular 8564)

Includes bibliography.

1. Hearing. 2. Noise control. 3. Noise–Physiological effect. 4. Mineral industries–Safety measures. I. Title. (Series)

TN23.U71 no. 8564 622.06173

U.S. Dept. of the Int. Library

CONTENTS

ILLUSTRATIONS

TABLES

HEARING CONSERVATION FOR THE MINERAL INDUSTRY

by

Raymond Derzay[1]

ABSTRACT

This publication is intended to be of value to the mineral industry in establishing and maintaining effective programs for preventing noise-induced hearing loss. Factors involved in this loss and the need for and the requirements of an effective hearing conservation program are discussed. The legal and legislative history of compensation for hearing loss is briefly reviewed.

A review of statutes is not attempted since several States have recently modified, or are in the process of modifying their laws regarding permissible noise exposures, required hearing protection, and/or compensation for hearing loss.

A review of other aspects of the problem of industrial noise in terms of medical, physiological, and psychological frames of reference is included. A hearing conservation program is described in detail.

Appendixes detailing the names and addresses of a few equipment suppliers are included. References are provided for those who may wish to delve more deeply into the medical, technical, and scientific considerations of noise and its effect on man.

INTRODUCTION

Noise, like other forms of pollution in the environment, has reached a level of national and international importance and public concern. Many have long considered it an inevitable byproduct of modernization. While it has been recognized for more than 100 years that workers in noisy occupations develop a greater than average decrease in hearing sensitivity, the concern over excessive noise in industrial environments has increased significantly only in the past few years. Part of this concern stems from the recognition that pollution of any type may be damaging to individual welfare. Some authorities feel that excessive noise causes not only hearing damage, but may also cause or contribute to physiological and psychological damage as well.

---

[1] Mining engineer

The concern about noise has resulted in various actions to control it. Perhaps most far-reaching in effect as well as most publicized is the noise standard contained within the Department of Labor Occupational Safety and Health Act of 1970, previously referred to as the "Walsh-Healey noise standard." The Departments of Transportation (DOT) and Housing and Urban Development (HUD) as well as several cities are working to reduce aircraft noise. DOT has established an Office of Noise Abatement. HUD and the Federal Housing Administration sponsor research in architectural acoustics and control. The Department of Defense, long interested in the effects and control of noise, continues to conduct research. The Environmental Protection Agency has conducted hearings on noise pollution covering agriculture, recreation, transportation, urban noise problems and social behavior, psychological and physiological effects, and other facets of the problem. Various cities have legislated traffic noise limits.

A survey conducted in 1969 of operations considered typical of mines, mills, and shops across the Nation, in coal and noncoal plants, indicated that a significant number of men in the industry are excessively exposed to noise when compared with presently accepted standards.

Our efforts in the Bureau of Mines are directed toward accomplishing two goals. They are: (1) zero hearing loss due to exposure to industrial noise, and (2) work environments controlled through engineering techniques so that men eventually will not need to wear hearing protection devices while performing their work. Unquestionably, years of effort will be required to achieve these goals, notably the second. However, with time and persistent effort, they can be achieved.

THE TECHNICAL PROBLEM

Background

General

Hearing loss is an affliction which has existed throughout the history of man. It occurs in all walks of life and has many causes. Hearing problems received little attention in past years because there was no means of measuring hearing acuity with any degree of accuracy until the development of the audiometer within the past 30 years. The partial losses which constitute minimal handicap or disability, and which are predominant in the total picture, were seldom recognized (2, 23).[2]

Attention was focused on the effects of noise on human behavior during the Second World War and following it. Significant research was done as a result of the industrial revolution and resultant increase of the number of persons exposed to intense noise, both in industry and in the military forces.

[2] Underlined numbers in parentheses refer to items in the list of references preceding the appendixes.

Workmen's Compensation

Hearing loss, either partial or total, was not regarded as a significant factor in workmen's compensation prior to 1948. Some claims occurred, but these were primarily of traumatic origin, such as from concussive blasts or blows to the head.

Legislative precedents occurring between 1948 and 1959 changed the situation. The first of these was the case of Slawinski versus Williams & Co., New York, in 1948. The New York Workmen's Compensation Board ruled that Slawinski was entitled to a scheduled award for partial loss of hearing, even though he had not been disabled from earning full wages at his usual employment. The ruling was upheld by the State Supreme Court and by the Court of Appeals.

Similar cases and decisions occurred in the following cases: Wojcik versus Green Bay Drop Forge Co., Wisconsin; Marie versus Standard Steel Works, Missouri; Shipman versus Lockheed Aircraft, Georgia; and The Longshoreman's precedent, Travelers Insurance Co., Todd Shipyards, and others versus Cardillo. Exceptions to the pattern indicated are found in two 1959 cases in Maryland, Vinson versus Bethlehem Steel Co., and Telschuer versus Anchor Post Products. In both cases the courts held that no compensation can be paid as long as the claimant is not actually prevented from doing his work and suffers no wage loss. In June 1967, the statutes of Maryland were changed, making noise-induced hearing loss compensable and establishing provisions for claims.

In essence, workmen's compensation laws hold that industrial employers should assume costs of occupational disabilities without regard to any fault involved (13). The laws serve to relieve employers of liability from common-law suits involving negligence.

Prior to 1950, occupational loss of hearing was not viewed as a significant problem in workmen's compensation because of two major factors. First, hearing loss is not an affliction specific to industrial exposures. Second, seldom does hearing loss result in loss of wages or earning capacity, and disability schedules in the various workmen's compensation laws had been considered applicable only to accidental injuries.

The workmen's compensation laws of all 50 States make traumatic (caused by an incident which ruptures the eardrum) hearing loss compensable. Noise-induced hearing loss is allowed as a compensable disability by at least 36 States.

When the much-publicized decisions in New York and Wisconsin interjected noise-induced hearing loss into the compensation picture, fears were expressed that the result would be a deluge of claims with possible catastrophic effects upon the economic stability of some segments of industry. Predictions were made of possible costs running into billions.

Claims have not been as numerous as once was expected, because standards have been adopted which discourage the filing of claims by persons whose hearing is within average normal limits of variability and who have no actual handicap or impairment. Another roadblock to filing of claims is the fairly common provision requiring 6 months' absenteeism from a noisy environment. Few workers can afford to quit work for 6 months to make themselves eligible to file for compensation and few companies will transfer employees to quiet jobs for 6 months.

The median possible awards for noise-induced hearing loss under the various workmen's compensation laws are $2,700 for one ear and $8,500 for both ears. Most state jurisdictions make no provision for loss of hearing due to aging; at least 11 do, if medical testimony indicates its presence; and at least seven States automatically assume that it accompanies age and provide a schedule, usually starting at age 40.

Department of Labor

Public Law 91-596, dated December 29, 1970, "Occupational Safety and Health Act of 1970," promulgated by the Department of Labor, provides hearing standards precisely as in the Walsh-Healey Public Contracts Act.[3] The only effective change regarding this standard is to include essentially all occupations not otherwise included by other governmental agencies (31). The Department of Labor hearing standards require engineering control of noise levels or exposures and hearing protection where noise exposures are excessive even after feasible engineering controls have been instituted. Preemployment and periodic audiometric testing of personnel whose exposure to noise exceeds that of the recommended standards is urged (30). Use of earplugs, muffs, or other hearing protective devices, while desirable and in many instances the only practical way of conserving hearing, will not cancel the need for audiometry on an annual or more frequent basis.

Physical Characteristics of Sound

The unit for measuring sound intensity or pressure is the decibel. This is a relative term which, unlike the inch or pound, has no absolute value. It simply is a ratio between two sound pressure levels. A measured sound of 60 decibels means that the sound is 60 decibels (dB) above a standard zero reference level. The measurement has no meaning unless the reference is either stated or implied. The zero reference level used in acoustical measurements, 0.0002 dynes per square centimeter or 0.0002 microbar, represents approximately the faintest sound that can be heard by ears with acute hearing.

[3] The Walsh-Healey Public Contracts Act, U.S. Department of Labor, was enacted in 1936 to establish and promote safety and health conditions for employees of contractors doing at least $10,000 worth of sales or $2,500 of services per year with the U.S. Government. The Occupational Safety and Health Act of 1970 is essentially an expansion of the Walsh-Healey Act concept into virtually every worker environment in every State and the District of Columbia except those employments in the jurisdiction of other Federal agencies, such as the mineral industry, or State agencies. The Occupational Safety and Health Act of 1970 supersedes and replaces the Walsh-Healey Act.

The decibel is a logarithmic rather than a linear ratio. Each 20 decibel increase in the sound pressure level represents a tenfold increase in sound pressure and a hundredfold increase in sound energy. Sound with a pressure level of 120 dB represents 10^6 (one million) times the pressure at the standard zero reference level. From the foregoing comments, it should be apparent that decibels cannot be added arithmetically. For example, if a motor producing 90 dB of noise is placed adjacent to another producing 90 dB, the total noise level would not be 180 dB--rather it would be 93 dB. Figure 1 can be used as an aid to add decibels. To further illustrate the point, if two noises, one 97 dB and the other 95 dB, are added, they total a sound pressure of 99.2 dB.

Another important characteristic of noise is frequency. Frequency describes the rate of vibrations of the sound wave and is expressed in terms of cycles per second (cps). The term Hertz (Hz) has been adopted in lieu of cycles per second. For purposes of analysis, the frequency domain is divided into octave bands, which is a geometric grouping. To designate an octave band, we refer to its geometric mean frequency, which is equal to 1.414 times the low frequency, or 0.707 times the high frequency of a band. Current, preferred, octave bands start at 1,000 Hz and extend up and down in frequency. Other octave groupings have been used in the past and were designated by their upper and lower limits, as the 1,200 to 2,400 octave band.

How We Hear

To understand how we lose our hearing from exposure to excessive noise requires a knowledge of how we hear. This review of how we hear was excerpted

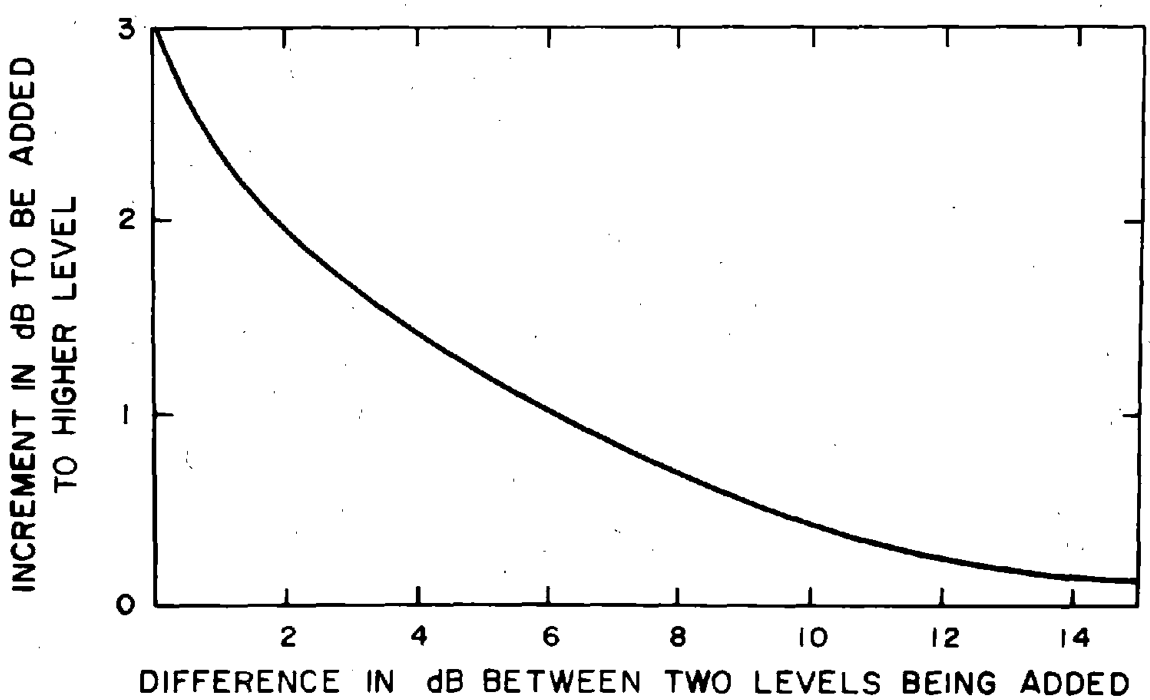

FIGURE 1. - Combining Decibels.

principally from a talk by Dr. J. Sataloff (27) and partly from the American Industrial Hygiene Association Industrial Noise Manual (1).

The process of hearing is one of converting the energy of sound waves in air to neural impulses which are interpreted by the brain. This involves the three following stages: Changing wave motion in air to mechanical vibration, changing the mechanical vibration to wave motion in fluid, and changing the motion in fluid to neural impulses.

The ear canal, usually about 1-1/8 inches long, ends at the ear drum. The wax and hairs present in the outer half of the canal are protective features to prevent injury occurring to the more tender and sensitive parts of the ear which lie beyond. Insects and dust thus are caught by the hairs and sticky wax before they can reach the eardrum.

The shape of the canal is usually oval and the majority are in the range of 5 to 11 mm in diameter. A person's two ear canals are not necessarily similar in size, shape, or position, and there is no apparent correlation to the size and shape of the external ear. The canal ends at the eardrum. The eardrum is about half the diameter of a dime, 9 to 10 mm, and is semitransparent. The eardrum vibrates in response to sound wave stimuli somewhat like the top of a bass drum, but with one outstanding difference. When the bass drum is struck the membrane continues to vibrate for a time after the actual striking; the eardrum, however, stops vibrating practically immediately after the sound waves cease. The vibration displacement of the eardrum is less than the diameter of a hydrogen molecule.

Beyond the eardrum is the middle ear, which is a cavity containing air and three bones linked in series. The first of these, the malleus, is attached to the eardrum so intimately that the slightest motion of the eardrum is perceived and transmitted through the series. The second bone is the incus, and the third is the stapes; the latter is U-shaped as a stirrup. The bottom of the stapes fits exactly into a hole in the bone that marks the outer boundary of the inner ear. The stapes is attached to this window by an elastic membrane around its edge and the motion of the series of bones terminates in an in-out vibration of the stapes.

The area of the window to the inner ear is about 1/20 that of the eardrum, so that sound signals are intensified 20 times from the eardrum to the fluid-filled inner ear.

Two muscles in the middle ear act to damp very intense noises, the tensor tympani attached to the eardrum and the stapedius attached to the stapes. Studies have shown that these muscles become taut with loud noises, primarily those below 1,000 Hz. The amount of contraction is much less with moderately loud noises than with very loud noises. While these muscles probably have a very important role in conserving hearing when loud noises last only a short time, their effectiveness will diminish with prolonged exposure. The action is too slow to be effective against sudden, transient sounds.

The middle ear also contains the opening for the eustachian tube which terminates in the nasopharynx. This tube is constructed with a valvelike action that permits air to readily pass from the middle ear, but restricts the ready flow of air to the middle ear. Thus the eustachian tube permits equalization of air pressure on both sides of the eardrum.

The oval window through which the stapes transmits sound energy to the inner ear opens into the cochlear canal. Shaped like a snail's shell, this canal makes 2-3/4 turns around a central pillar, the modiolus. The bony canal consists of three galleries which, from the top downward, are the scala vestibuli, the scala media, and the scala tympani. Within the scala media exists the sensitive hearing mechanism, the organ of Corti. This organ contains essential sensory elements, the hair cells, which total some 20,000. The free surface of each hair cell is surmounted by about 20 hairlike processes. The physical damage caused by excessive noise occurs at these hair cells. The mechanical vibration of the base of the stapes in the oval window sets up wave motion in the fluid. As this wave motion traverses the scala vestibuli, it exerts pressure upon the minute hair cells distributed along the basilar membrane. The hair cells respond selectively by frequency to the fluid waves within the inner ear. While the hair cells at the base of the cochlea respond to the highest frequency, those nearest the apex respond to a lower frequency.

The neural impulses generated in the hair cells of the organ of Corti are collected by five arborizations of the cochlear division of the eighth nerve. These impulses are transmitted through the central connections of the nerve to the cortex, where the various phenomena associated with sound are interpreted.

The range of sounds which the ear can hear is limited. The extreme range of audible frequencies, usually found in young persons, is from 16 to almost 20,000 Hz. Certain of these frequencies are perceived at lower intensities than others. From 16 to about 1,000 Hz requires progressively less intensity for a tone to become audible. From 1,000 to 4,000 Hz the ear's response is fairly constant. From about 4,000 Hz to higher frequencies the trend reverses and a progressively greater intensity is again required to make the tone audible. Thus, we obtain a curve of hearing, or of auditory sensitivity, with the most sensitive hearing where we need it for the hearing of speech.

The human ear is not sensitive to frequencies in the ultrasonic range and, therefore, the ear probably is not damaged substantially by sound waves in these frequencies.

When sound levels reach 100 to 120 dB (zero reference is 0.0002 microbar) in the normal ear, the listener describes the sound as uncomfortable, and around 130 to 140 dB actual pain results. This tolerance threshold does not vary markedly with frequency, although higher frequencies often seem more unpleasant than lower frequencies of equal pressures. Auditory damage can be produced by sustained exposure to sound of sufficient intensity without noticeable pain or discomfort.

Effects of Noise Exposure

Sudden noises of high intensity as from an explosion may produce severe damage to the structures of the middle and inner ear. The eardrum may be ruptured and the continuity of the ossicular chain may be destroyed. The sensorineural effects of acoustic trauma usually do not stabilize for several months. During this time the auditory threshold level may increase or decrease (1).

Noise levels less than those causing acoustic trauma can also produce hearing loss if the exposure is of sufficient intensity and duration. The pathology is not precisely understood; apparently a degeneration process of the hair cells occurs. The changes are restricted to the receptor mechanism of the inner ear; the middle ear and central pathways are in no way affected. Once the hair cell in the inner ear is damaged, there is no way to reverse the process (1).

Overexposure to steady noise may initially produce a temporary diminution of the ability to detect weak auditory signals. This is termed temporary threshold shift (TTS). If the exposure is continued, then noise-induced permanent threshold shift will occur (NIPTS) (32).

The usual case first shows the greatest hearing loss (increase in auditory threshold) at 4,000 Hz but it may be found anywhere between 2,000 and 6,000 Hz. The increase in threshold level then spreads to the adjacent frequencies. Intensive studies of permanent and temporary threshold shift have shown that, if the exposure remains constant, the threshold shift at 4,000 Hz reaches a maximum level in about 10 years with the usual industrial exposures. Unfortunately, this is not true for the frequencies below 3,000 Hz, at least under the conditions imposed by most industrial noises. At these frequencies, no maximum is reached, and the threshold levels continue to rise as long as the exposure continues (33).

Other effects may take the form of interference with spoken communications or other audible signals, psychological reactions and/or physiological reactions in addition to possible deterioration of hearing acuity. No two persons react to sound energy identically, anymore than they are identical in other human characteristics. Also, a person may react quite differently at different times (1, 33).

Hearing Standards Criteria

To establish any clearcut distinction between safe and unsafe noise exposures is unfeasible for the individual himself. Variables which complicate the situation include differences in individual susceptibility, the consideration of whether to conserve the entire audible spectrum or only the speech frequencies, and how much loss of hearing constitutes impairment (1, 10, 21, 32).

It is generally agreed that the inability to hear and understand normal speech constitutes the best measure of auditory impairment. Few people complain of a hearing problem until they have difficulty understanding spoken words.

Speech ranges in frequency from 300 to 4,000 Hz, but to obtain speech intelligibility, not all the frequencies need be heard, because everyday speech contains much redundancy. Investigations indicated that when the loss of hearing of the average of the 500, 1,000, and 2,000 Hz octaves is less than 25 dB, speech is intelligible. This is the present basis for compensation for loss of hearing. Hearing impairment, then, can be said to exist when the average of the hearing levels at 500, 1,000, and 2,000 Hz exceeds 25 dB as measured from ISO[4] or present ANSI[5] reference level. Some sources believe that more work in this area should be performed; possibly the 500 octave is not as important as presently believed, while the 3,000 octave is more important, particularly with some interferring background sounds present (personal communication, Herbert Jones, National Institute of Occupational Safety and Health, Cincinnati, Ohio). When the average of the hearing levels at the three octaves is 92 dB, hearing loss is total.

Since individuals respond somewhat variously to noxious stimulants, criteria that would prevent impairment in the highly susceptible would be conservative for another. Threshold limit values, listed in table 1, represent conditions under which it is believed that nearly all workers may be repeatedly exposed day after day without adverse effect. Because wide variations in individual susceptibility do exist, exposure of an occasional individual at or even below the recommended limit values may not prevent damage to his hearing. Thus, the exposure data should be used as guides and not as fine lines between safe and dangerous levels of exposures.

TABLE 1. - Permissible noise exposures

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

Note.--115 dBA is the ceiling value; no exposure should exceed this pressure level.

The recommended maximum noise exposures, for an 8-hour day, permits increasing the exposures by 5 dB for each halving of time. For impulsive or impact noises the peak sound pressure should not exceed 140 dB.

[4] ISO is the International Organization for Standardization of which the United States is a member. Reference is to "Standard Reference Zero for the Calibration of Pure Tone Audiometers," ISO Recommendation 389-1964.

[5] ANSI is American National Standards Institute; formerly USASI; also ASA. Reference is to "Specifications for Audiometers," ANSI standard S3.6-1969.

The hazard criteria of the Intersociety Committee, American Conference of Governmental Industrial Hygienists and the Department of Labor Occupational Safety and Health Act of 1970, are based on sound pressure levels A-scale, designated dBA (decibels A-scale). The A-scale frequency-weighting corresponds to the sensitivity of the ear, with the attenuation of energy in the upper and lower audible frequencies in a manner similar to that of the ear, with slight amplification in the region where the ear is most sensitive.

The hearing standards criteria was formulated by the Intersociety Committee which is composed of representatives from the American Conference of Governmental Industrial Hygienists, the American Academy of Ophthamology and Otolaryngology, the American Academy of Occupational Medicine, the American Industrial Hygiene Association, and the Industrial Medical Association.

The values listed in table 1 apply to total time of exposure per working day, regardless of whether this is one continuous exposure or a number of short-term exposures, but does not apply to impact or impulsive type noises.

When the daily noise exposure is composed of two or more periods of noise at different levels, their combined effect should be considered, rather than the individual effect of each. If the sum of the fractions

$$\frac{C_1}{T_1} + \frac{C_2}{T_2} + \ldots \frac{C_n}{T_n}$$

exceeds unity, then the mixed exposure should be considered to exceed the threshold limit value. C_1 is the total time of exposure at a specified noise level, and T_1 is the total time of exposure permitted at that level. Noise exposures of less than 90 dBA do not enter into the calculations.

Example 1: A worker during a shift is exposed 2 hours to 97 dBA, 15 minutes to 100 dBA, 3 hours to 92 dBA and the remainder of the shift to less than 90 dBA. Thus,

$$\frac{2}{3} + \frac{1/4}{2} + \frac{3}{6} = \frac{2 \times 2}{6} + \frac{3 \times 1/4}{6} + \frac{3}{6} = \text{more than } 1$$

and exposure is excessive.

Example 2: A worker during a shift is exposed 2 hours to 95 dBA, 1 hour to 92 dBA, 2 hours to 90 dBA and 3 hours to 75 dBA. Thus,

$$\frac{2}{4} + \frac{1}{6} + \frac{2}{8} = \frac{6 \times 2}{24} + \frac{4 \times 1}{24} + \frac{3 \times 2}{24} = \frac{12+4+6}{24} = \frac{22}{24} = \text{less than } 1$$

and exposure is not excessive.

Example 3: A worker during a shift is exposed 3 hours to 90 dBA, 15 minutes to 117 dBA, and the remainder at 80 dBA. Exposure is excessive since 117 dBA is over ceiling limit.

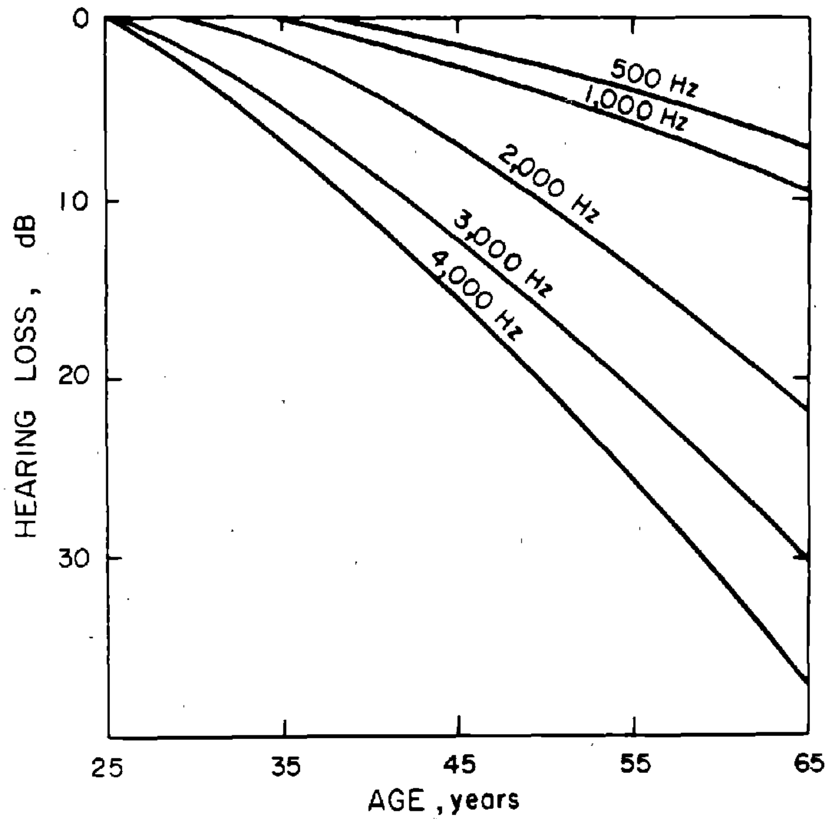

FIGURE 2. - Hearing Loss Progression by Age. (Data from ANSI standard Z 24-X2.)

Age and Nonoccupational Hearing Loss

Presbycusis is a loss of hearing associated in part with the physiological aging process and in part with harmful stresses common in a modern social environment. Presumably, it would proceed at the same rate whether industrial noise were present or not. Figure 2, a composite of three studies, shows the progression of presbycusis for men by octave bands. The greatest loss is in the 4,000 Hz octave; lower octaves indicate progressively less loss (8).

Sociocusis is not dependent on age; instead, it is loss of hearing attributable to noxious influences other than the noise associated with the individual's employment. Hearing loss produced by sporting firearms, chain saws, rock music, or blows to the head would be called sociocusis for those who are not professional hunters, loggers, musicians, or boxers, respectively. While employees' exposure to noise in nonoccupational pursuits may not be a responsibility of management, this type of exposure can have a substantial effect on employees and, in turn, on employers. Some examples of nonmineral industry sound pressure levels are as follows: rock bands, 108 to 114 dBA; power mowers, 95 dBA; motorcycles, 95 dBA; and shooting firearms (impulse noise), to 160 dB.

There are no comprehensive data concerning the number of persons in the total population with some degree of hearing loss. Numerous estimates, based on relatively small samples, have been made. Two of these studies (21) indicating impaired hearing among those not exposed to noise, and of the general population follow:

Percent with impaired hearing		Age group
Nonnoise (2,282 tested)	General population (20,459 tested)	
3	2	20 - 29
5	5	30 - 39
10	14	40 - 49
20	24	50 - 59

Noise Levels in Mining Facilities

Noise surveys made in metal, nonmetal, and coal mines and associated mineral preparation plants and shops indicate that many employees work in an environment of high noise levels. Sound pressure levels measured were as high as 130 dBA. Many levels exceeded 115 dBA, the ceiling value of established criteria. Many workers use equipment which generates excessive noises in various phases of their work cycle.

A total of 68 different sources of noise creating 90 dBA or more have been measured in mines and associated facilities. Of these, four had values of 120 dBA or more, 14 had values of 110 dBA or more, and 40 had values of 100 dBA or more. Drills powered by compressed air are the noisiest of all sources.

Some correlation exists between the amount of noise generated by drills and rock type. The noisier drills were observed in harder rock formations. The dimensions of the section where the driller worked influenced noise levels if the rock were reverberant. Coal apparently is not reverberant--seam thicknesses did not correlate with pressure levels measured. Data obtained in coal mines and washing plants are not included in the tables.

Comparisons of dBA noise levels produced by typical equipment used in different types of mines and ore preparation plants are made in table 2 (15). These data represent measured sound pressure levels of separate operations for several units of a particular item. For example, data on bulldozers ranges from a low of 84 to a high of 107 with a median of 100 dBA. Sound pressure levels of several bulldozers are included in this spread. Conditions of measurement varied, including units with and without cabs, those working in hard rock and in soil, and ranging in size from D-7 to D-9 equivalent. Each phase of the work cycle, such as pushing rock, idling, and backing up, was measured and recorded as discrete data and is part of the noise range tabulated.

Good safety practice precludes riding some equipment, necessitating taking measurements as the equipment moves by and when loading and dumping. Thus, not all data are necessarily representative of workers' exposure.

Many operations in mineral facilities are of an intermittent nature, noise consisting of discrete occurrences followed by periods of relative quiet. These include, but are not limited to drilling and operating a shovel, and to locomotives, shuttle cars, roof bolters, and some trucks. Other personnel, though working with equipment which produces a steady noise, may have exposure classed as intermittent by virtue of frequent access to a low noise-level control booth or alternate work in areas of low- and high-noise intensity.

TABLE 2. - Noises in mines and mills, dBA

Machine	High	Medium	Low
UNDERGROUND MINES			
Fans, vane axial	107	104	91
Fans, propeller	110	104	90
Drills:			
Air leg	125	117	96
Stopers	130	112	94
Jumbo	120	114	106
Long hole	114	106	98
Jackhammer	113	112	111
Diamond	-	103	-
Mucking machines	109	108	85
Slushers	109	91	89
Hoists	109	91	90
Pumps	100	96	92
Crushers	96	90	82
Transloaders	108	100	92
Trucks	98	95	92
Front-end loaders	101	91	87
Belt transfer chutes	-	94	-
Impact wrenches (rock bolts)	-	105 to 120	-
Measuring pocket	-	105 to 120	-
Shaft, man cage	-	93	-
OPEN PIT MINES			
Motor patrol graders	104	91	76
Shovels	101	92	78
Trucks	109	92	74
Bulldozers	107	100	84
Locomotives	95	85	75
Conveyors	-	97	-
Drills, rotary	100	93	72
Drills, jumbo	100	100	87
Front-end loaders	101	91	83
Scrapers	104	95	92
ORE PREPARATION PLANTS			
Bagging plant	96	89	84
Flotation	91	86	63
Screens	106	91	71
Blowers	109	98	92
Furnaces (boilers)	104	92	73
Filters	93	87	72
Rod-ball-pebble mills	98	90	65
Conveyors	113	89	82
Crushers	106	95	69
Vibrators	101	93	79
Pumps	100	91	89

Mining Industry Hearing Loss

Only limited audiometric data is available on men working in mines and associated facilities. One operation, with 2,000 hourly wage employees, has been obtaining audiograms of each employee since they began operations in 1957. (Personal communication, James Bowen and Robert Ginliani, Erie Mining Company, Minnesota.) While many of the men have impaired hearing loss in the upper frequencies, none have critical losses in the speech range. When an audiogram indicates hearing loss is starting to encroach into the speech range frequencies, the use of hearing protection becomes a condition of employment at this mine.

In one study (28) hearing threshold levels of men exposed to intermittent noise levels of drill intensity, 115 to 120 dBA, was compared with those of men exposed to constant noise levels of lesser intensity, 105 dBA. The comparative percent of men with hearing impairment is as follows:

Percent with hearing impairment		Age group
Intermittent noise (115-120 dBA)	Constant noise (105 dBA)	
2	7	20 - 29
20	27	30 - 39
26	40	40 - 49
65	60	50 - 59

Earplugs had been issued at one time or another to all miners examined, and a positive effort had been made to encourage their use. When workers were asked during the survey whether they used the ear protectors, 82 percent of the men replied affirmatively.

The data tends to confirm damage risk criteria allowing longer daily exposures to intermittent noise followed by periods of relative quiet. Furthermore, it compares with hearing loss incidence in selected nonmining populations by age groups and occupational noise exposure of various intensities, which are tabulated below.

Noise level exposure (dBA)	Percentage having impaired hearing by age groups				No. of persons in study group
	20-29	30-39	40-49	50-59	
85	2	8	15	25	1,100
92 (Est.)	3	9	15	28	9,653
95	8	15	25	38	1,092
97	7	22	32	48	400
102	10	18	30	45	666
104	5	21	35	57	174

Source: Guidelines for Noise Exposure Control (21).

Attention is called to the large increase of men exposed to intermittent noise with hearing impairment in the 50 to 59 age group as compared with the 40 to 49 age group. Some of this may reflect damage done before earplugs were issued and worn. Possibly of more significance is the 40 to 49 age group which has only a slightly greater percentage with a hearing loss than the 30 to 39 age group, especially when compared with the list. This also could be due to wearing hearing protection. Those in the 50 to 59 age group would likely have had the damage done before starting to wear hearing protection.

The study cited (28) concluded that "the intermittent noise in this study was about 15 dB more intense than continuous noise reported to produce the same additional hearing impairment in men between the ages of 30 and 50. In relation to the Intersociety Guidelines, intermittent drilling noise causes the same impairment as steady noise 20 dB lower. This is consistent with the prediction that the hazard of noise interrupted 40 times per day is the same as a steady noise 20 dB lower." Confirmation of the permanent effects that actually result from exposures to interrupted noise is needed. The reader is reminded that the total audio spectrum is not of concern in hearing conservation, only that part of the speech range--500 to 2,000 Hz octave bands--which are weighted for compensation purposes.

THE HEARING CONSERVATION PROGRAM

General

In considering problems of noise in industry, it is logical to first consider the prevention of injury and later the improvement of the environment.

The basic objectives of a hearing loss prevention program are as follows: (1) Evaluate the environment, (2) control exposure, and (3) monitor results and establish records.

An effective industrial hearing conservation program normally consists of five elements in achieving the above objectives:

1. Analyze the worker environment and the work cycle for noise intensities and exposure, respectively;

2. control exposure by eliminating or reducing noise levels or limiting the time workers are subjected to noise environment where practicable;

3. provide hearing protective devices where indicated in the first element until control is achieved;

4. periodically measure employee's hearing acuity; and

5. provide education for supervisors and employees regarding the problem and encourage enthusiasm for maintaining such a program.

The Noise Survey

To determine the locations or the tasks where harmful noise exposures may exist requires a noise survey and a time study or estimate of men's exposure to each noise intensity. While noise levels of all operations should be measured and recorded on a form such as figure 3, only noises of 90 dB and greater on the A scale of the meter currently are of primary concern.

DATE	
TIME	
SURVEYOR	
METER	
LOCATION	
SOURCE OF NOISE	
NO. OF PERSONS EXPOSED	
PLUGS - MUFFS WORN	
NOISE INTENSITIES (dBA, slow)	
HRS. EXPOSURE (per day, ave.)	

Diagram and description of work, equipment, conditions (as type of rock, etc.). Show relationship of men, noise source, meter.

Diagram:
(show measuring
location with an X.)

FIGURE 3. - Noise Survey Form.

Noise may be classified into two broad categories; continuous and impulse. Impulse noises have a sharp, quick character as from a drop hammer, pistol shots, or expulsion of air from a compressed air cylinder when released suddenly. These levels cannot be measured accurately with a sound level meter because of inertia of the meter. The peak sound pressure level during the impulse may be 20 to 30 dB greater than the highest reading obtained on a sound level meter. An impulse noise analyzer or other sophisticated equipment must be used for the accurate measurement of these noises. An estimate can be made using a sound level meter, however, by setting the meter to C scale, fast response, C_F. Indications of needle fluctuations over 110 to 120 dBC may be in excess of the 140 dB ceiling for impulse noises.

Continuous noises are more easily measured. Noise produced by rapidly repeated impacts as rivet guns and rock drills are considered continuous when the impacts occur at intervals of one or more per second.

Undulating noises of a continuous nature should be measured noting the range of variation, that is, noise in a truck cab when climbing out of the pit; 95 to 102 dBA, weighted average 97 dBA. The averaging may be done either mentally or by instruments designed to provide a daily weighted average. If high levels occur frequently, their maximum intensities and rates of repetition should be noted. A simple average of extreme values should be recorded for variations of 6 dBA or less.

Octave band analyses may be made of the noise source spectrum. Information regarding frequency distribution is of value principally for engineering control purposes.

A sound level meter adequate for the noise survey indicates the sound pressure level by a single number, which is descriptive of the sound pressure levels over the audible frequency range. All sound level meters and octave band analyzers used in noise determination should meet the pertinent specifications of type 2, or better, meters of the American National Standards Institute (ANSI), S1.4-1961, Specifications for General Purpose Sound Level Meters (3). Reference may also be made to International Electrotechnical Commission, an agency of the International Standards Organization, publications number 123, Recommendations for Sound Level Meters, and number 179, Precision Sound Level Meters (17-18). Most sound level meters now offer three electrical weighting networks, A, B, and C. The C scale has an essentially flat response; the B scale has a low frequency filter which provides less weighting to frequencies below 200 Hz than the C scale. The A scale gives still less weight to low frequency sounds, simulating the response of the human ear (fig. 4).

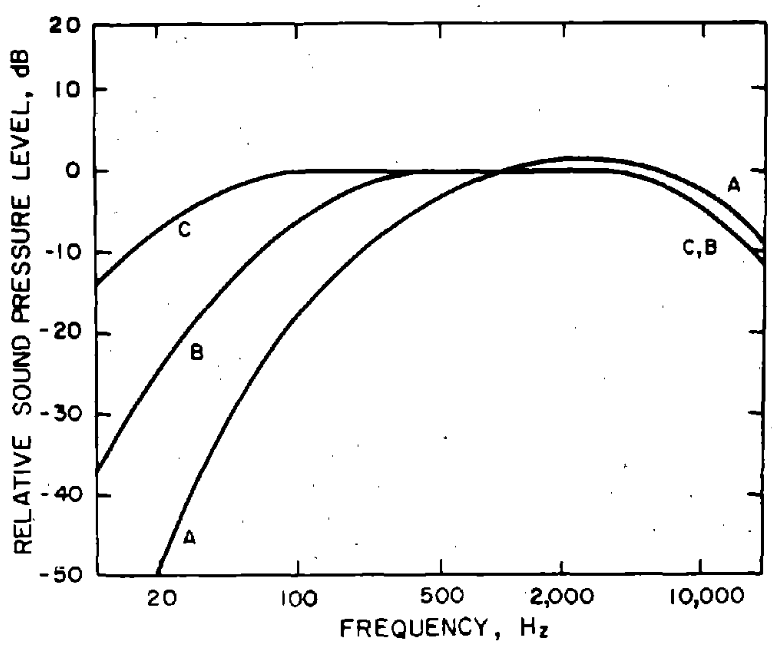

FIGURE 4. - A, B, and C Weighting Scales.

A partial list of meter suppliers is listed in appendix B.

Surveys should be conducted by competent persons according to accepted practices (4, 20). An adequate appraisal of workers' exposures to noise requires care, judgment, and an awareness of the behavior of sound waves as well as of instrument response. The measurement should be taken as near as possible to the space normally occupied by the worker's ears; it should not be made at the worker's head, however. The worker should either be removed or the instrument held at the same radius from the noise source as the worker's ears, about a foot away (fig. 5). Sound waves reflected from a surface away from the noise source, for example, behind him if he is facing the source, may affect the primary waves. The observer should make note of all such possible reflective surfaces and position himself to minimize obstructing wave energy. The meter should be held away from the surveyor at or nearly at arm's length. Scale settings should be dBA, slow response. The decibel range should be such to read the sounds measured on the plus side of zero. When attempting to approximate impulse noises the dBC scale, fast response, is used.

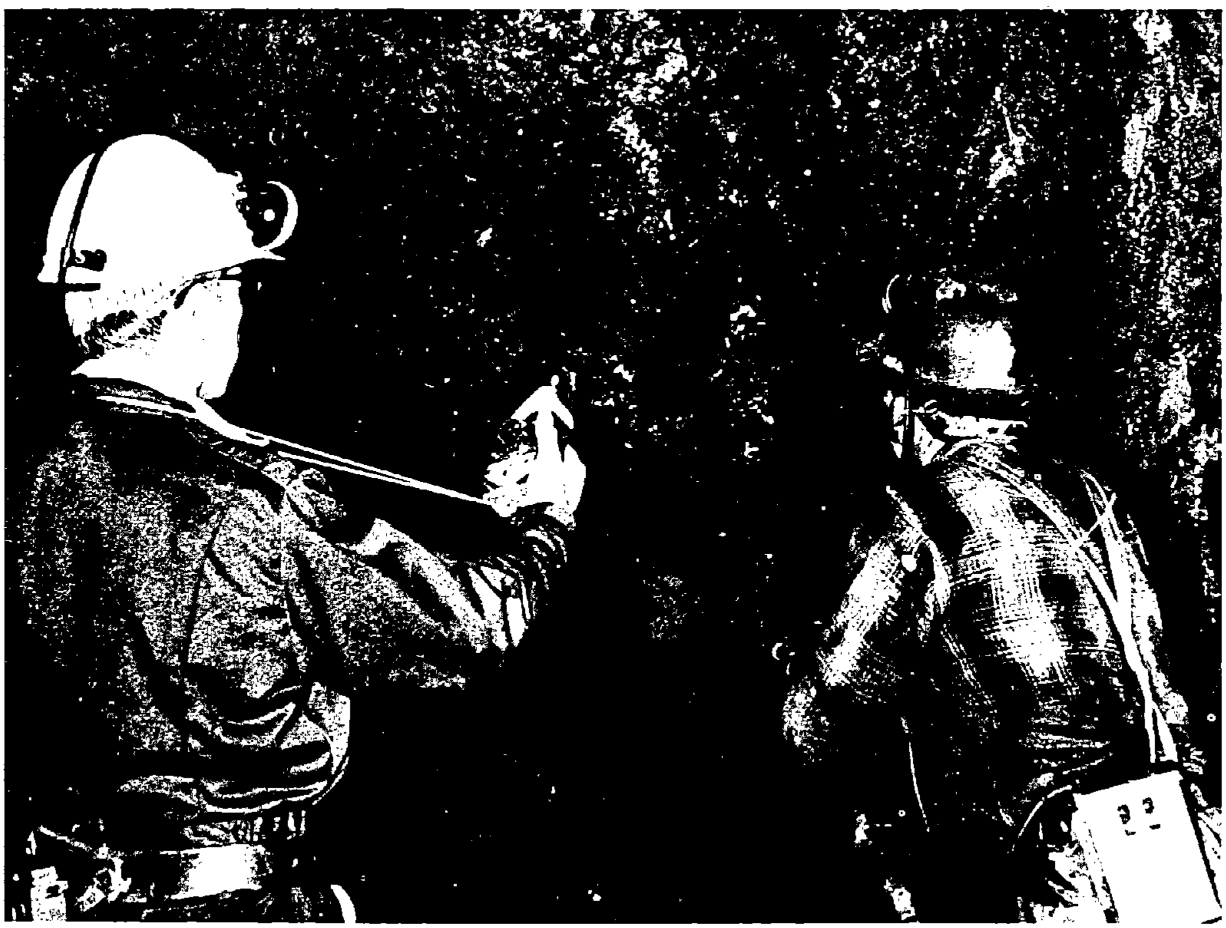

FIGURE 5. - Measuring Drill Noise Levels.

The surveyor should be aware of the characteristics of the microphone on his instrument. In some situations, the indication given by the sound level meter will depend upon the angle of incidence of the sound on the microphone. For the ceramic microphone on the GR 1565A meter, as an example, readings of directional high frequency noise would be too high for perpendicular (0) degree incidence and too low for grazing (90) degree incidence. The most accurate measurements would be obtained by using an intermediate angle of incidence to approximate the response for random incidence (fig. 6).

Care should be exercised to record all pertinent information. A suggested form is illustrated in figure 3.

To insure reliable readings the instrument must be calibrated, adjusted, and handled in accordance with manufacturer's instructions. When the equipment is purchased, it usually has been calibrated and adjusted to within limits approved by ANSI. In most equipment, the microphone is the limiting factor determining the accuracy of measurement. Inaccuracies can result from interaction between the microphone and the sound field, from nonuniformities in sensitivity over wide frequency ranges, and also from changes in

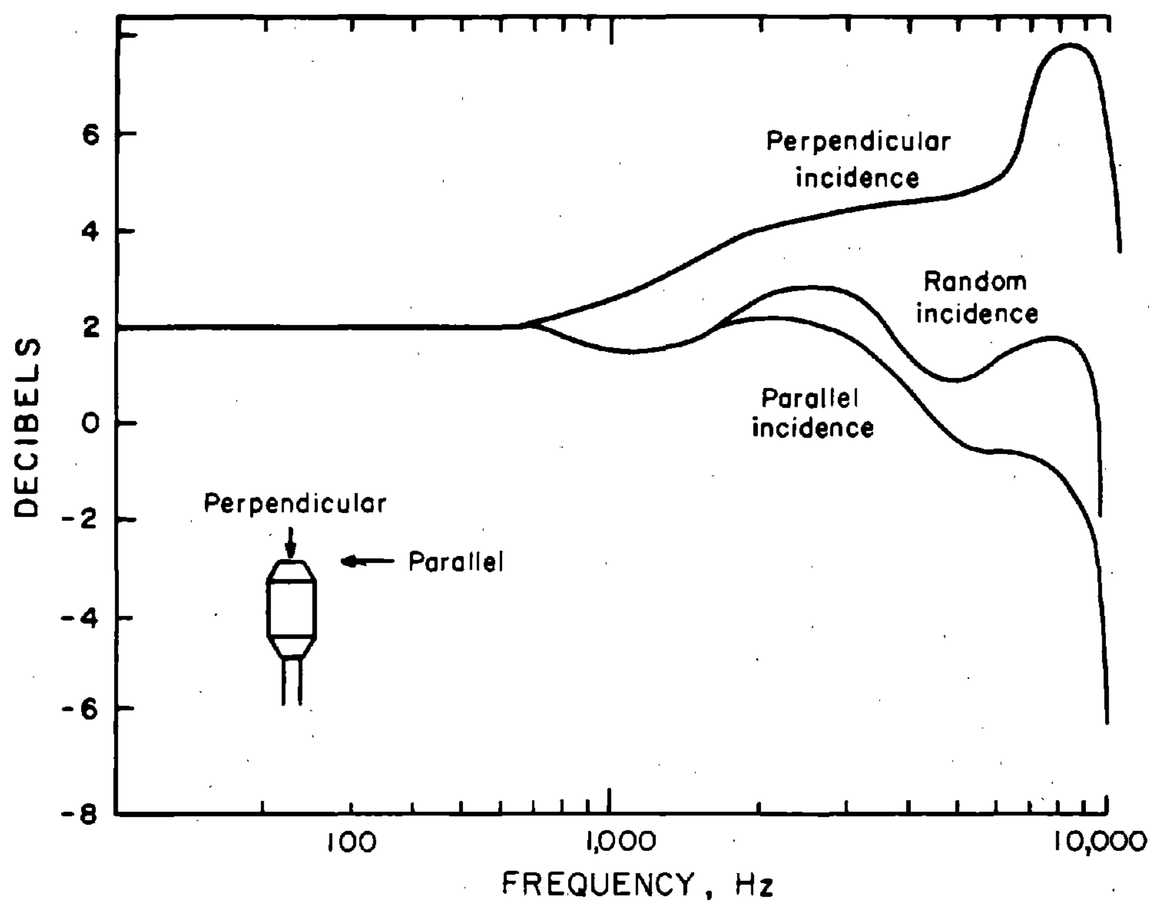

FIGURE 6. - Typical Response Curve for a Ceramic Microphone. (From General Radio Handbook of Noise Measurement.)

sensitivity caused by aging, temperature, humidity effects, and mechanical abuse. Spurious signals may be generated by wind, vibration, stray magnetic fields or electric circuit noise. A battery check should be made four or five times throughout the day. An acoustic calibration should be made at least at the start and the end of each day at the elevation where the readings are made.

Engineering Control

There can be little argument regarding the need to attain a work environment with little or no hazardous noise.

The reduction of environmental noise levels at existing facilities should be a primary effort in a competent hearing conservation program. Consideration should be given to probable noise exposures when new equipment is ordered or new facilities planned. A competent acoustical consultant can provide valuable services at this stage. Noise data should be obtained from suppliers so that realistic estimates of noise exposure can be made.

Control of noise is a system problem consisting of three major parts: the source, the path, and the receiver (9).

The source is that unit or combination of units from which the sound energy emanates--a drill, an engine, a crusher, several ball mills, classifiers, and filters.

The sound energy from the source travels over the path. This may be simple, such as the air between the drill and the driller, or complex, including sound from vibrating mill structural members as well as straight and reflected air conduction. The total path includes all possible avenues along which the noise in question may reach a destination.

The receiver is the person(s) affected by the sounds.

The engineering control of sound energy is not synonymous with noise reduction anymore than temperature control means turning the heat up. True, most noise control problems are best solved by effecting a reduction of energy reaching the receiver. But a situation where the appropriate solution would be to introduce sounds in the "too quiet" office, where normal or even low-voiced conversation in an adjoining area impinges on the concentration of those trying to perform work, particularly if it is of a creative or exacting nature. Here, an introduced level of noise would mask extraneous conversations and laughter. The employee trying to work would not be so distracted and could work more effectively and efficiently.

To reduce sound energy affecting the receiver, that is to reduce the damage risk to a specified acceptable limit at a reasonable cost, will normally require an analysis of the system problem. Diagramming and careful analyses of each component and factor within the system will frequently help define the problem. Some degree of energy reduction may be achieved by each or by a combination of several possible measures, such as the following:

1. Replace the noise-creating device with a new type.

2. Keep the device in good repair, lubricate and maintain.

3. Enclose part of the device and rearrange the controls.

4. Attach a muffler or a specially designed absorptive duct to the exhaust of the device.

5. Mount the device on vibration isolators.

6. Use sound-absorptive damping, and/or barrier materials in the worker environment or sound path.

7. Restrict the amount of time a worker may stay in areas of high-sound-pressure levels, transferring him to a low-noise task for the remainder of his shift; or provide a quiet "doghouse" to where he may retreat when possible.

Although octave band analysis is not necessary for noise exposure determinations, and may even be cumbersome in this regard, it will be necessary for the solution of many engineering control problems.

Figures 7A and 7B illustrate the octave band analysis of two rock drills, before and after muffling.

Ear Protection

Although the most desirable and certain means of protecting workers against noise would be the elimination of noise through engineering controls, this is often technically unfeasible and prohibitively expensive, particularly if the objective is to be accomplished in a relatively short time. Noise control measures applied at the source or along the transmission path provide the most effective means of eliminating a potential hazard to hearing. When such measures are impractical or economically prohibitive, the needed noise reduction may be gained at the receiver through the use of ear protectors.

Neither plugs nor muffs have a universal advantage. Their effectiveness depends on several physical and physiological factors related to the manner in which noise energy is transmitted through or around the barrier. These factors include seal leaks, material leaks, vibration of the device, conduction through bone and tissue, and whether the men will wear them.

Small air leaks in the seal between the protector and the head or through the material in the protector can reduce significantly the low frequency attenuation, but will affect only slightly the high frequency attenuation (24). Vibration of the ear protector will regenerate sound into the ear canal in a manner dependent on the compliance of the protector. The vibration of poorly designed protectors may actually amplify certain frequency characteristics of noise. The threshold of hearing by conduction through bone and flesh is between 30 and 55 dB above that of the normal pathway. Thus, a perfect ear protector worn on the head cannot provide more than about 55 dB attenuation.

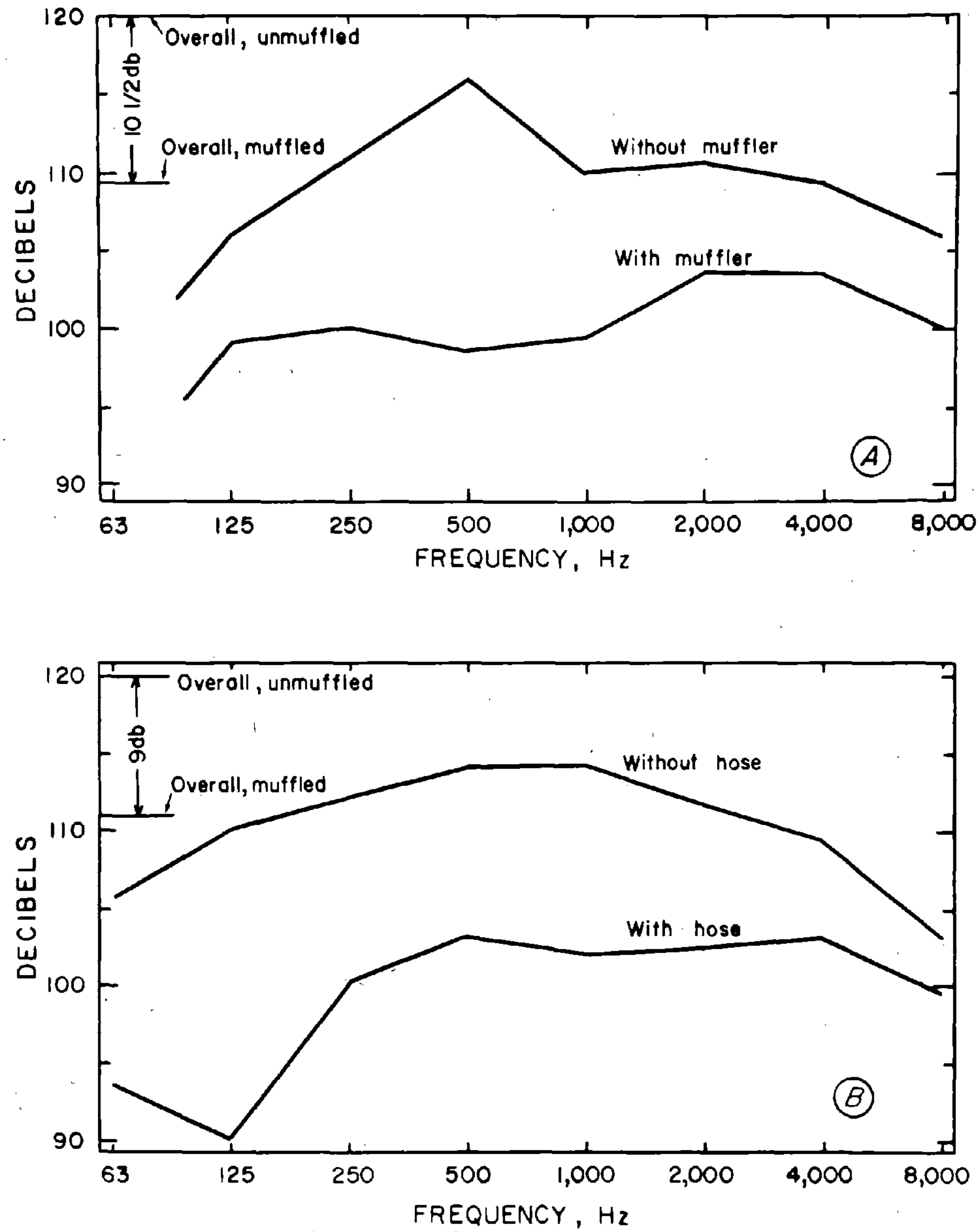

FIGURE 7. - Noise Spectra of Drills, Muffled and Unmuffled. *A*, Noise spectra of air leg drill with and without aluminum muffler. *B*, Noise spectra of stoper with and without 50 feet of hose on exhaust.

Appendix A lists the attenuation to be expected at various frequencies from types of protectors properly fitted.

A worker is more apt to be happy with and to use a protector if he has the opportunity to choose from an assortment. Providing he chooses earplugs, after he selects a set he must be given initial assistance and instruction in fitting, inserting, and caring for them. Good protection from earplugs requires knowledge on the part of the person who fits the protectors and instructs in their use; it requires care on the part of the users.

Many ear canals become large with age and possibly with regular use of earplugs. A person's two ear canals are not necessarily similar in size, shape, or position.

Most earplugs come in several sizes to assure good fit. Wax-impregnated cotton and glass down, if properly inserted, provide excellent attenuation characteristics in almost any ear canal. They present a hygienic problem in instances where the wearer forms and inserts the plugs with hands contaminated with grease, metal filings, or other materials. Although the initial cost of some wax-impregnated cotton or glass down plugs is much lower than that of other kinds of plugs, over a long period of time the cost will probably equal or may exceed that of others because of daily replacement (35).

Dry cotton plugs, rags, or paper give an illusion of protecting the wearer from noise; however, they provide very little attenuation.

Some insert protectors, which are advertised to pass speech but attenuate harmful noises, provide improved speech communication over normal plugs only when used at noise levels lower than about 88 dB (24). Above 88 dB, conventional plugs pass communication as well as, and better than, the filter-type plugs. Other plugs with metal built-in acoustical filters provide similar attenuation characteristics. All the insert protectors with acoustical filters provide less overall protection than do conventional well-designed plugs.

Two types of custom-fitted insert protectors are available. One is made from a set of previously cast ear canal impressions. The finished earplugs are formed from standard ear-mold materials. The other is made by placing a quick setting silicone rubber in the ear canal and molding it into the outer ear. It cold cures in 8 to 12 minutes. The outer ear molding assures that the user will not confuse which is the correct plug, and also provides anchorage for the molds.

A well-designed, muff-type ear protector can be fitted much more easily than insert protectors. Figure 8 shows attenuation provided by a well-designed muff compared with that provided by an insert protector and the total effect of the two combined.

A well-designed set of ear muffs will be sufficiently adjustable to allow for proper seating against the head. Each muff must be free to rotate several degrees in both horizontal and vertical directions to accommodate variations

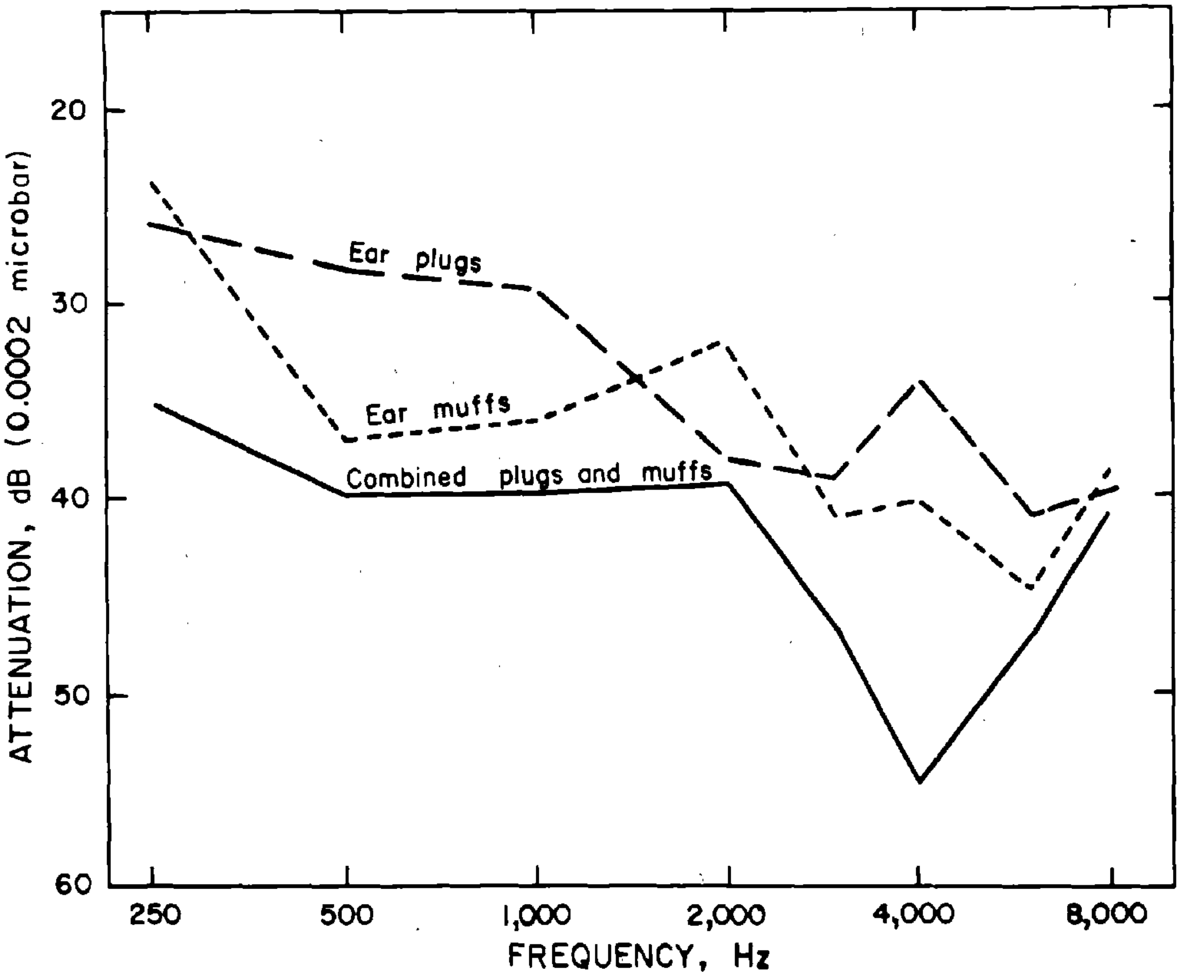

FIGURE 8. - Effects of Combining Ear Muffs and Earplugs.

in head shapes. There may be as much as 4 inches difference in men between the entrance to the ear canal and the crown of the head. Muff suspension must provide a force sufficient to give a good acoustical seal against the head without causing discomfort to the wearer.

Attenuation data of cap-mounted muffs is valid only for the muff mounted on the cap tested. Men wearing hard hats, of course, cannot also wear muffs with over-the-head suspension. Behind-the-neck and under-the-chin suspension muffs are available from some suppliers. Some models of the latter types are equipped with a nylon strap which fits over the head and over which a hard hat easily can be worn. This eliminates the need for extra tension to prevent the muffs from slipping down. Some men may have difficulty wearing a muff and a hard hat, owing to inadequate clearance between the top of the ears and the hat brim.

Long hair and spectacle or goggle temples, if fairly substantial, will interfere with the seal of the muffs against the head. Glasses with normal size temples will reduce attenuation characteristics of muffs by about 5 dB.

The amount of protection required depends on the noise spectrum and intensities to which an individual is exposed, the duration of exposure, the rest time between exposures, and the susceptibility of the individual. Hearing conservation criteria are guides for groups. It is not possible at this time to establish an accurate exposure-level threshold for hearing damage for a particular individual.

Table 3 shows an example of how protection is determined, using octave band analytical data. The effectiveness of specific types of protectors can be determined in this way, knowing the spectrum and intensity of the noise source and the attenuation curve of the ear protector.

TABLE 3. - Attenuation calculations

Noise source, insert and muff attenuation data, and noise reaching wearer	Frequency in octave bands							
	Overall	125	250	500	1,000	2,000	4,000	8,000
Noise of GD 93 AR Stoper, dB......................	120	110	112	114	114	112	110	103
Attenuation provided by V51R insert..............	-	24	21	23	29	30	31	27
Attenuation provided by AO 1701 muffs............	-	8	19	28	40	39	41	30
Noise reaching ears of man with V51R inserts....	-	86	91	91	85	82	79	76
Noise reaching man with AO 1701 muffs.......	-	102	93	86	74	73	69	73

Application of the above data to figure 9 will show that either protective device is adequate to reduce the worker's exposure to within limits prescribed by the standards in table 1 for up to 8 hours of drilling.

Properly fitted insert or muff protectors will reduce most noises to safe levels. If more protection is required than that provided by a single set of muffs or plugs, additional protection can be achieved by wearing both (fig. 8). Obviously their individual attenuation characteristics are not added directly, but the additional, seemingly small, protection will be well worthwhile in extended high-level exposures.

In some areas of mines and mills it is necessary that employees be able to communicate with one another and to hear warning signals. The degree of interference with communication depends to a large extent on the spectrum of the noise. Interference is greatest when the noise levels in the speech frequencies are high. The most important of these frequencies are within the three octave bands 500, 1,000, and 2,000 Hz. Certainly, better articulation scores are made in areas of quiet when no protective devices are worn. However, in noisy environments, better scores are possible when wearing ear protectors. This advantage is true for both insert and muff type protectors.

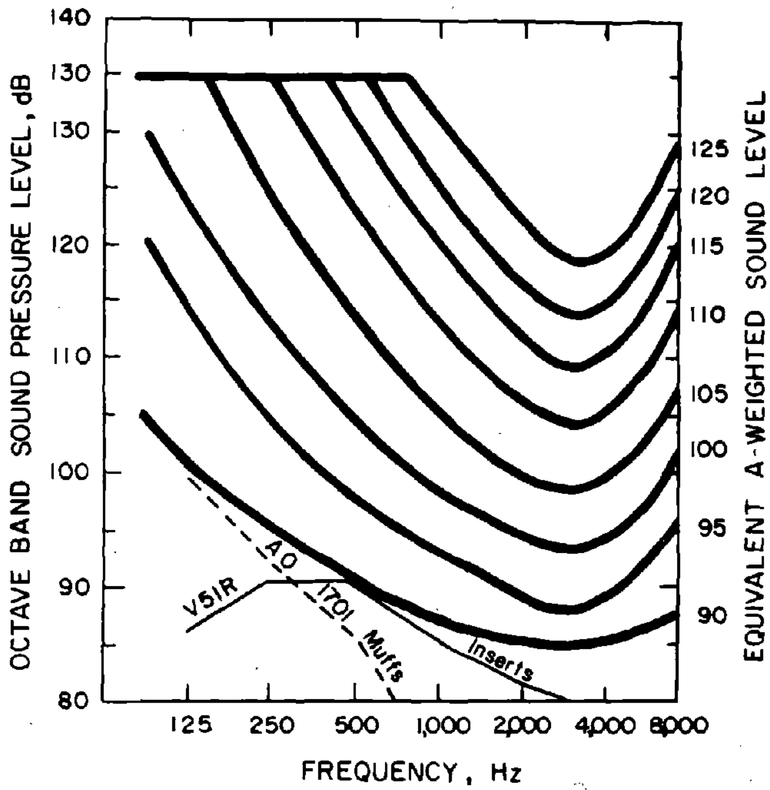

FIGURE 9. - Equivalent A-Weighted Sound Levels.

Some persons in the mineral industry are of the opinion that the use of hearing protectors might prevent hearing rock and timber noises which announce the impending collapse of ground.

Exposure to high noise levels can cause temporary threshold shift (TTS). This TTS is greatest at and immediately after exposure to noise. Upon cessation of the noise, the TTS begins to diminish, somewhat as grass springs up after having been trampled. As noise-induced permanent threshold shift grows, the recovery from temporary impairment is less and less rapid--much as grass loses its resilience with additional trampling. The ability to hear speech or warning signals, such as rock noises, "roof talk," or timber taking weight is reduced with TTS. Only the louder of such noises can be heard either with ear protectors or without, when equipment is operating. When the equipment is turned off, ears that have been shielded by protectors are unencumbered with TTS and will be capable of detecting weaker and more subtle signals. Ears with TTS will not hear the lesser sounds and, with passage of time and increased loss of hearing, will fail to hear progressively louder signals.

Good safety practice dictates that the worker wearing hearing protection should periodically shut off the noisy equipment, remove his protection, and listen for rock noises. He also should remove his protection when the need for it has passed.

Audiometry

General

The hearing test is an important element in any program for protection of workers' health (16, 20). In general, it has two primary objectives. The first of these is to serve as a means of control by (1) checking the effectiveness of noise control measures, and (2) spotlighting unusual susceptibility to noise damage in individuals. The second objective is to provide a medical and audiometric record of the worker's hearing. Incidentally, such a record would have a high degree of admissibility and validity in court in the event of claims (2).

Both industry and the employee have a proper concern to know whether the employee had a hearing loss at the time he started his employment, whether he is incurring a loss at his occupation, and whether or not hearing conservation measures are successful. An audiometric program, properly initiated, maintained, and conducted, can provide an important element in a program for the protection of workers' health.

A person with normal hearing is capable of detecting weak sounds. Tests to determine the weakest sounds a person can hear is threshold audiometry. Practically all audiometry for industry uses pure tones--sinusoidal waves--for stimuli, and a response on the part of the subject such as raising his finger or pushing a button.

The hearing tests should be made after a period of removal from noise exposures. The longer the period, the better, such as when the employee is returning from a vacation or weekend. At least 16 hours should lapse from exposure to noise before the test is made. This requirement is usually met by making the test at the start of the work shift. A permanent record of the worker's history and hearing tests should be maintained. This record may become important should questions arise concerning the origin of the hearing loss. Also, such a record will be of value to the otologist or other doctor in reaching conclusions concerning causes of the loss, if it occurs.

Because hearing tests involve an expense, the question arises as to who should be tested--all employees or only those working in high noise levels. If only employees working, or those who might be expected to work in hazardous areas were tested, a false sense of security could evolve, since there is no assurance that an employee will not be transferred or at some time exposed to noise, even though employed for a noninjurious exposure. Failure to secure a record of preexisting hearing losses may result in the latest employer becoming liable for the entire loss in the event of a claim. Examination of workers previously employed will furnish invaluable data for the need for hearing conservation measures. For these reasons, a good practice would be to provide hearing tests for all new employees and for existing employees, either at the next routine physical checkup or immediately following vacations before returning to work.

Accuracy in the measurement of air-conduction hearing thresholds requires a well-trained technician, a quiet test environment, and an accurately calibrated audiometer. Audiometry should be conducted under medical supervision.

Instrument

Audiometers should meet the specifications of American National Standards Institute (ANSI), standard S3.6-1969 (6), and should be maintained in calibration in accordance with recognized procedures.

An audiometer that is in calibration produces a specified test tone at the level and frequency shown on the dial settings. Further, it produces the test tone only in the earphone to which it is directed, and it produces the signal free from unwanted noises or tones.

It is important to realize that a properly calibrated audiometer can lose its accuracy in time if mistreated, or even by the aging of its components. The following is a list of factors which can affect the accuracy of an audiometer:

1. Rough handling of the earphones or instrument.

2. Heat, causing components to change value and resulting in loss of accuracy. Common causes of overheating are storing the instrument in a warm place or leaving power on when the dust cover is on.

3. Dust or dirt, causing switches to become noisy, and in some cases causing poor electrical contacts.

4. High humidity, salt air, and acid fumes, causing the corrosion of electrical contacts.

5. Normal aging of components, changing an instrument's response significantly. Thus, an audiometer can go out of calibration even if it has not been in use.

An audiometer should be sent to a qualified laboratory for a complete calibration check at any time there is reason to suspect its accuracy, and, in any case, at least once each year. Obviously, much time and effort would be wasted if hearing measurements are made with an instrument that is out of calibration. Because accuracy drift may be a slow process, daily checks on the audiometer by the technician are as important as the laboratory calibration.

The laboratory calibration should be in accordance with ANSI S3.6-1969. Because pertinent performance specifications may not be well understood by some laboratories offering calibration services, a statement that the audiometer meets specifications should not be accepted without an explanation of the calibration procedure and a copy of the calibration data.

Automatic or self-recording instruments are gaining in popularity. A distinct advantage of this type is effected where a large number of persons are to be tested. One technician can supervise two or more tests at the same time. One source of error in the threshold determination results from the influence of poorly motivated or poorly trained technicians. The use of automatic audiometers tends to reduce this difficulty. The technician instructs the subject and he starts and stops the equipment. A complete test can be performed in 6 to 7 minutes.

With a manually operated audiometer, the hearing threshold determination is made with the assistance of a technician. The time for a complete test may take a few minutes longer than with an automatic audiometer.

The audiograms should include hearing thresholds for each ear at frequencies of 500, 1,000, 2,000, 3,000, 4,000, and 6,000 Hz. The frequency of followup audiograms will generally be related to the type and intensity of the noise exposure. A periodicity of once a year is typical of many programs.

In 1964 the International Organization for Standardization (ISO), of which the United States is a member, accepted zero hearing level reference values that meet the most rigid standards possible. The ISO standard, now also adopted in the United States since 1969, has threshold levels that are approximately 10 dB lower than the previous ASA[6]-1951 Standard. The reference zero used should be noted on each audiogram.

Test Facilities

Audiograms should be obtained only in environments which meet the requirements of the American National Standards Institute for background noise, described in standard S3.1-1960 (5). A calibrated acoustical environment is required, regardless of whether manual or automatic instruments are used. The calibrated acoustical environment can be defined as a room with an ambient sound level that will permit the determination of the subject's threshold of hearing.

The assumption that correction factors for background noise can be applied is completely false and misleading.

The calibrated acoustical environment may be achieved by the construction or purchase of a testing room. A one-man examination room, complete with ventilation system, will cost about $1,800. It may be located inside another room. After the location of the test facility has been selected, which may be influenced by proximity to the medical or personnel department, an acoustic survey must be made. This survey will indicate the amount of attenuation necessary to be provided by the testing room. Care should be taken to isolate the test room from effects of vibration.

The maximum permissible background sound-pressure levels that would not interfere with or mask the test tone can be defined in terms of octave bands, column 3 in the following tabulation, and also for narrow-band sound which center frequency is nearly that of the test tone (column 4) (5):

Audiometric test frequency, cps	Octave band cutoff frequencies, cps	Sound pressure level, dB	Level of narrow band sound,[1] dB
250	150 - 300	40	18
500	300 - 600	40	15
1,000	600 - 1,200	40	12
2,000	1,200 - 2,400	47	16
3,000	2,400 - 4,800	52	18
4,000	2,400 - 4,800	57	23
6,000	4,800 - 9,600	62	25
8,000	4,800 - 9,600	67	30

[1]Which has a center frequency nearly that of the test tone.

[6]ASA was an early designation for the association now termed ANSI.

Lower levels are required if the masking or interfering frequencies are close to those of the test tone. The test room should be as far away as possible from telephones, ventilating ducts, drain pipes, personnel and vehicular traffic patterns, and other sources of disturbing and extraneous noises.

Personnel

Persons performing the audiometric testing, whether by a manual or automatic instrument, should be trained in air-conduction audiometry either by formal course work at accredited educational institutions, or by individual instruction provided by an audiologist or otologist. Such a course has been described in an Intersociety document (19). The technician should have the responsibility only for determining hearing levels. He should not interpret, diagnose, or advise on the results of the tests, since that is the function of the responsible physician.

Education

An awareness through education of potential loss of hearing acuity induced by excessive exposure to noise whether incurred on the job or during leisure hours will increase the probability of success of a hearing conservation program.

Building employee acceptance of a hearing conservation program requires planning, educational efforts, and enthusiastic, persistent promotion. Maintaining the program and assuring its success requires persistence--someone who will shoulder the responsibility to rekindle men's efforts when the first wave of enthusiasm has waned and who will pursue a program to achieve engineering control of the environment.

Unless employees, labor and supervision are sufficiently motivated, the program cannot succeed regardless of how much sense it makes to an enlightened management. Success will be enhanced by the following:

1. Enlisting the cooperation of employees by teaching them the problems and the intended hearing conservation program, previously described.

2. Assigning the responsibility of the program's success to one person or to the leader of a group of persons.

3. Supervision must set a good example by wearing ear protectors in noisy areas and by expressing interest in the conservation of the hearing of others.

4. Introducing the program to new employees at the start of employment.

5. A persistent, keep-at-it attitude.

The effort must have the full support of management and supervision. The lines of communication must be kept wide open regarding every aspect of the program--who must wear ear protection, who will provide it and under what conditions it will be replaced, who is to establish and maintain the program, just what his responsibilities are, and who will pursue control of noise problems.

The following movies on hearing conservation are available to assist in the educational program:

Film	Time	Cost	Company
Hear--It Takes Two (Parts I and II)	20-1/2 min	$350 purchase; $35 rental	Price Filmakers 3491 Cahvenga Blvd. West Hollywood, Calif. 90028
Hearing: The Forgotten Sense	17-1/2 min	$225 purchase; $25 rental	Do.
Protect Your Hearing (color)	20 min	$10 rental	Bray Studios 630 9th Avenue New York, N.Y. 10036

It may be anticipated that additional films will become available as interest grows.

SIGNIFICANCE OF THE PROBLEM IN TERMS OF HUMAN WELL-BEING AND ECONOMIC IMPACT

A meaningful description of some of the basic effects of noise on man can be divided into three broad areas: Effects of noise on man's auditory system; the subjective, psychological effect of noise; and the effects of noise on man's nonauditory systems.

Losses in hearing sensitivity, both temporary and permanent, together with the masking of speech and other desired sounds, constitute the most significant sensation and perception problems posed by noise. Although the damage to the auditory system is deplorable, the temporary interference by noise with the proper functioning of hearing during daily work and social activities is, from a practical point of view, perhaps more important and causes more suffering (12).

In general, the greater the voice intensity and the broader the voice spectrum, the greater the intelligibility. The ability to communicate by voice in noise is determined by the level and spectrum of the noise, the voice level of the talker, the distance between the talker's mouth and listener's ear, and the vocabulary used (34).

Losses in hearing ability for sounds critical to a worker's task or lack of adequate speech communication can reduce efficiency on those jobs having such requirements.

Noise has effects on nonauditory sensory and perceptual experiences (14). Although only limited work in this area has been done, the more positive conclusions about the adverse effects of noise on task performance have come from laboratory studies of vigilance in which the subject is required to maintain a watch over numerous dials, any one of which may show a faint signal deflection at any time. The number of signals correctly detected and the speed of response provide measures of performance on this task, and both these measures suffer when individuals have been prolongedly exposed to high noise levels (11, 22). Balance and certain aspects of visual accommodation are other nonaural sensory functions affected by noise (25, 29).

Noise does affect attitudes and feelings. This effect can vary widely among individuals. The same noise will affect an individual variously, depending on other personal factors. For example, the sound of chalk scraping on a blackboard or other abrasive types of noise can cause an irritating response. Musical sounds, by varying the rhythm, tempo, and melody can evoke moods ranging from calmness and contentment to excitement and elation.

The amount to which mental or nervous illness results from, or is aggravated by, prolonged or recurring types of noise exposure cannot be answered from the inadequate data at hand. One study, reported by Cohen (14), evaluating the effects of noise on steelworkers, found that those in the noisiest workplaces had a greater frequency of social conflicts both at home and in the plant. Increasing signs of chronic fatigue and neurotic complaints were noted in workers who were exposed daily to noise levels over 110 dBA.

Some idea of the magnitude of the compensable and potentially compensable cases in this country is achieved by noting that in the 50 to 59 age group, 20 percent of the individuals in a nonexposed population show significant hearing impairment. In an industrial group of the same age bracket the percentage varies upward to 57 percent, depending on noise exposure.

The economic impact of excessive industrial noise, exclusive of dollar figures of insurance, court costs, and compensation claims, include the loss of job capability, present and potential, owing to hearing loss. Other economic impacts derive from less apparent byproduct effects. Noise-caused physiological effects might involve the heart and other glands in a manner similar to a general stress or anxiety situation. In his book "Hearing Loss," Dr. J. Sataloff states that no physical disability affects personality so adversely as a hearing loss--and the loss need not be severe (26).

The noises of the mining industry impinge on nearly every worker at the face and on a high percentage of those involved in support and milling. A concerted effort to stop the interference of communications, the adverse psychological impacts and the erosion of hearing acuity is urgently needed.

REFERENCES

1. American Industrial Hygiene Association. Industrial Noise Manual, Westmont, N.J., 2d ed., 1966, 171 pp.

2. American Mutual Insurance Alliance. Background for Loss of Hearing Claims. Chicago, Ill., 1964, 60 pp.

3. American National Standards Institute. Specifications for General Purpose Sound Level Meters (S1.4). New York, 1961, 13 pp.

4. _____. Method for the Physical Measurement of Sound (S1.2). New York, 1962, 23 pp.

5. _____. Criteria for Background Noise in Audiometer Rooms (S3.1). New York, 1960, 15 pp.

6. _____. Specifications for Audiometers (S3.6). New York, 1969, 22 pp.

7. _____. Measurement of the Real-Ear Attenuation of Ear Protectors at Threshold (Z24.22). New York, 1957, 10 pp.

8. _____. The Relations of Hearing Loss to Noise Exposure (Z 24-X2). New York, 1954, 63 pp.

9. Bolt, R. H., and K. V. Ingard. System Considerations in Noise-Control Problems. Ch. 22 in Handbook on Noise Control, ed. by C. M. Harris. McGraw-Hill Book Co., Inc., New York, 1957, 20 pp.

10. Botsford, J. Current Trends in Damage Risk Criteria. Sound and Vibration, April 1970, pp. 16-19.

11. Broadbent, D. E. Effects of Noise on Behavior. Ch. 10 in Handbook on Noise Control, ed. by C. M. Harris. McGraw-Hill Book Co., Inc., New York, 1957, 33 pp.

12. Carpenter, A. Effects of Noise on Performance and Productivity. Symposium 12, Control of Noise. London, 1962, pp. 297-310.

13. Chamber of Commerce of the United States. Analysis of Workmen's Compensation Laws. 1971, 33 pp.

14. Cohen, A. Effects of Noise on Psychological State. The American Speech and Hearing Association, Rept. 4, 1968, pp. 74-87.

15. Derzay, R., and A. Goodwin. Evaluation of Noise in the Mineral Industry. 1969. Available for inspection at the Technical Support Center, Bldg. 55, Denver Federal Center, Denver, Colo.

16. Glorig, A., and J. D. Harris. Audiometric Testing in Industry. Ch. 6 in Handbook on Noise Control, ed. by C. M. Harris. McGraw-Hill Book Co., Inc., New York, 1957, 24 pp.

17. International Electrotechnical Commission. Recommendations for Sound Level Meters. Pub. 123, 1961, 24 pp.

18. _____. Precision Sound Level Meters. Pub. 179, 1965, 26 pp.

19. Intersociety Committee. Guide for Training of Industrial Audiometric Technicians. American Industrial Hygiene Assoc. V. 27, No. 3, 1966, pp. 303-304.

20. _____. Guidelines for Noise Exposure Control. Sound and Vibration. November 1970, pp. 21-24.

21. _____. Guidelines for Noise Exposure Control. American Industrial Hygiene Assoc. V. 28, No. 5, 1967, pp. 418-424.

22. Jerison, H. J., and S. Wing. Effects of Noise and Fatigue on a Complex Vigilance Task. Wright Air Dev. Ctr. Tech. Rept. TR-57-14, Wright Patterson Air Force Base. 1957, 13 pp. Available on loan from Librarian, 2750 Air Base Wing, SSLT/Bldg. 12, Wright Patterson Air Force Base, 45433.

23. Kalmykow, A. Address to noise symposium. American Optical Company, Southbridge, Mass., 1966, 10 pp. Available from the American Optical Company, Safety Products Division, Southbridge, Mass. 01550.

24. Michael, P. Ear Protectors. Archives of Environmental Health, v. 10, April 1965, pp. 612-618.

25. Nixon, C. W., C. S. Harris, and H. E. Von Gierke. Rail Test To Evaluate Equilibrium in Low-Level Wide-Band Noise. Arco Medical Research Library Tech. Report 66-85, Wright-Patterson Air Force Base, Ohio. 1966, pp. 1-16. Available on loan from Librarian, 2750 Air Base Wing, SSLT/Bldg. 12, Wright Patterson Air Force Base, 45433.

26. Sataloff, J. Hearing Loss. J. B. Lippincott Company, Philadelphia, Pa. 1966, 404 pp.

27. _____. How We Hear. Address to noise symposium. American Optical Company, Southbridge, Mass., 1966, 17 pp. Available from the American Optical Company, Safety Products Division, Southbridge, Mass. 01550.

28. Sataloff, J., L. Vassalo, and H. Menduke. Hearing Loss From Exposure to Interrupted Noise. Archives of Environmental Health, v. 18, No. 6, 1969, pp. 972-981.

29. Stevens, S. S. The Effects of Noise and Vibration on Psychomotor Efficiency. Prel. Rept., Psychoacoustics Lab., Harvard University, 1941, pp. 11-19.

30. U.S. Department of Labor. Guidelines to the Department of Labor's Occupational Noise Standards for Federal Supply Contracts. Bull. 334, December 1970, 16 pp.

31. U.S. Congress. Occupational Safety and Health Act of 1970. Public Law 91-596. Dec. 29, 1970, 84-stat 152, sec. 50-204.10.

32. Ward, W. D. Effects of Noise on Hearing Thresholds. The American Speech and Hearing Assoc. Rept. No. 4, 1968, pp. 40-47.

33. Ward, W. D., A. Glorig, and D. L. Sklar. Temporary Threshold Shift From Octave Band Noise; Applications to Damage Risk Criteria. J. Acoustical Society America, v. 31, 1959, pp. 522-528.

34. Webster, J. C. Effects of Noise on Speech Intelligibility. The American Speech and Hearing Assoc. Rept. No. 4, 1968, pp. 49-71.

35. Zwislocki, J. Ear Protectors. Ch. 8 in Handbook on Noise Control, ed. by C. M. Harris. McGraw-Hill Book Co., Inc., New York, 1957, 27 pp.

APPENDIX A.--ATTENUATION OF EAR PROTECTORS

The threshold shift method is the most widely accepted method for evaluating ear protectors. It is described in standard Z24.22-1957, "Measurement of the Real-Ear Attenuation of Ear Protectors at Threshold," a publication of the American National Standards Institute (ANSI), 1430 Broadway, New York 10018 (7).[1] This standard specifies that the hearing thresholds of at least 10 randomly selected listeners with normal hearing shall be taken with and without the ear protector under test, on no less than three separate occasions, at each test frequency. The differences between thresholds with and without protectors are taken as a measure of the protector's attenuation at each test frequency.

In the following two tables, table A-1 lists attenuation data for various hearing protectors as provided the California Division of Industrial Safety, Department of Industrial Relations and table A-2 lists suppliers of additional protectors. The data listed in tables A-1 and A-2 meet the specifications of the above described ANSI standard.

TABLE A-1. - Attenuation data of ear protectors, dB, octave bands, Hz

Attenuation, dB	125	250	500	1,000	2,000	3,000	4,000	6,000	8,000
American Optical Corp. Safety Products Div. 14 Mechanic St. Southbridge, Mass. 01550:									
Hear-guards, V 51 R, insert, $0.63/pair	24	21	23	29	30	35	31	29	27
Muffs, No. 1200, headband, $11.55 each	14	21	32	46	41	45	40	31	30
Muffs, No. 1275, backband, $8.05 each	6	13	23	34	36	41	40	36	24
Muffs, No. 1701, headband, $7.30 each	8	19	28	40	39	42	41	34	30
Rockford, I. C. Webb 301 N. Madison St. Rockford, Ill. 61110:									
Billesholm antinoise ear protector (wool),[1] $6.45/20 pack.	10	13	18	22	38	37	36	34	33
David Clark Co., Inc. 366 Park Ave. Worcester, Mass. 01610:									
Muffs, No. 19A, headband, $6.60 each	20	30	40	45	38	-	37	-	35
Muffs, No. 10A, headband, $12.00 each	15	23	31	38	37	-	44	-	31
Muffs, No. E-805, headband, $3.85 each	16	21	30	43	43	-	49	-	36

See footnotes at end of table.

[1]Underlined numbers in parentheses refer to items in the list of references preceding the appendixes.

TABLE A-1. - Attenuation data of ear protectors, dB, octave bands, Hz--Continued

Attenuation, dB	125	250	500	1,000	2,000	3,000	4,000	6,000	8,000
H. E. Douglas Eng. P.O. Box 7209 Burbank, Calif. 91505:									
Sound Sentry, ear cap with headband, $3.95 each	20	20	19	20	30	38	30	27	31
Environmental Acoustical Research P.O. Box 2146 Boulder, Colo. 80302:									
Sound Suppressor,[2] $12.00/pair	26	28	28	35	36	43	44	46	45
Flents Products Co., Inc. 103 Park Ave. New York 10017:									
Model N, backband, $5.00 each	8	11	23	36	37	41	37	37	31
Ear muffs, Universal model H, headband, $6.00 each	9	13	25	38	38	44	39	38	33
Ear stopples (wax-impregnated cotton),[1] $4.29/100	19	20	21	26	30	38	40	41	36
Antinoise ear plug (one pouch makes 8 to 10 pairs, wool),[1] $0.40/pouch	9	17	21	25	30	41	43	37	35
French Laboratory 1938 Marconi Ave. Sacramento, Calif. 95815:									
Soundown Personal Sound Attenuators,[2] $10.50/pair	21	23	26	31	35	42	39	39	34
Frontier Industrial Prod. 3521 Sunset Blvd. Los Angeles, Calif. 90026:									
Antinoise ear plugs (wax-impregnated cotton),[1] $0.55/pair	18	22	22	28	29	38	36	36	37
Human Acoustics, Inc. 888 E. Williams St. Carson City, Nev. 89701:									
Halco safety earpiece, No. VCP 60,[3] $27.50/pair	3	3	5	10	26	29	25	21	17
Mine Safety Appliances Co. 201 N. Braddock Ave. Pittsburgh, Pa. 15208:									
Ear Defenders, V 51 R, insert, $0.63/pair	22	22	25	28	31	36	28	30	25
Mark II-M muffs, headband, $6.00 each	18	23	33	42	35	40	41	39	38
Mark IV muffs (muff can be worn in any suspension position), $6.00 each	12	16	27	35	37	41	46	42	43
Oto-Cure, Inc. 3175 Christy Way Saginaw, Mich. 48602:									
Ceps[3] $25.00/introductory kit, $3.70/kit subsequently	14	13	17	20	29	32	39	38	34

See footnotes at end of table.

TABLE A-1. - Attenuation data of ear protectors, dB, octave bands, Hz--Continued

Attenuation, dB	125	250	500	1,000	2,000	3,000	4,000	6,000	8,000
Safety Ear Protector Co. 5356 W. Pico Blvd. Los Angeles, Calif. 90019:									
Sepco ear protector, insert, $1.25/pair	11	13	14	19	23	29	31	39	45
Sigma Engineering Co. 11320 Burbank Blvd. North Hollywood, Calif. 91601:									
Comfit insert, $1.25/pair	18	24	25	24	32	40	44	40	41
Auri-Seal insert, $1.98/pair	24	33	32	33	39	43	44	38	40
Sound Master Co. 1520 Broadway, Oakland, Calif. 94612:									
Noise Attenuator,[3] $7.80/pair	19	20	23	24	34	42	44	39	42
Stayrite, Inc. 20-19 37th Ave. Long Island City, N.Y. 11101:									
Series "A," olive shape, straight, $0.75/pair	21	25	21	23	27	32	38	43	52
Series "B," olive shape, curved, $0.75/pair	17	21	19	21	27	30	35	38	49
Series "C," flanch top insert, $0.65/pair	18	22	15	21	27	28	25	30	47
Surgical Mechanical Research Inc. Box 1185,960 W. 16th St. Newport Beach, Calif. 92663:									
Insert, $1.50/pair	30	31	34	32	34	39	43	43	43
U.S. Safety Service Co. 1535 Walnut St. P.O. Box 125 Kansas City, Mo. 64108:									
Insert, $0.63/pair	24	21	23	29	30	35	31	29	27
Muffs, series 840000, headband, $11.00 each	15	23	31	38	37	-	44	-	31
Welsh Mfg. Co. 9 Magnolia St. Providence, R.I. 02909:									
Muffs, model 4510, $4.75 each	15	23	31	38	37	-	44	-	31
Willson Products Div. ESB, Inc. P.O. Box 622 Reading, Pa.									
Sound Silencer, insert, $1.50/pair	22	25	25	27	33	41	44	40	38
Muffs, No. 360, $6.25 each	19	27	37	44	41	-	46	-	42
Muffs, No. 360A, $6.75 each	21	24	35	46	42	-	45	-	41
Muffs, No. 258, headband (fluid-filled ear cushion), $12.60 each	16	19	34	46	40	44	53	52	40
Muffs, No. 250, $7.35 each	8	17	26	34	35	40	40	31	25
Muffs, No. 151, $7.30 each	10	17	27	35	35	-	43	-	32

See footnotes at end of table.

TABLE A-1. - Attenuation data of ear protectors, dB, octave bands, Hz--Continued

Attenuation, dB	125	250	500	1,000	2,000	3,000	4,000	6,000	8,000
Willson Products Division ESB, Inc.--Continued									
Muffs, No. 151A, backband (fluid-filled ear cushion), $7.80 each	11	16	25	37	35	-	36	-	30
Muffs, No. 150, headband, $7.30 each	14	16	32	43	39	30	48	47	42

[1] Insert--molded by user.
[2] Insert--molded from ear-canal impressions.
[3] Insert--cast in place.
NOTE.--Discounts are available for quantity purchases.

TABLE A-2. - Additional suppliers of ear protectors

Company	Address	Type of protectors
AMF Beaird, Inc.	P.O. Box 1115 Shreveport, La. 71102	Muffs.
Bausch & Lomb, Inc.	635 St. Paul Street Rochester, N.Y. 14602	Muffs.
General Electric Co.	Medical Development Op. Bldg. 5, Room 127 Schenectady, N.Y. 12305	Insert plugs cast in place.
Glendale Optical Co., Inc.	130 Crossways Park Drive Woodbury, N.Y. 11797	Muffs, plugs (preformed).
Heckler Bros., Inc.	22-19 37th Avenue Long Island City, N.Y. 11101	Plugs (preformed).
Safeline Products	P.O. Box 550 Putnam, Conn. 06260	Muffs, plugs (preformed).
Sellstrom Mfg. Co.	Sellstrom Industrial Park 240 Hicks Road Palatine, Ill. 60067	Muffs.
Wade Products Co.	109 E. 29th Street New York 10016	Plugs formed by user.

NOTE.--Information on cap-mounted ear muffs is not included in tables A-1 and A-2, inasmuch as the author has not seen attenuation data for this type of protector per ANSI standard Z24.22-1957.

APPENDIX B.--EQUIPMENT SUPPLIERS

Only those sound level meters which meet specifications of the American National Standards Institute (ANSI) Standard S1.4-1961 or more rigid specifications are recommended. While the frequency range, sound level range, tolerances, and other characteristics of these instruments may have many similarities, the prospective user should compare them for other mechanical features.

The octave band analyzer is an instrument that is used to separate the overall measurement of noise or complex sound into bands of noise. The instrument consists of an input attenuator for controlling the input level to the amplifier, an amplifier that is part of the filter circuit, and a separate output amplifier and meter circuits. It can be used either directly with a microphone or on the output of a sound-level meter or vibration meter.

Following are lists of manufacturers and suppliers of meters and audiometric equipment. The lists are not complete and presence of a supplier's name does not imply endorsement of the equipment by the author or the Bureau of Mines, nor does omission from the list necessarily imply disapproval.

Suppliers of sound level meters and octave band analyzers include the following:

B and K Instruments, Inc
5111 W. 164th Street
Cleveland, Ohio

Conwed Corporation
2200 Highcrest Road
St. Paul, Minn. 55113

General Radio Company
300 Baker Avenue
Concord, Mass. 01742

Hewlett-Packard
1501 Page Mill Road
Palo Alto, Calif. 94304

Ithaco, Incorporated
735 W. Clinton Street
Ithaca, N.Y. 14850

Korfund Dynamics Corporation
81 Cantiague Road
Westbury, N.Y. 11590

Rohde & Schwartz Sales Co., Inc.
111 Lexington Avenue
Passaic, N.J. 07055

Meters and calibrators to be used in potentially explosive atmospheres such as gassy mines must have been tested and approved for such use by the Bureau of Mines. Approved equipment bears the Bureau's approval plate.

A variety of other instruments are available for specific tasks. These include impulse meters, vibration meters, tape recorders, oscilloscopes, graphic recording analyzers, stroboscopes and auxiliary equipment.

Manual audiometers can be purchased for about $400 and up, whereas automatic units will cost approximately $1,600.

The following is a partial list of suppliers of audiometers:

Beltone Electronics Corporation
Audiometric Instruments Division
Beltone Building
4201 W. Victoria Street
Chicago, Ill. 60646

Grason-Stadler Company
Concord, Mass. 01742

Maico Hearing Instruments
7375 Bush Lake Road
Minneapolis, Minn. 55435

Tracor Medical Instruments
6500 Tracord Lane
Austin, Tex. 78721

Zenith Sales Corporation
6501 W. Grand Avenue
Chicago, Ill. 60635

The following companies also have other noise and vibration control devices and services available, such as mufflers, sound absorption and barrier systems and vibration isolation systems:

Areo Acoustics Corporation
P.O. Box 65
Amityville, N.Y. 11701

AMF Beaird Co., Inc.
P.O. Box 1115
Shreveport, La. 71102

Audio Suttle Corporation
50 Keeler Avenue
Norwalk, Conn. 06854

Barry Controls
Division Barry Wright Corporation
700 Pleasant Street
Watertown, Mass. 02172

Dynasonic Systems, Inc.
4814 Cass
Dallas, Tex. 72535

Eckel Industries, Inc.
155 Fawcett Street
Cambridge, Mass. 02138

General Acoustics Corporation
12248 Santa Monica Blvd.
Los Angeles, Calif. 90025

Industrial Acoustics Co., Inc.
380 Southern Blvd.
Bronx, N.Y. 10454

Koppers Company, Inc.
200 Scott Street
Baltimore, Md. 21203

Korfund Dynamics Corporation
Cantiague Road
Westbury, N.Y. 11590

Overly Manufacturing Co.
574 W. Otterman Street
Greensburg, Pa. 15601

Rink Corporation
P.O. Box B
Hazelton, Pa. 18201

Starrco Company, Inc.
711 N. 9th Street
St. Louis, Mo. 63101

APPENDIX C.--SUGGESTED READING

Reading for anyone who wishes to pursue the subject matter in more detail is recommended, as follows:

Industrial Noise Manual ($15)
American Industrial Hygiene Association
210 Haddon Avenue
Westmont, N.J. 08108
Attn: E. Lynn Schall, Managing Director

Handbook of Noise Measurement ($2)
General Radio Co.
West Concord, Mass. 01742

For the acoustic engineer and advanced student interested in noise control the following are recommended:

Handbook of Noise Control ($22)
by C. M. Harris
McGraw-Hill Book Co., Inc.
330 W. 42nd Street
New York 10036

Noise Reduction ($20)
by L. Beranek
McGraw-Hill Book Co., Inc.
330 W. 42nd Street
New York 10036

INT.-BU.OF MINES,PGH.,PA. 17991

BIBLIOGRAPHIC DATA SHEET	1. Report No. BuMines IC 8564	2.	3. Recipient's Accession No. PB-214 644
4. Title and Subtitle Hearing Conservation for the Mineral Industry			5. Report Date January 1973
			6. Performing Organization Code
7. Author(s) Raymond Derzay			8. Performing Organization Rept. No. BuMines IC
9. Performing Organization Name and Address Denver Technical Support Center Bureau of Mines, USDI Building 55, Denver Federal Center Denver, CO 80225			10. Project/Task/Work Unit No.
			11. Contract/Grant No.
12. Sponsoring Agency Name and Address Health and Safety Technical Support Bureau of Mines, Assistant Director U.S. Department of the Interior Washington, DC 20240			13. Type of Report & Period Covered Research, Final report
			14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstracts

This publication describes effective programs for preventing noise-induced hearing loss in the mineral industry. Factors involved in this loss, and the need for and requirements of an effective hearing conservation program, are discussed. The legal and legislative history of compensation for hearing loss is briefly reviewed.

A review of other aspects of the problem of industrial noise in terms of medical, physiological, and psychological frames of reference is included. A hearing conservation program is described in detail.

Appendices detailing names and addresses of a few equipment suppliers are included. References are provided for those who may wish to delve more deeply into the medical, technical, and scientific considerations of noise and its effect on man.

17. Key Words and Document Analysis. 17a. Descriptors

Key Words	Code	Descriptor
Mining	2001	Acoustics
Noise	0616	Physiology
Deafness	0619	Stress physiology
Economics	0617	Protective equipment
Control Sequences	0510	Psychology
Protective Equipment	1402	Laboratories
Threshold	0503	Economics
Survey		
Audiometry		
Training		

17b. Identifiers/Open-Ended Terms

17c. COSATI Field/Group 05E

18. Distribution Statement	19. Security Class (This Report)	21. No. of Pages
Release unlimited by NTIS.	UNCLASSIFIED	
	20. Security Class (This Page) UNCLASSIFIED	22. Price

FORM NTIS-35(10-70) US COMM-DC 40329-P71