

IV. REVIEW OF EFFECTS OF NOISE ON MAN

Exposures to noise levels found at the workplace, particularly in mechanized industries, are likely to be the most intense and sustained of any experienced in daily living. As such, they represent the severest form of acoustic insult to man and therein pose the greatest harm to human function. Real or alleged effects of occupational noise exposures include the following:

- Temporary and permanent losses in hearing sensitivity.
- Physical and psychological disorders.
- Interference with speech communications or the reception of other wanted sounds.
- Disruption of job performance.

These different listed effects of noise can be classified in various ways. For example, the first two effects can be treated in the context of health or medical problems owing to their underlying biological basis. That is, noise-induced hearing loss, as will be described later, involves damage to the cell structures of the hearing organ, and physical or psychological disorders due to noise presume alterations in normal physiologic or nervous system responses. In contrast, the remaining two effects, interference with sound reception and performance loss, are deemed annoyance or economic problems since they involve no pathology or physical dysfunction to the organism.

The aforementioned noise effects can also be classified as "auditory" and "extra-auditory" in nature. In this regard, hearing loss and speech interference caused by noise are deemed auditory effects since they both involve disturbance to the hearing organ and/or its functional processes.

Noise effects on physical and psychological health states and/or performance represent extra-auditory effects in that they extend beyond or are apart from auditory experience per se.

The intent of this part is to summarize current knowledge of these various adverse effects of noise as it relates to occupational noise conditions, and to establish their importance relative to needs for noise control in industry.

Hearing Loss

The ear is the organ structure of the body especially adapted and most responsive to the pressure changes underlying airborne sounds or noise. Anatomically, it is divided into three subdivisions - the outer, middle, and inner ear. Some key structures within these subdivisions are shown in Figures 3 and 4. The principal functions of the outer and middle ear are to collect and transmit sound pressure to the inner ear where the hair cell receptors for hearing are located. The latter are arranged in several rows along the entire length of the basilar membrane, one of two partitions which spiral around the bony axis of the cochlea. These hair cells together with their supporting cells comprise the Organ of Corti, the auditory sense organ.

Outer and middle ear structures are rarely damaged by exposure to intense noise, although explosive sounds or blasts can rupture the eardrum and possibly dislodge the ossicular chain.⁷ These disorders prevent or reduce the normal passage of sound energy from the outer to the inner ear and therein create a conductive-type of hearing loss. More commonly, excessive noise exposure produces hearing loss of a neural type involving

injury to the hair cells of the inner ear. Histological studies of animal ears subjected to a high level noise have confirmed the site and extent of damage to the cell structures of the Organ of Corti.^{8,9} These observed lesions closely resemble those in post-mortem specimens of ears of humans known to have had prolonged high level noise exposure. Figure 5 illustrates different degrees of injury that excessive noise might cause in a section of the Organ of Corti. For proper perspective it is important to realize that the degree of hearing loss actually produced by noise not only depends upon the severity of damage at one location but also on the extent of such damage along the length of the Organ of Corti. "In this regard, the upper part of the cochlea is broadly responsive to low frequency stimulation and loss of hair cells here can be quite extensive without showing a corresponding change in low frequency sensitivity. On the other hand, much more localized portions of the basal region of the cochlea are responsible for high frequency sound sensation. Hence, less extensive losses of hair cells in these lower portions are reflected in sensitivity changes for such sounds."¹⁰

Many theories have been proposed to explain noise-induced injuries to the Organ of Corti. One is that vigorous stimulation of the hair cell structures by high level sounds subjects them to shearing forces or other mechanical stresses that may jar them loose from their supporting cells or otherwise damage them.¹⁰ Another is that constant intense sound stimulation forces the hair cell receptors to high metabolic levels that cannot be maintained. As a result, the metabolic processes essential for cellular life become exhausted or poisoned, leading to the death of the cells involved.^{11,12}

Since direct observation of the cell structures of the intact ear on a live human is impossible, injury to these parts are inferred from audiograms which show losses in threshold hearing levels for certain pure tone frequencies relative to some reference value. Such losses, when due to noise, may be of a temporary or permanent nature. Temporary hearing loss, more usually called temporary threshold shift or TTS, can be produced by brief exposures to high level sound and shows recovery following a period of time in quiet. Figure 6 describes an example of TTS caused by a two-hour exposure in the laboratory to a broad-band noise of fairly high level (103 dBA). In this instance an audiogram was taken on the listener just before and at various times after the cessation of the noise exposure. Differences between pre- and post-exposure threshold levels for the specified test frequencies display the amount of TTS induced by the noise. TTS is greatest immediately after exposure and progressively diminishes with increasing time in the quiet, reflecting ear recovery from the apparent noise overstimulation.

As a general rule, a noise capable of causing significant TTS with brief exposures is probably capable of causing significant permanent losses in hearing, given prolonged or recurrent exposures. In fact, some limited evidence from animal studies suggests the presence of minor hair cell damage even in those ears showing complete recovery from noise-induced temporary threshold shift.¹³ In any case, daily exposures to TTS-producing noises for several hours per day for months or years would pose a risk of permanent hearing loss. That is, the ear is not likely to recover completely with recurrent exposures of this type. Rather, only partial recovery may occur

in due course with new resting thresholds established, poorer than those found at the beginning of the overall noise experience. This residual loss is indicative of permanent hearing damage. Figure 7 describes these permanent losses in one group of employees as a function of their years of exposure to workplace noise levels approximating the level used in the TTS example above.¹⁴ The TTS component in the losses evident in these hearing data was eliminated by allowing sufficient time after the workshift ended before taking audiograms on the worker group. Deductions have also been made in the hearing levels to remove those hearing changes related to aging (i.e., presbycusis).

Figure 7 indicates that the most significant noise-induced hearing losses occur first in the high frequency range, most prominently at 4,000 cycles per second or Hertz (Hz). Decreased sensitivity to these high frequency sounds may go unnoticed by the listener since they are relatively unimportant to speech reception. With increasing exposure years, however, the losses grow and also broaden to involve other frequencies which are more critical to speech reception, namely, those in the range 500 to 3,000 Hz. In actuality, in the United States, generally accepted procedures for rating hearing handicap for speech consider losses only at frequencies 500, 1000, and 2000 Hz on the audiogram.¹⁵ Controversy centers around the need to include 3000 Hz in these judgments since consonant discrimination may depend on hearing sensitivity for sounds higher than 2000 Hz.^{16,17,18}

The pattern of permanent hearing loss shown in Figure 8 seems typical of noise-induced hearing damage as revealed in noise and hearing surveys in assorted industries (see Table IV). Why high frequency hearing, particularly around 4000 Hz, shows most vulnerability to noise is not altogether

clear. One possible explanation is that the resonant frequency of the ear canal is in region 2000 - 5000 Hz which, in effect, adds strength to corresponding frequencies in an incoming noise signal.^{19,20}

Complicating evaluations of hearing loss due to industrial noise are a number of factors. First, hearing sensitivity normally decreases with age, and these losses (presbycusis) are quite similar to those caused by excessive noise, i.e., differentially greater losses at the higher frequencies.^{21,22} Consequently, how much of an employee's hearing loss is due to occupational noise exposure? -- and how much due to his age? Hearing data for different age and sex groups with negligible noise exposure can be used to supply correction factors to remove the aging component from audiograms collected on noise exposed employees. These presbycusis corrections are also incorporated in workman's compensation formulae used by different states in rating hearing loss disability from occupational noise exposure.

Other causes of hearing loss besides noise and age include use of drugs, illness and disease processes, blows on the head.²³ Special audiometric procedures are sometimes necessary to diagnose a given case of hearing loss in order to determine the likelihood that it may have been caused by excessive noise rather than other agents.

Even when there is clear audiometric evidence of noise-induced hearing loss, questions may be raised as to whether such damage was produced entirely by workplace noise. It is apparent that off-job noise conditions, particularly in recreation, can pose some risk of hearing change by themselves or can exacerbate the acoustic insult associated with the job situation.²⁴

While indicating the need for close appraisal of audiometric results, the aforementioned complicating factors should not be construed as minimizing the seriousness of noise and hearing loss problems in industry. As will be noted in subsequent section, noise surveys in assorted manufacturing, construction, mining, transportation and farm operations indicate exposure conditions potentially harmful to millions of workers. Indeed, the population at risk with regards to noise-induced hearing loss may be greater than any other hazard in the work environment. Audiometric data already collected on samples of employees in many of the jobs surveyed above for excessive noise show them to have poorer hearing relative to other groups of workers not so exposed. Composite reviews of published occupational noise and hearing studies are found in Bell,²⁵ and Passchier-Vermeer,²⁶ and the Intersociety Guidelines.²⁷ A number of individual survey studies are listed in Table IV.

Recognition of industrial noise hazards to hearing have spurred research to identify noise exposure factors and other variables of consequence to the development of temporary and permanent threshold changes. These variables are cited below together with some summary statements describing their implications to threshold shift in hearing.

a. Overall sound level: Sound levels must exceed 60 - 80 dBA before a typical person will experience TTS even for exposures that last as long as 12 - 24 hours.¹³ Other things equal, the greater the intensity over 60 - 80 dBA, the greater the amount of TTS. Relationships between permanent threshold loss and noise exposure at work suggest that such losses could occur under conditions comparable to those noted for TTS above, given long-term, repeated exposures.^{26,27}

b. Noise Spectra: Most common sounds and noises are each composed of many different frequencies within the audible frequency range. The spectrum of these sounds refers to the manner in which their acoustic energy is distributed across the component frequencies. In general, noises having most energy above 1500 Hz are more potent in causing threshold shift than are those with most energy below this frequency.^{28,29} Also, strong pure tones are potentially more noxious to hearing than broader bands of sound stimulation of equal sound level.³⁰⁻³²

c. Total Duration: Other things equal, the longer the time in noise, the greater the amount of threshold shift. With regard to TTS, exposure durations beyond 8 - 16 hours may not produce further increase in the magnitude of the shift measured within a few minutes after cessation of the exposure.¹³ However, it does result in a slower recovery. The amount of permanent threshold shift at the most noise sensitive hearing, 4000 Hz, seems to reach an asymptote after about 10 to 12 years of exposure to the same noise.^{26,32} Further losses at this frequency with continuing exposure appear to be due to the aging process. For test frequencies below 4000 Hz this is not true.

d. Temporal Distribution of Noise Exposure: Interruptions in noise exposure (intermittency) reduces the amount of temporary as well as permanent threshold shift over that obtained with continuous noise at equal levels during on-periods.³³ The increased ear tolerance to intermittent noise exposure may depend on the sound level present during the quiet intervals as well as during the noise segments. The number and length of quiet periods relative to the amount of noise on-time also influences the potentiality of threshold shift.

e. Individual Differences in Ear Tolerance to Noise: Susceptibility to TTS and permanent threshold losses from noise may vary greatly among individuals. This has prompted attempts to develop techniques for identifying those persons with tender ears. Such tests have largely involved TTS measurements following certain test exposure conditions, the notion being that persons displaying the greatest amount of TTS would be most vulnerable to permanent hearing loss.³⁴ Unfortunately, differences in TTS susceptibility are not uniform across the audible range of frequencies. That is, vulnerability to TTS from low, middle, and high frequency noise may be relatively independent. Even more important, data actually validating relationships between TTS and permanent threshold loss for the same subject group are lacking.

f. Type of Noise: Most of the discussion here has dealt with steady-state noise or sounds which predominate in industrial operations. Another class of sounds are those produced by explosive discharge of gases, termed an impulse, or by objects being struck together, called an impact. Individual impulse and impact sounds can be characterized in terms of their rise time, peak sound level, and pulse duration. Available data from TTS studies indicate that ear tolerance to impact peak sound pressures is greatly reduced by increasing the rise time and/or burst duration of the sound.^{35,36} Obviously, the rate and number of such impact sounds constituting an exposure period are also factors in making hazard judgments for these types of sounds. Noise and hearing surveys in industry dealing with these types of exposure conditions are just beginning. Most permanent hearing loss data reflecting impulse noise hazards have been based on military studies involving gunfire.

Physical and Psychological Disturbances

Aside from hearing loss, noise may trigger changes in cardiovascular, endocrine, neurologic, and other physiologic functions,^{35,37-39} all of which are suggestive of a general stress reaction. These physiologic changes are produced typically by intense sounds of sudden onset, but can also occur under sustained high level or even moderately strong noise conditions. Whether repeated noise induced reactions of this type can ultimately degrade one's physical and mental health is still uncertain. For example, the aforementioned physiologic changes tend to subside with recurrent exposures to the same sounds, suggesting adaptation and presumably no health difficulty. These observations, however, may not have been conducted over a sufficiently long time period to judge the possible long-term cost of this adaptation to the health of the organism.⁴⁰

There are some reports which show that prolonged exposure to high level noise may lead to physiologic disorders in animals. For example, Anthony and Ackerman reported that guinea pigs presented with intense siren-type noises for fairly long periods of time eventually revealed endocrine and metabolic deficits which reduced their ability to cope with the noise stress.⁴¹ Additional siren exposure here resulted in gastrointestinal ailments, cardiovascular disease and even tissue damage in the kidneys and liver. Reproductive dysfunction and reduced resistance to infectious disease have also been reported in animals subjected to recurrent or prolonged high level noise conditions.^{42,43} The results of these studies have not been without criticism.^{10,37} In some instances, they have lacked for certain controls, e.g., handling of test animals in noise but not in non-noise groups, or not differentiating the groups. Also, rodents have often been used as subjects, and these animals are known to have special

susceptibility to the effects of certain sounds. Furthermore, the sound levels used in many of these experiments have usually been well above those normally encountered by man even in the noisiest environmental situations.

With regard to human exposures, there are indications in the foreign literature which suggest that routine exposures to intense industrial noise might lead to chronic physical disturbances. A German study, for example revealed a higher incidence of circulatory and neurologic irregularities among steel workers in noisy jobs as compared with other worker groups in less noisy plant areas.⁴⁴ Neurological examinations of Italian weavers exposed daily to intense noise showed their reflexes to be hyperactive, and in a few cases, electroencephalography traced a pattern of desynchronization similar to that seen in personality disorders.²⁵ A study in the Russian literature showed workers in noisy ball-bearing and steel plants to have a relatively greater prevalence of cardiovascular irregularities such as bradycardia.⁴⁵ Complaints of fatigue, irritability, and social conflicts in many noise exposed workers have also been reported in connection with several of the investigations just noted.^{25,44}

The fact that those who work in high noise levels show greater medical difficulties than those who work under quieter conditions is not conclusive evidence that noise is the crucial causal factor. In each case, it is possible that the differences in the specified health parameters may be explained by other factors such as age, other environmental contaminants, work load and job habits. In any case, replication of these findings seems indicated with attempts being made to statistically isolate and better control factors that could confound possible noise effects on a variety of health indicators.

Concern may be raised as to whether excessive noise poses any added hazards to persons with preexisting health problems. The literature references individual cases where noise has provoked seizures in certain persons with epilepsy or caused headaches in those suffering from migraine problems.^{46,47} The generality of these findings remains to be demonstrated. In fact, little systematic information is available describing the stress tolerance of persons with chronic neurologic, cardiovascular, and gastrointestinal ailments. Presumably, it would be lower than that for individuals in normal health. There is also a great likelihood that those unduly distressed by noise or other stress-producing conditions would remove themselves from the sources of such disturbances.

It is evident from this discussion that no statements can be offered in terms of dose-response relationships between noise and the occurrence of physical and psychological disturbances. It must be emphasized, however, that noise limits designed to provide hearing protection should also reduce the possibility of any extra-auditory health disturbance. That is, the ear owing to its sensitivity to acoustic energy is most vulnerable to damage from overexposure to sound. Other bodily functions, less sensitive to sound stimuli, would not appear as prone to noise-induced alterations or damage.

Interference with Sound Reception

The most demonstrable effect of noise is masking or the interference with the reception of wanted auditory signals, notably speech. Noise conditions not intense enough to cause hearing damage may still interfere with desired sound transmissions. Table V describes the nature of speech

communications possible under different ambient noise levels. Even moderate noise levels would require use of a loud voice or shouting to communicate effectively, especially for distances of 10 feet or more between talker and listener. Telephone use can also be affected.

In industry, lack of adequate speech reception due to noise masking can degrade efficiency in those jobs dependent on such functions.⁴⁸ Inability to hear warning signals or shouts of caution because of noise have also been implicated as a causal factor in worker accidents.⁴⁹ While this is plausible, data to support the latter contention are not available.

Special measures for rating or predicting the masking effects of noise have been developed which take account of the acoustic energy found within those frequency bands of noise which encompass the critical speech frequency range.³ These measures are used in defining acoustic requirements for offices or other living spaces where speech and other forms of sound reception serve important functions.

Interference with speech reception by noise or masking can take place under noise conditions which may be safe for hearing. This problem is specific to offices or other work areas where communication needs can be critical to job functions. Acoustical design criteria for assuring the adequacy of speech reception in these workplaces are available.

Disruption of Job Performance

The effects of noise on performing tasks for which voice communications are unnecessary are quite variable and appear to depend on the acoustic conditions present, features of the task being performed, and the attitude or make-up of the performing person.^{38,50-52} With regard to acoustic factors,

repeated impulse and intermittent sounds of high level appear more likely to disrupt performance than continuous or steady sounds of comparable level.^{53,54} Impulsive sounds have the more notable effects which are largely confined to the brief periods during or immediately following their occurrence. Intermittent noise exposure may cause losses in performance that are not specific to the on-times of the noise.³⁸ That is, losses in performance may occur when the noise appears and also when it disappears. Apparently, change in noise levels is the degrading factor. Of interest here is that sound levels required to cause notable performance changes may exceed hearing conservation limits for routine workday exposure. Thus, noise standards for safeguarding hearing could also offset possible noise effects on job efficiency.³⁸

More moderate levels of noise may actually benefit task performance relative to quiet conditions. The presence of such noise may provide for a more uniform acoustic background, masking stray sounds which could be otherwise audible in a quiet work area and cause distraction. Also on the positive side, pulsating-type sounds may pace or drive performance and, in effect, reduce fatigue on tasks that are trying. The rhythm component in music may serve this purpose too.⁵⁵

Not all performance capacities suffer equally from the disruptive effects of noise. In fact, noise may aid performance on simple, well-practiced or repetitive tasks through causing increased arousal in an otherwise boring job. There are indications in fact, that only those tasks which require unremitting attention (e.g., vigilance in machine monitoring, product inspection) or which place extreme mental demands on

the employee (short-term high-memory loads) may be most vulnerable to the degrading effects of noise.⁵¹ In short, tasks which by themselves tax the total capacity of the individual do not permit any accommodation to noise and consequently show loss. In some instances, noise seems more inclined to disturb the quality rather than the quantity of work. That is, noise might not change work output, but may cause more errors. Along these lines, performance under noise may be subject to worker fluctuations, with periods of poor performance being interwoven with periods of heightened effort.⁵⁶ These performance swings, when averaged across the total work session, may yield little or no overall performance decrement.

Individual differences are quite commonly found in investigations of noise effects on performance. Attitudes toward noise are a basic factor in this variance. A recent laboratory study found subjects sensing that they had no control over randomly occurring noise intrusions to perform poorer than those who could terminate such sounds.⁵⁷ Personality factors also seem to underlie performance variations in noise. Tense, anxious persons, as defined by personality inventories and certain physiologic indicators, seemed less able to cope with certain laboratory tasks as compared with those who were more relaxed.⁵⁸

The importance of attitude factors in noise-performance studies is even more evident in field investigations. For example, morale and ego-involvement in one's job can override stresses imposed by noise.⁵⁹ Other employees dissatisfied with their job situations can use noise as a "scape-goat" for poor performance. It should be mentioned, too, that through a process of self-selection, only the more noise tolerant employees probably stay at a noisy job. The more noise sensitive persons would remove themselves from these situations. Measures of absenteeism and labor turnover could

reflect the latter occurrences, but could be difficult to relate causally to noise.

The numerous factors that can influence noise effects on performance make for highly qualified conclusions and conservative predictions. Generally speaking, intense sounds, preferably impulsive, and a taxing task performed by a tense person offer the combination of conditions most likely to display a noise-induced decrement in performance.

Cumulative Effect

This discussion has separately treated different adverse effects of noise that may result from occupational exposures. It is unrealistic, however, to conceive of employees in their everyday job routines experiencing one form of noise disturbance to the exclusion of the others. Indeed, one's daily encounters with workplace noise may degrade hearing, mask reception of desired sounds, heighten emotions and physiologic activity, disrupt concentration, or otherwise hinder job efficiency or safety. The collective impact of these noise effects clearly poses a significant challenge to the employee's health, productivity, and well-being.

The establishment of noise exposure limits for safeguarding the employee's hearing will in the main prevent the occurrence of the worst physical defect that noise can have in humans. Adherence to these limits may also have other benefits. Specifically, physical and psychological disturbances from occupational noise exposures will be less likely to arise under more controlled exposure conditions. Of course, the question remains as to whether excessive noise by itself can cause physical and mental disorders. Nevertheless, noise levels which meet hearing conservation requirements may also be within limits that do not cause losses in job performance.

V. PROCEDURES FOR REDUCING EXPOSURES

The information in this part (1) substantiates the existence of a considerable number of industrial employees who are exposed to potentially hazardous noise levels; (2) presents noise levels for selected industrial operations; and (3) describes procedures for reducing hazardous noise exposures in the industrial setting.

Survey Data for Estimating Noise Exposed Population

In response to a questionnaire survey conducted by the NIOSH 341 plants in 24 states involved in 18 different types of manufacturing procedures reported the information listed in Table VI.⁶⁰ The table is not an attempt to present exact figures as to how many employees are exposed to hazardous noise levels; rather it substantiates that noise is indeed a common occupational hazard which could affect a large number of employees. The companies were asked to answer the following question: "How many of your employees are located in areas where noise levels are 90 dBA or above?"

When this question was asked in August 1971, the recommended level for an 8-hour exposure limit was still 90 dBA, however, it can be assumed that a greater population is at risk. In interpreting the answers to the question stated in the preceding paragraph and the results which appear in Table VI the following points must also be considered:

1. The answers from this question cannot be used to determine how many employees are incurring hazardous noise exposures because information concerned with length of exposure time and the exact level of the exposure is not available.
2. The 341 plants volunteered this information, and the information is based upon their own noise level evaluations.
3. Many other plants involved in the questionnaire survey could not or did not answer the question.
4. The table does not contain information concerned with the 4,511,000 transportation workers, the 3,502,000 construction workers, the 626,000 miners, or the 4,746,000 agricultural workers.

The projected numbers of employees located in areas of noise 90 dBA or higher were computed by multiplying the number in the total work force of a particular industry by the percentage of work force reported to be exposed to 90 dBA. The total work force populations were based on August 1, 1971, Department of Labor figures.⁶¹

Noise Levels for Selected Industrial Operations

Over the past twenty-five years, numerous noise surveys have been made in a wide variety of occupational settings. A listing of selected surveys that included both noise and hearing is presented in Table IV.

Table VII presents samples of noise levels actually measured for a variety of industrial operations. In each case the noise was generated by operating machinery, and each dBA level listed represents observations taken in operation areas.

The list is intended only to give a general impression of industrial noise levels. For many of the noise sources listed one could expect variations over a range of 20 dBA, or even more, due to such factors as machine type, make, and age; acoustical characteristics of location; design of supporting structure; type of raw material being worked by the machine; idiosyncrasies of operator; location of operator with respect to machine; condition and lubrication of machine.

The data contained in the list have been taken from several Public Health Service surveys and other sources in acoustical and industrial hygiene literature.⁶²⁻⁶⁵

Noise Control

Abatement of environmental noise such as that listed in Table VI is afforded by engineering controls which reduce the intensity of the noise either at the source or in the immediate exposure environment. A number of these procedures will require consultation, and it is recommended that employers avail themselves of the services of a competent acoustical engineer in development of their noise abatement program. However, several controls may be implemented by company personnel at relatively little expense. The following are some examples:

1. In ordering new or replacement equipment, the exposure limits should be taken into consideration. In those areas where several pieces of equipment are to be operated at the same time, it may be desirable to specify individual equipment operating noise levels lower than the limits set by the standard in order to insure compliance with the standard.

2. Maintenance

- A. Replace worn or unbalanced parts in existing equipment.
- B. Maintain proper adjustment of equipment.
- C. Secure all covers or safety shields on machines.
- D. Lubricate all moving parts on equipment.
- E. Use proper coolants.
- F. Use sharp and properly shaped cutting and drilling tools.

3. Substitution of Machines

- A. Substitute belt drives for gears.

4. Vibration Dampening

- A. Increase mass.
- B. Increase stiffness.
- C. Use rubber or plastic linings to dampen noise.
- D. Improve supports.

5. Reduction of Solid-Borne Transmission

- A. Flexible mounts for motors and other types of machinery.
- B. Flexible hose in pipes or electrical conduits.
- C. Flexible coupling on shafts.

6. Reduction of Noise Caused by Fluid Flow

- A. Install or replace intake and exhaust mufflers on internal combustion engines and compressors.

7. Isolate Noise Source

- A. Construct sound reduction enclosures around equipment or parts of equipment.

8. Isolate Operator

- A. Provide a relatively sound-proof enclosure for the operator or attendant of one or more machines.

Of the items listed above, the preferred procedures for reducing environmental noise are those which are directed at reducing the noise at its source (Items 1 - 7). Generally, these procedures have proven to be far more efficient in terms of actual noise reduction than the procedure listed as Item 8. Furthermore, source noise controls provide protection for both the operators of the equipment as well as workers in the immediate exposure environment.

Administrative Controls

Another effective approach to reducing the hazard of excessive noise exposure is to limit the daily amount of exposure which each employee receives, by means of strict control of the work schedule. The following are several methods suggested by the Department of Labor:⁶⁶

- "1. Arrange work schedules so that employees working the major portion of a day at or very close to the criteria limit are not exposed to higher noise levels.
2. Ensure that employees who have reached the upper limit of duration for a high noise level, work the remainder of the day in an environment with a noise level well below criteria limit.
3. Where the man-hours required for a job exceed the permissible time for one man in one day for the existing sound level, divide the work among two, three, or as many men as are needed, either successively or together, to keep individual noise exposure within permissible time limits.
4. If less than full-time operation of a noisy machine is needed, arrange to run it a portion of each day, rather than all day for part of the week.

5. Perform occasional high level noise producing operations at night or at other times when a minimum number of employees will be exposed."

When personnel are rotated, extreme care must be taken to insure that no single employee is exposed to a high level noise for a period longer than is allowed by the noise exposure limits.