REPORT TO THE PRESIDENT AND CONGRESS ON NOISE

December 31, 1971

U.S. Environmental Protection Agency
Washington, D.C. 20460

Wm. E. Roper

NRC500.1

REPORT TO THE PRESIDENT AND CONGRESS ON NOISE

December 31, 1971

Prepared by

THE U.S. ENVIRONMENTAL PROTECTION AGENCY

as required under

The Noise Pollution and Abatement Act of 1970
Title IV to the Clean Air Amendments of 1970
(PL 91-604)

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FOREWORD

Title IV of PL 91-604, signed into law on December 31, 1970 by the President, directed that the Environmental Protection Agency conduct "a full and complete investigation and study of noise and its effect on public health and welfare" and to report, within 1 year, the findings to the Congress. To those ends, authorization was given to the Administrator to hold public hearings and to conduct research, experiments, demonstrations, and studies. The public hearings were held in eight major cities throughout the country, where some 225 witnesses representing the scientific community, industry, and the public gave testimony on all aspects of the noise problem. In addition, the Agency, through its Office of Noise Abatement and Control, developed contracts and otherwise worked closely with a variety of noise experts, both within the Government and from the private sector, to review all aspects of current knowledge about the effects of noise and methods of control.

The result of these extensive efforts is this report to the President and the Congress of the United States. Hopefully, this document will be helpful in the current deliberations on Federal noise control legislation. It should also be useful to state and local governments and the general public in making decisions that will more rapidly solve a problem that affects more Americans than is generally realized.

INTRODUCTION

NOISE, commonly defined as unwanted sound, is an environmental phenomenon to which man is exposed before birth and throughout life. Noise can also be considered an environmental pollutant, a waste product generated in conjunction with various activities of man. Under the latter definition, noise is any sound – independent of loudness – that may produce an undesired physiological or psychological effect in an individual and that may interfere with the social ends of an individual or group. Those ends include all of man's activities – communication, work, rest, recreation, and sleep.

As waste products of his way of life, man produces two general types of pollutants. The general public has become well aware of the first type, the mass residuals (such as associated with air and water pollution) that, to a greater or lesser degree, remain in the environment for extended periods of time. However, only recently has attention focused on the second general type of pollution, the energy residuals such as the waste heat from manufacturing processes that creates thermal pollution of our streams. Energy in the form of sound waves constitutes yet another kind of energy residual, but, fortunately, one that does not remain in the environment for extended periods of time. The total amount of energy dissipated as sound throughout the earth is not large when compared to other forms of energy; it is only the extraordinary sensitivity of the ear that permits such a relatively small amount of energy to adversely affect man and other biological species.

It has long been known that noise of sufficient intensity and duration can induce temporary or permanent hearing loss, ranging from slight impairment to nearly total deafness. In general, any source of sound producing noise levels of 70 to 80 dBA at the ear can contribute to a pattern of exposure that may produce temporary hearing threshold shifts if exposure is long enough, and this in turn could lead to permanent hearing impairment. In addition, noise can interfere with speech communication and the perception of other auditory signals, disturb sleep and relaxation, be a source of annoyance, interfere with an individual's ability to perform complicated tasks, influence mood, and otherwise detract from the quality of life.

Society has, since antiquity, made attempts to abate and control noise. The Romans enacted perhaps the first prohibitory noise law when, by popular decree, chariot movements were prohibited in the streets of Rome during the night. In England, the first reported court decision concerning noise abatement is dated in the thirteenth century. Today, many communities in the United States have antinoise ordinances, although these statutes vary widely in standards, scope, and degree of enforcement.

With the technological expansion that began during the Industrial Revolution and that has accelerated since World War II, environmental noise in the United States and other industrialized nations has been gradually and steadily increasing, with more geographic areas becoming exposed to significant levels of noise. Whereas noise levels sufficient to induce some degree of hearing loss were once confined mainly to factories and occupational situations, noise levels approaching such intensity and duration are today being recorded on city streets and, in some cases, in and around the home.

There are valid reasons why widespread recognition of noise as a significant environmental pollutant and potential hazard or, as a minimum, a detractor from the quality of life has been slow in coming. In the first place, noise, if defined as unwanted sound, is a subjective experience. What is considered as noise by one listener may be considered desirable by another. Even in the same individual, wanted sound on one occasion may be considered as noise on another.

Secondly, noise has a rapid decay time and thus does not remain in man's environment for extended periods of time, as do air and water pollution. By the time the average individual is spurred to action to abate, control, or, at least, complain about sporadic environmental noise, the noise in many situations may no longer exist.

Thirdly, the physiological and psychological effects of noise on man are often subtle and insidious, appearing so gradually and slowly that it becomes difficult to associate cause and effect. Indeed, to those persons whose hearing may already have been affected by noise, it may not be considered a problem at all.

Further, the typical citizen is proud of this nation's technological progress and is generally happy with the things such progress has given him in the way of rapid transportation, labor-saving devices, and new recreational devices. Unfortunately, many technological advances have been associated with increased environmental noise, and there has been a tendency in large segments of the population to accept the additional noise as part of the price of progress.

The scientific community has already accumulated considerable knowledge concerning noise, its effects, and its abatement and control. In that regard, noise differs from most other environmental pollutants. Generally, the technology exists to control most indoor and outdoor noise. As a matter of fact, this is one instance in which knowledge of control techniques exceeds the knowledge of biological and physical effects of the pollutant. These facts have been brought out in previous Federal reports on this problem such as "Noise: Sound Without Value" (Office of Science and Technology) and "The Noise Around Us" (Commerce Technical Advisory Board, Department of Commerce).

ORGANIZATION OF THIS REPORT

This report first addresses the effects of noise on living things and property. Reviewed are: human auditory, psychological, physiological, and sociological effects; effects on wildlife and other animals; effects of sonic boom and similar impulsive noises; and physical effects of noise on structures and property.

Chapter 2 deals with the sources of noise and their current environmental impact. Included in this chapter are discussions on community noise; transportation systems; devices such as lawn mowers and chain saws powered by internal combustion engines; noise from industrial plants; construction equipment and operations; household appliance and building equipment noise; and an assessment of the environmental impact of major noise sources.

Chapter 3 discusses present and future control technology for the noise sources discussed in Chapter 2.

Laws and regulatory schemes are dealt with in Chapter 4. Considered are current governmental noise regulations and regulatory schemes and their effectiveness.

Chapter 5 is concerned with government, industry, professional, and voluntary noise control activities.

Chapter 6 presents an assessment of noise concern in other nations. Among items reviewed are legislation and regulations relating to noise sources and noise environments.

Finally, for those unfamiliar with the terminology of acoustics and noise, a glossary is provided.

The emphasis in this report on noise source control technology should not obscure the importance of other noise abatement procedures. A comprehensive, systematic approach to noise abatement should include, in addition to source control, such features as land use planning and zoning, requirements for noise control in building codes, and standards for enforcement of regulations.

The reader of this report is cautioned that the material presented herein is a condensation of the extensive technical and detailed material contained in the appropriate EPA Technical Information Documents and in the transcripts of the public hearings held by the Agency. As a condensation, generalities may occur, although every effort has been made to qualify statements when required for clarity. Those interested in more detail or verification of information sources should consult the appropriate EPA documents, and the specific references cited therein.

GENERAL OBSERVATIONS AND CONCLUSIONS

The Character of Noise as an Environmental Problem

That sound and hearing play an important role in human life is a proposition so self-evident it requires no further comment. However, some effects of noise on man, such as interference with sleep and communication or noise-produced irritation and annoyance, are difficult to define and evaluate with objective precision.

Sparse information is available on typical cumulative exposures to noise associated with a variety of sources normally present in most of society's current environment. Much of the information contained in this report is concerned with specific sources, although first efforts have been made to estimate the magnitude of cumulative exposures of typical segments of the U.S. population.

Furthermore, there is a general lack of information on the effects of noise on various living nonhuman organisms. It is evident that under certain conditions there may be some ecological effects, particularly when new noises intrude into wildlife habitats. At the same time, certain species seem to show some adaptation to noise. The present state of knowledge in this area is incomplete.

Reasonable evidence exists of the damaging effects of high intensity noise on inert objects. Physical damage to property from sonic booms generated by aircraft has been repeatedly confirmed. As the scale of intensity decreases, there is insufficient valid data regarding direct structural effects on property. Insofar as the effects of noise on property values are concerned, the evidence remains inconclusive.

The data developed in this report and its supporting documents indicates that noise has an impact on the people in the United States. This impact manifests itself by interfering with speech communication, disturbing sleep, and creating other disturbances of life that lead to annoyances. In addition, some noise levels encountered in non-occupational situations may also contribute to the risk of incurring hearing impairment. Since the subject of occupational noise has been extensively covered in connection with the Occupational Safety and Health Act, it is dealt with only by reference in this report.

Noise Control Technology and Possible Changes in the Noise Problem to the Year 2000

Current technology and that expected to be available in the next 5 to 10 years indicate that a substantial reduction in the noise from various sources is feasible.

Application of available technology is lagging because of inadequate social, economic, or governmental pressures for noise abatement. Further, there must be a balance between application of technology to noise sources and the other measures required in controlling the total noise environment, such as land use planning and regulation of source use. In this connection the requirements of the National Environmental Policy Act relative to Environmental Impact Statements (Sec. 102(2)C, PL 91-190) and of the Noise Pollution and Abatement Act of 1970 (Title IV, PL 91-604, Sec. 402(c)) provide a basis for noise control associated with both planned and existing Federal activities. Procedures to accomplish these requirements are now being implemented.

The projections of noise impact conducted for this report clearly indicate the need for aggressive efforts at all levels of government. Without such efforts, residual noise levels in typical urban communities can be expected to rise from the 1970 level of slightly over 46 dBA to just under 50 dBA by the year 2000 (the residual level as used in this report is the lower noise level boundary that is exceeded approximately 90 percent of the time). Of more concern is the estimate that the noise energy from highway vehicles would double by the year 2000. On the other hand, the early and vigorous institution of available technology and comprehensive planning, in conjunction with effective enforcement and regulatory schemes, could reduce the residual to

42 dBA and the noise energy from highway vehicles by a ratio of nearly 4.5 to 1. This latter figure takes into account the estimated growth in the number of noise sources.

An additional significant measure of the situation may be obtained by considering the size of noise-impacted land areas near airports and freeways. The total noise impact area in 1970 is estimated at approximately 2000 square miles, and this area could increase to approximately 3300 square miles by the year 2000. The projected increase in the impact of aircraft noise could be reduced through a combination of actions such as the development and use of quieter aircraft engines, changes in aircraft operating procedures, and tighter regulation and enforcement. More work is needed to clearly identify the relationships among the various actions required, their cost, their effect on impacted areas and the benefits that would result. Comparable actions regarding highway vehicles could also reduce the impact of vehicular noise. As with aircraft noise, the relationships among the various actions required and their costs and benefits need additional investigation.

Methodologies for Noise Measurement and Evaluation

A considerable variety of methodologies and terminologies are presently used to describe, measure, and evaluate noise. Some of these are complex and confusing even to those well versed in acoustics. This bewildering array of terminology, such as PNdB, EPNdB, NEF and CNEL (see the Glossary for description of these terms) represents efforts on the part of voluntary institutions, members of the professions, and segments of governmental authorities to deal with specific situations, problems of measurement, and needs for evaluation techniques. Many terms have some degree of commonality, if not interchangeability, while others simply are not comparable. Similarly, few, if any, were developed with the idea that they might be incorporated in a statutory procedure for noise abatement and attendant legal and enforcement provisions. Even with existing statutory requirements at Federal, state, and local levels, widely different and sometimes conflicting procedures exist.

This problem is further compounded by differences in scientific semantics associated with noise control and evaluation in the private and quasi-governmental usage. The terms criteria and standards have come to have specific meanings regarding the environment as pertains to air and water pollution and other environmental stresses. These terms are loosely used interchangeably in relation to noise. In most texts and nongovernmental standards documents, they often have the same meaning. There is a clear cut need to develop a uniformly understood, adequate scheme for measurement and evaluation of noise.

Economic Implications of Noise and Noise Abatement

Information on the adverse effects of noise and the costs associated with various types of abatement measures are contained in several chapters of this report. In addition, a significant portion of the data developed in the eight public hearings held by the Agency under PL 91-604 relates to economic aspects of the noise problem.

As background material for this report, EPA commissioned a study of the economic impact of noise, which is referenced in the body of the document. However, at this time, the rudimentary state of knowledge regarding costs, benefits, and the impact of abatement expenditures upon the nation's economy make it extremely difficult to perform meaningful economic analysis related to the problem of environmental noise.

In order to evaluate alternative noise abatement strategies, there are three major types of economic factors to be considered. It is desirable to know the magnitude of the benefits derived from proposed actions in terms of damages avoided and positive gains attained. A second factor is the cost of attaining each of the levels of control under study. Finally, an analysis of the impact of these costs upon the economy is needed. With such information, economic analyses can be undertaken to facilitate rational decision-making.

Unfortunately, in the noise area, the currently available data is often imprecise and relates to some limited problem such as the effects of highway noise on property values in selected locations. In general, the data does not exist that would permit good aggregate estimates of the magnitude of noise damage and the cost and impacts of abatement measures.

There is a need for additional research on and analysis of the economic aspects of noise as an environmental problem. More needs to be known about the adverse effects on such factors as health, the quality of life, productivity, and property values; the cost of attaining various levels of control; and the impact of abatement costs on the economy. With a better understanding of these economic considerations, it should be possible in the future to evaluate alternative control strategies and identify cost-effective solutions.

SPECIFICS OF A PROGRAM FOR THE FUTURE

The material developed in preparing this report, and discussed in detail in supporting documents, is supported in the EPA public hearings on noise and leads to one over-riding conclusion: there is a need for improved and comprehensive efforts at all levels of government for environmental noise control. The local and state governments have the primary responsibilities, in most respects, for the actions necessary to provide a quieter environment. This includes land-use planning and zoning, building codes, use regulations and the necessary enforcement programs. However, there are some functions that are best carried out by the Federal government. The Administration's legislative proposals now being considered by the Congress provide the basis for these needed functions. Specific recommendations to achieve the needed objective of a significant reduction of noise over the next 5 to 10 years are embodied in the following recommendations.

1. <u>Federal Leadership in Noise Abatement and Control</u>

Federal governmental programs relating directly to noise research and control are among the activities of several Federal departments and agencies. There is a need for improved coordination of this effort. To that end, it is recommended that:

a. The Environmental Protection Agency should provide the leadership and should promote coordination of efforts of the various agencies that would be responsible for their respective activities.

b. The Federal government should provide leadership in controlling noise associated with its activities.

c. Programs of technical assistance to states and their political subdivisions for regulations and enforcement should be developed.

2. <u>Standards and Regulations</u>

A regulatory scheme should be established, and accelerated noise abatement efforts should be made by local, state, and Federal governments as follows:

a. Federal noise emission standards should be established for the principal sources of environmental noise including:

(1) Transportation equipment -- including aircraft, for which EPA should have authority to approve FAA standards for regulation of aircraft noise.

(2) Construction equipment.

(3) Internal combustion powered devices.

b. Product labeling authority requested in legislative proposals presently being considered is a necessary element in an overall noise abatement and control program.

c. Uniform noise codes, regulations, and standards should be developed by EPA and other Federal agencies, in accordance with the above-mentioned plan, and should be enacted into law by states and localities. Technical assistance should be provided by EPA on enforcement and other related activities.

3. Research and Analysis Needs

Some investment of effort and funds in noise research has already been made at the Federal level (and to a lesser degree in the private sector as brought out in this report). There remain, however, numerous gaps in knowledge and extensive areas of technical and scientific disagreement that require a continuing research effort. To meet these needs, the following steps are recommended:

a. Present Federal research and development on specific noise source control should be continued and expanded, but with a more direct focus on environmental aspects. Such a program should directly involve the considerable expertise already existing in the professional and academic community and in industry.

b. Federally planned, directed, and supported research for improved methodologies of measurement and evaluation are needed. In particular, a critical assessment of a large number of the varying measuring systems and methodologies now in use is required. Simplification, standardization, and interchangeability of data should be the goal of this project.

c. Continuing efforts to determine the noise exposure of the American public should receive early attention.

d. Research on physiological and psychological effects of noise should be continued. Such research provides the basis for the necessary criteria documents to be used in setting standards and in formulating state and local regulations.

e. Analysis of the economic implications and economic impact of noise control is essential in the decision-making process and for the development of realistic standards and should be undertaken as part of the existing EPA investigation of the broader issue of environmental economics.

4. Education and Public Awareness

Although there is awareness of some aspects of the noise problem and control techniques, the typical citizen, while vexed by the intrusion of environmental noise into his life, is generally unaware that methods to alleviate the problem are already at hand. The efforts called for in the above recommendations will lead to the improved information needed to move ahead with effective measures to lessen the impact of noise.

5. Legislative Recommendation

Legislation proposed by the Administration in February 1971 would provide the authority that is needed to meet the problems revealed in the studies leading to this report.

ACKNOWLEDGEMENT

The Environmental Protection Agency gratefully acknowledges the assistance of the many people who contributed to the preparation of this report. Their unselfish contributions have helped make it possible to produce a useful document. Those deserving specific mention are:

Dr. E.K. Bender
Deputy Manager of Applied Physics Dept.
Mechanical Engineer
Bolt, Beranek & Newman

Dr. Alexander Cohen
Acting Director, Behavioral & Motivational Factors Branch
National Institute for Occupational Safety and Health
Dept. of Health, Education and Welfare

Dr. R.K. Cook
Special Asst. for Acoustics
National Bureau of Standards

Kenneth McK. Eldred
Vice President for Engineering
Wyle Laboratories

Dr. John Fletcher
Professor of Psychology
Memphis State University
Division of Research and Services

Louis S. Goodfriend
President
L.S. Goodfriend Associates

Klaus Liebhold
Associate Director
Informatics Inc.

Col. Dale Lindall, USAFMC

Dr. Louis Mayo
Vice President for Policy Studies and Special Projects
The George Washington University

Dr. James D. Miller
Head of Psychology Lab.
Central Institute of the Deaf

Dr. Peter Siegel
Federal Air Surgeon
Federal Aviation Administration

Dr. Henning von Gierke
Director Biodynamics & Bionics Div.
Aerospace Medical Laboratory
Wright-Patterson AFB

Dr. Milton A. Whitcomb
Executive Secretary
Committee on Hearing, Biomechanics & Bioacoustics
National Academy of Science

CHAPTER 1

EFFECTS OF NOISE ON LIVING THINGS AND PROPERTY *

The definition of noise as unwanted sound implies that it has an adverse effect on human beings and their environment, including land, structures, and domestic animals. Noise also affects natural wildlife and ecological systems. Cause and effect relationships between noise and its adverse effects are not always readily demonstrable. Conversely, certain effects of noise on people are clear cut, such as with noise-induced hearing loss.

Physiological and psychological changes in people exposed to noise are less well established than the hearing loss response, since for the most part they are subtle and cannot be distinguished from similar changes produced by other environmental stresses that are byproducts of our advanced technological society. Regarding

* This chapter is based on material prepared by the Staff EPA Office of Noise Abatement and Control as result of testimony received during public hearings and on data contained in EPA reports NTID300. 7, "Effects of Noise on People" (EPA contract 68-01-05000, Central Institute for the Deaf); NTID300. 11, "Social Impact of Noise" (Interagency agreement with National Bureau of Standards), and NTID300. 5, "Effects of Noise on Wildlife" (EPA contract 68-04-0024, Memphis State University). See Appendix A regarding procurement of these source materials, which contain bibliographic references.) The material on the effects of noise on humans in pages 1-5 to 1-32 was reviewed by a special committee composed of members of CHABA of the National Academy of Sciences, National Research Council.

domestic animals, only sparse research data on noise effects is available; and virtually no research data is available regarding wildlife. There also appears to be little information available regarding effects of noise on plant life.

Extrapolation of human data as to effects of noise on domestic animals (or vice versa) cannot be accomplished with any degree of validity, and similar cautions must be applied concerning effects on wildlife. Conclusions derived from such extrapolated data must therefore be labeled tentative, possible, or probable.

The effects of noise, particularly sonic boom and other high intensity intermittent sources, on man-made or natural structures are reasonably well understood. It is possible to conduct well controlled and verifiable damage studies on inanimate material, and such studies have been undertaken, as cited briefly in this chapter. For ethical and other reasons, it is impossible to conduct such studies on people and animals. This is not to say, however, that the entire subject area has not been extensively investigated by a wide variety of researchers and reported in the literature. This chapter summarizes available knowledge on the effect of audible noise on living things and property. It does not consider the effects of nonaudible, high or low frequency sounds (ultra- or infrasound).

As brought out by many expert witnesses appearing at public hearings on noise held under Title IV to PL 91-604, sound and hearing play a subtle and not well understood role in human life. Whether it be the hum of a mosquito or the ringing of a church bell, the hearing process conveys many communications resulting in varying responses: pleasure, annoyance, and, in some instances, intense emotional reactions. Unlike sight with a directional limitation of coverage*, the hearing response allows the comprehen- of signals from diverse sources (such as simultaneous receipt of signals from a crying baby, a ringing telephone, and the audible signalling of the completion of the work cycle of a home appliance -- situations familiar to many housewives).

From the foregoing, it is evident that one of the major values of hearing, in addition to verbal communication, is the detection of objects and events. This phenomenon is evidence of close ties between hearing on the one hand and psychological and physiological activation on the other. Humans can be aroused and alerted by sound (as is true of many animals). Sound often triggers muscular and emotional responses that appropriately prepare people to cope with possible events signalled by the sound.

Of even greater importance is the role of sound and hearing in human speech communication. Perhaps more than any other attribute, this ability sets human beings apart from lower animals. The combination of human vocal capabilities for transmission of sound, the human response in hearing, and the operation of the large complex human brain is fundamental to effective speech communication and the progress of civilization. Much of human social and intellectual life is dependent on the phenomena of speech communication and language. The aesthetic quality of life as reflected in moods and experience are vastly influenced by what is heard. The importance of this consideration is not a newly discovered matter of environmental concern. As quoted by James L. Hildebrand in his article "Noise Pollution: An Introduction to the Problem and an Outline for Future Legal Research, "Schopenhauer in 1844 said, 'I

* The central field of vision for the human eye is approximately 21^{o}, whereas the ear perceives omnidirectionally.

have long held the opinion that the amount of noise which anyone can bear undisturbed stands in inverse proportion to his mental capacity and may therefore be regarded as a pretty fair measure of it. . . Noise is a torture to all intellectual people.' "

When unwanted sounds intrude into an environment so as to affect the ability of people to receive aural communications, noise exists. Sounds that have value in one location may travel to other locations where they may disrupt useful and desired activities, thus changing their character as an element of the environment and becoming noise.

The effects of noise on people have been extensively studied, classified, and, to some degree, quantified. In the main, the effect of audible-acoustical energy on people falls into four general overlapping categories:

1. Demonstrable hearing loss, accompanied by any social ramifications of that loss.
2. Interference with the ability to communicate or to hear desired sounds or acoustical signals.
3. Annoyance and irritation effects of varying degrees, such as interference with sleep, distraction from desired avocations, or other responses associated with the receipt of an audible signal.
4. Other physiological reactions.

These, at least in view of present knowledge, are characteristic of human responses to other stress stimuli and are not peculiar to noise or acoustical energy. The four categories of effects are discussed in the following subsections of this chapter, after which material on effects of noise on wildlife and other animals and upon property will be found.

AUDITORY EFFECTS

The most obvious effects of noise on people are auditory. One set of auditory effects is noticeable after a noise has disappeared; this consists of temporary hearing loss, permanent hearing loss, and permanent injury to the inner ear. Another set of auditory effects is noticeable while a noise is present; this consists of masking and interference with speech communication. Both sets of auditory effects are adverse in terms of human response.

Exposure to noise of sufficient intensity for long enough periods of time can produce detrimental changes in the inner ear and can seriously decrease the ability to hear. Some of these changes are temporary and last for minutes, hours, or days after the termination of the noise. After recovery from the temporary effects, there may be residual permanent effects on the ear and hearing that persist throughout the remainder of life. Frequent exposures to noise of sufficient intensity and duration can produce temporary changes that are chronic, although recoverable when the series of exposures finally ceases. Sometimes, however, chronically maintained post-exposure changes lose their temporary quality and become permanent.

The hearing changes that follow sufficiently severe exposures to noise include distortions of the clarity and quality of auditory experience and partial loss of the ability to detect sound. These changes can vary in degree, from only slight impairment to nearly total deafness.

Ear Damage

The primary site of auditory injury produced by excessive exposure to noise is the receptor organ of the inner ear, the organ of Corti. Cross-sections of this organ are shown on Figure 1-1 in normal and injured states. Such injuries result from excessive exposure to noise.

The sensory cells of hearing are the hair cells in the organ of Corti and the fibers of the auditory nerve. The integrity of the sensory cells and the organ of Corti is important for normal hearing. The injuries shown on Figure 1-1 are in single locations. For proper prespective, it is important to realize that the human organ of Corti is about 34 millimeters long and contains about 17,000 hair cells. The degree of hearing loss depends not only on the severity of the injury at any one location but also on the spread of injury.

Intense sound can produce vibrations of such severity in the organ of Corti that some of it is simply torn apart. Or, severe exposures to noise can cause structural damages that lead to rapid breakdown of the processes necessary for maintaining the life of the cells. Such an injury is termed an acoustic trauma. Another kind of injury results from prolonged exposure to noise of lower levels. Such an injury is a noise-induced cochlear injury and is probably the result of requiring the cells to work at too high a metabolic rate for too long a period of time. In a sense, the cells of the organ of Corti can die from overwork.

The results of both kinds of injuries are indistinguishable. Once the cells are destroyed, they are lost forever. They do not regenerate and cannot be stimulated to regenerate.

Hearing Loss

The primary measure of hearing loss is depicted by the hearing threshold level. The hearing threshold level is the lowest level of a tone that can be detected. The

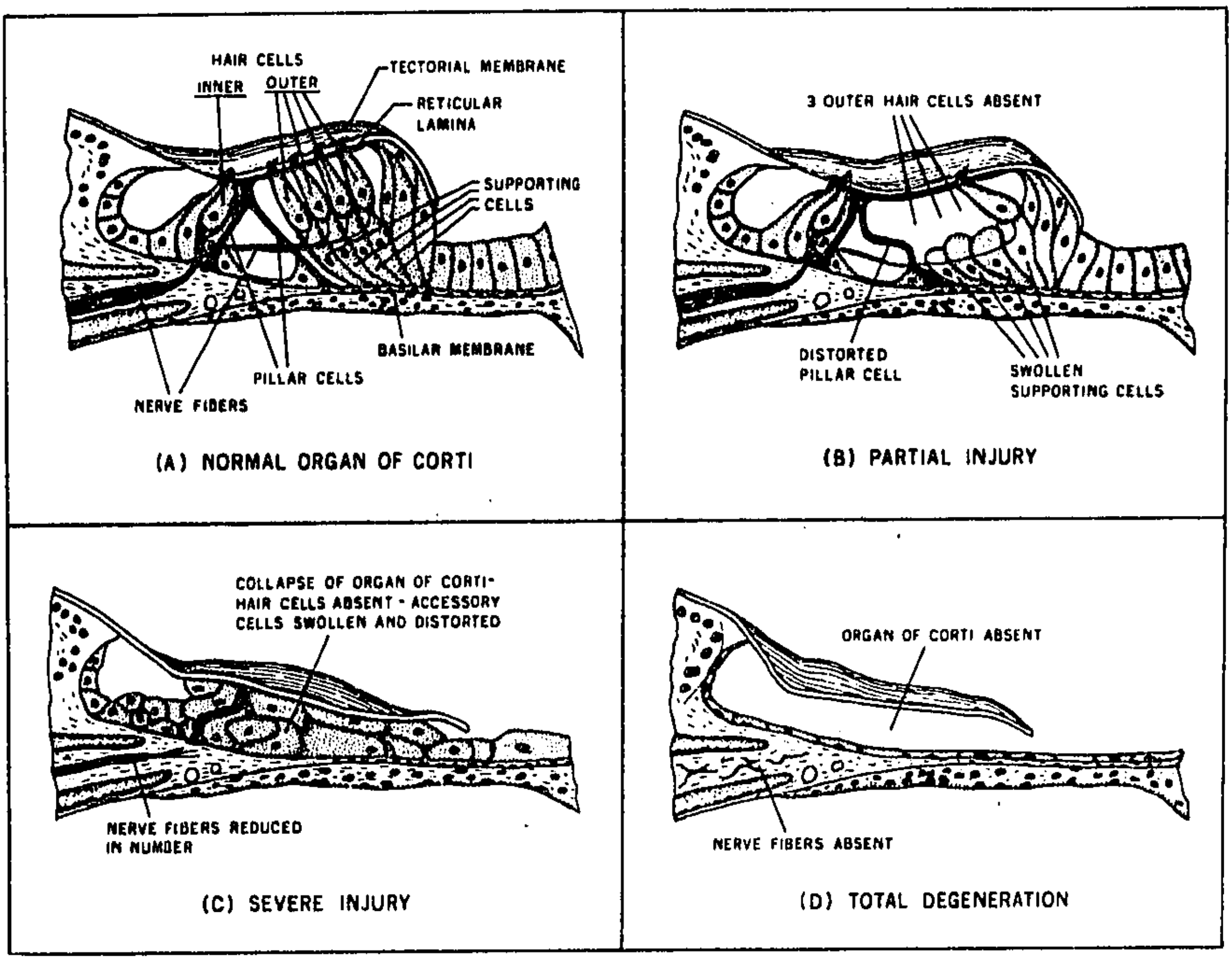

Figure 1-1. Sensory Organ of the Inner Ear

greater the hearing threshold level, the greater the degree of hearing loss or partial deafness. In 1965, the Committee on Hearing of the American Academy of Ophthalmology and Otolaryngology offered the following definitions regarding hearing loss:

1. Hearing Impairment. A deviation or change for the worse in either structure or function, usually outside the normal range.
2. Hearing Handicap. The disadvantage imposed by an impairment sufficient to affect one's efficiency in the situation of everyday living.
3. Hearing Disability. Actual or presumed inability to remain employed at full wages.

By these definitions, any injury to the ear or any change in a hearing threshold level that places it outside of the normal range constitutes a hearing impairment. Whether a particular impairment constitutes a hearing handicap or a hearing disability can be judged only in relation to an individual's life pattern and occupation.

A guideline for the evaluation of hearing handicap is presented on Table 1-1. The guideline uses only the thresholds for tones in the region most important for the reception of speech, and judgments of handicap are based on the associated ability to understand connected speech in quiet surroundings. While most authorities agree that a person in Category B or higher has a hearing handicap, there is debate over whether handicap exists when a person in Category A also has large hearing threshold levels above 2000 Hz.

An increase in a hearing threshold level that results from exposure to noise is a threshold shift. A threshold shift that puts the hearing threshold level outside of the normal range constitutes a hearing impairment.

Table 1-1

HEARING HANDICAP GUIDELINE

Class	Degree of Handicap	Average Hearing Threshold Level for 500, 1000, and 2000 Hz in the Better Ear*		Ability to Understand Speech
		More Than	Not More Than	
A	Not significant		25 dB	No significant difficulty with faint speech
B	Slight Handicap	25 dB	40 dB	Difficulty only with faint speech
C	Mild Handicap	40 dB	55 dB	Frequent difficulty with normal speech
D	Marked Handicap	55 dB	70 dB	Frequent difficulty with loud speech
E	Severe Handicap	70 dB	90 dB	Can understand only shouted or amplified speech
F	Extreme Handicap	90 dB		Usually cannot understand even amplified speech

*Measured in a properly designed audiometric examination facility using an audiometer calibrated to meet ANSI standards.

Some threshold shifts are temporary and diminish as the ear recovers after the termination of the noise. Frequently repeated exposures can produce temporary threshold shifts that are chronic, though recoverable, when the exposures cease. After recovery from temporary threshold shifts, there may be residual threshold shifts that are permanent.

The amount of threshold shift produced by an exposure to noise depends on many factors. The intensity level and the frequency content of the noise, the temporal characteristics of the noise, and the susceptibility of the individual ear are all important.

Sometimes permanent threshold shifts result from a single exposure (or a small number of exposures) to noise. These permanent threshold shifts have their anatomical base in acoustic trauma. Intense impulsive sounds such as those produced by gunfire, firecrackers, and hammering on metal can be especially hazardous in this regard. The high amplitudes and frequency content of these sounds may produce acoustic trauma of the organ of Corti.

However, people rarely encounter a single noise exposure so severe as to produce a permanent threshold shift. More often, such shifts develop as one is repeatedly exposed to noises over a period of many years. Permanent threshold shifts result from noise-induced cochlear injuries.

Whether a person will suffer permanent threshold shifts from exposure to noise often depends on the pattern of exposure from all sources of noise that he encounters. Some of these exposures from particular sources of noise may be innocuous in isolation. But these same exposures, which are innocuous by themselves, may combine with other exposures from other sources to produce permanent threshold shifts.

In general, the higher the noise levels and the more years of exposure, the greater the risk of developing a hearing handicap. For example, it is estimated that the percentage of people who may develop a hearing handicap as a result of exposure for 20 years to a noise level of 95 dBA would be approximately twice the number of those exposed to 90 dBA for 15 years. From studies of hearing loss from occupational exposures to noise, one can identify patterns of noise exposure that in and of themselves increase the incidence of hearing handicap. *

Masking and Interference with Speech Communication

Noise can interfere with the perception of audible signals. This is called masking. By masking, an auditory signal can be made inaudible or the signal can be changed in quality and apparent location. Important auditory signals, the sound of an approaching vehicle for example, can be lost in noise. The facts of auditory masking are well

* Hearing loss due to exposure to noise can be eliminated if exposures to noise are: (1) held to sufficiently low levels; (2) held to sufficiently short durations; or (3) allowed to occur only rarely. Another approach is the use of earplugs or earmuffs when hazardous exposures to noise are encountered. Effective devices are available for this purpose, but they must be carefully selected and used. In spite of the effectiveness of earplugs or earmuffs, people will often refuse or neglect to use them for reasons of appearance, comfort, and convenience. A hearing aid can be somewhat useful to a person with noise-induced hearing loss, although the result is not always satisfactory. While the modern hearing aid can amplify sound and make it audible, it cannot correct for the distortions that often accompany injury to the organ of Corti.

established, and the masking effects of noise can often be calculated from measurements of the signal and the noise.

An important instance of masking is the interference with speech communication that results from noise. Figure 1-2 summarizes the relations between interfering noise and the possibilities for speech communication. The vertical axis is the A-weighted sound level of the interfering noise, while the horizontal axis is the distance between the talker and listener in feet. The area near the bottom of the graph (the lightly hatched region below the heavy curved line) represents the combinations of distances and levels of interfering noise for which speech communication can be nearly normal. Speech communication situations involving family groups or pairs of individuals often involve speaker-listener distances of 5 to 12 feet, corresponding to levels (for interfering noises) of 66 to 55 dBA.

The relationships shown in Figure 1-2 are for young adults with normal hearing, speaking the same dialect. Children under about 13 years of age, people beyond retirement age, hard-of-hearing patients, and communicating pairs with dialect differences are likely to require even quieter conditions than those indicated on the figure if they are to enjoy near-normal speech communication.

In a highly intellectual, technical society, speech communication plays an extremely important role. Noise can reduce the accuracy, frequency, and quality of verbal exchange. In excessive noise, formal education in schools, occupational efficiency, family life styles, the quality of relaxation, and the enjoyment of life can all be adversely affected. Speech reception by elderly persons seems to be especially affected by noise.

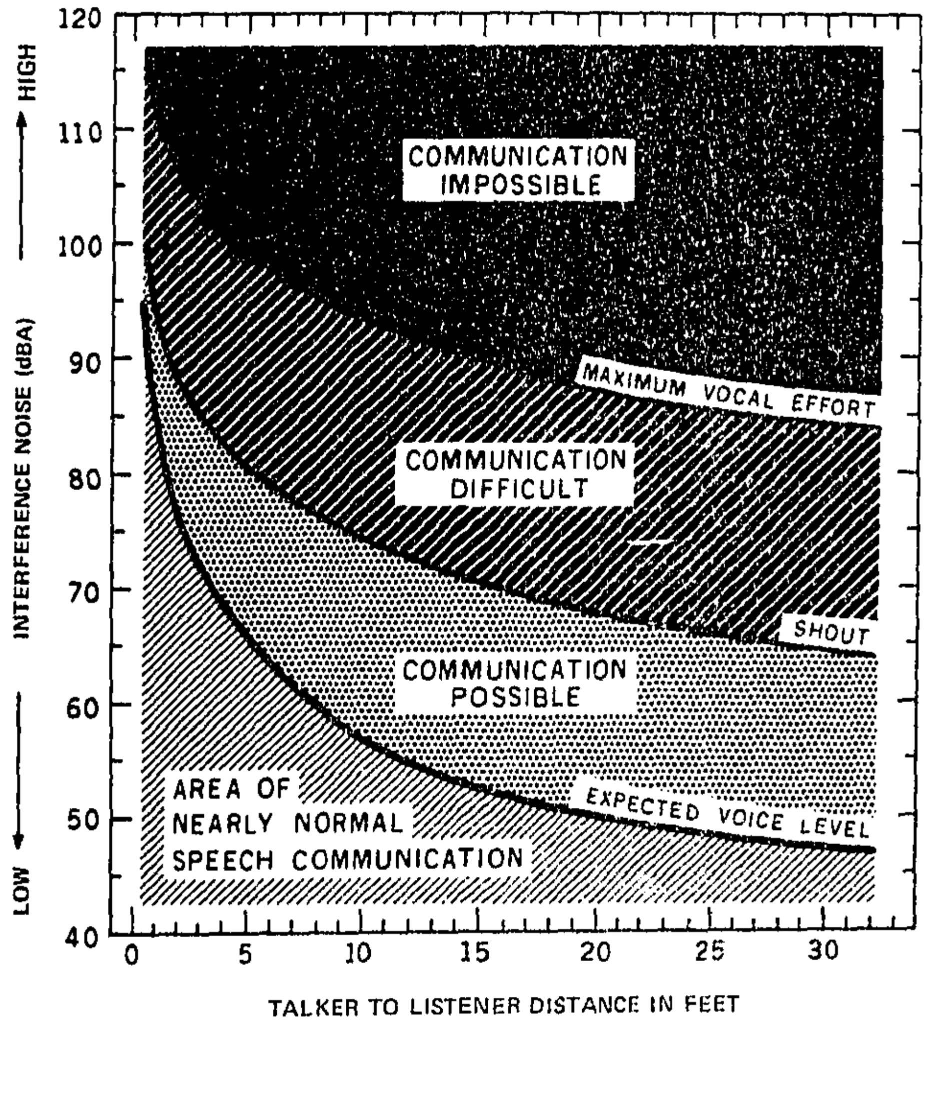

Figure 1-2. Speech Interference Levels

Interference with speech communication by noise is among the most significant adverse effects of noise on people. Free and easy speech communication is probably essential for full development of individuals and social relations, and freedom of speech is but an empty phrase if one cannot be heard or understood because of noise.

GENERAL PSYCHOLOGICAL AND SOCIOLOGICAL EFFECTS

Noise not only has direct auditory effects but also produces behavioral effects of a more general nature. Noise can interfere with sleep. Further, it can be a source of annoyance and can lead to community actions against those producing noise or those responsible for its regulation.* Noise may interfere with the performance of tasks, plays a role in privacy, and is sometimes associated with psychological distress. All of these topics are briefly treated in this discussion.

Interference with Sleep

Sleep is not a single state but consists of a series of stages that can be graded from light to deep. Physiological measurements allow one to identify the stage of sleep.

Everyday observations suggest that noise can and does interfere with sleep, and research, both in the laboratory and the field, confirms these observations. Messages from the sense organs reach the highest centers of the brain even during the deepest sleep. Whether a sleeping person is aroused by a stimulus depends on a variety of factors. Arousal can be recognized by brief changes in physiological functions, by shifts from deeper to lighter stages of sleep, or by behavioral evidence of awakening.

During normal sleep, arousal by noise depends upon the following factors: the intensity level of the noise, the fluctuation of the intensity level of the noise, the motivation of the person to be aroused by particular sounds as established while awake, the depth of sleep, the amount of accumulated sleep, previous sleep deprivation, and the

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* See also discussion in this chapter entitled, "Sociological Impact of Noise."

person's age and sex. Other factors such as drugs and psychological disorders can also affect the ability of a person to sleep through noise.

The greater the intensity of a brief noise, the greater are the chances that noise will arouse a sleeping person. In a quiet bedroom, noise levels below 30 dBA do not ordinarily have any arousal effect. As the noise level increases from 30 to 100 dBA, the chances of awakening increase. Brief noises with levels of 100 to 120 dBA awaken nearly everyone.

The chances that a particular noise will arouse a particular individual depend upon numerous personal characteristics of that individual. For example, the stronger the motivation to awake, the more easily one can be aroused by noise. The lighter the stage of sleep and the greater the amount of accumulated sleep, the more easily one can be aroused. Elderly people are much more easily awakened by noises than are middle-aged people and children; and once awakened, elderly people have more difficulty returning to sleep than do younger people. These differences with age are large and dramatic. While the difference between the sexes is not nearly as large in this respect, it does appear that middle-aged women are more easily aroused from sleep by noise than are middle-aged men; and there is also evidence that male patients suffering from depression are more easily aroused from sleep by noise than are normal men or women.

Much less is known about the effects of steady noise on sleep. One investigation of complaints about noise produced by air conditioning and heating equipment has shown that, in bedrooms, steady noise levels of 33 to 38 dBA resulted in occassional complaints, while those with levels greater than 48 dBA resulted in numerous complaints.

It is not known whether these complaints were due to interference with sleep or to other factors. It is known that steady noises produce less sleep disturbance than do fluctuating noises. Some products are, in fact, currently being sold for the purpose of producing a steady noise to mask out existing unsteady noises so that sleep may be enhanced.

While everyday observation suggests that some people adapt to noise and can learn to sleep through anything, this observation has not been confirmed by laboratory or field studies, although a few relevant experiments have been done. However, there is clear evidence of adaptation to the total sleeping environment. It may be that loud noises continue to awaken or arouse a sleeping person, but as he becomes familiar with the sounds he returns to sleep more rapidly. Also, since one cannot often remember awakening, just as one often cannot remember dreams, it is possible that he may erroneously believe that noises lose their power to awaken.

Whether sleep disturbance by noise constitutes a health hazard is debatable. The changes in sleep patterns produced by noise are away from the patterns of good sleep and toward the patterns of poor sleep. But, normal persons deprived of sleep compensate by spending more time in deep sleep, by becoming less responsive to external stimuli, and by napping. Thus, it may be difficult to deprive a normal person of sleep to the extent of adversely affecting his health.

In light of present knowledge, it seems reasonable that sleep disturbance by excessive noise will reduce an individual's feelings of well being. Furthermore, when noise conditions are so severe as to disturb sleep on a regular, unrelenting basis, then such sleep disturbance may constitute a hazard to physical and mental health.

Annoyance and Community Response

Annoyance by noise is a response to auditory experience. Annoyance has its base in the unpleasant nature of particular sounds, in the particular activities that are disturbed or disrupted by a particular noise, in the physiological reactions to a particular noise, and in the responses to the meaning or messages carried by a particular noise. The degree of annoyance is also related to other factors:

1. Differences among individuals in their sensitivity to annoyance by sound.
2. Attitudes of exposed persons toward the noise source, e.g., whether they consider the noise-producing activity to be important for their social and economic well being and whether they believe that the noise is a necessary by product of the activity producing it.
3. Whether they believe that those responsible for the creation of the noise-producing activity and its regulation are concerned about their (the exposed population's) welfare.
4. Factors specific to particular sound sources, such as neighborhood disagreements over barking dogs and fear of aircraft crashes, or the belief that sonic booms cause property damage.

That individuals can make fairly accurate and unbiased direct estimates of their own degree of annoyance from noise is confirmed by subtle and sophisticated questionnaire and interview techniques. *

* But see cautions regarding indiscriminate extrapolation of such data in the fol- discussion of sociological impact of noise.

The degree of annoyance averaged over a large number of individuals near a noise monitoring station can be predicted, in a statistical sense, from the physical characteristics of the noise. Each individual's degree of annoyance cannot be as accurately predicted as can the average annoyange. This is true because individuals differ considerably in the exact noise exposure they receive (due to variations in environmental acoustics), because individuals differ in their sensitivity to disturbance by noise and because individuals differ in other relevant psychological and social attitudes.

Community noise exposure can be measured and summarized by several competing methods, as discussed elsewhere in this report. There are also many similarities in these various techniques. Each takes into account several of the following, not necessarily independent, variables:

1. The levels and durations of identifiable noise events.
2. The number of occurrences of noise events.
3. The residual noise level.
4. The variability of noise levels.
5. The time of day.
6. One or more special factors related to perceived noisiness or loudness of sounds.

As previously stated, such acoustical measurements allow fairly accurate prediction of the level of annoyance averaged over a large number of individuals exposed to the noise as it might be measured at a monitoring station. Whether citizens will take action against those producing the noise or those responsible for its regulation is more difficult to predict.

Individual action against noise sources has been studied, and action may be a complaint in the form of a letter or telephone call to someone responsible for the operation of a noise-making activity or its regulation. Persons who complain, as defined, in general do not appear to be unusual. Neither are they unusually sensitive to noise. In fact, they may represent only 2 to 20 percent of the highly annoyed people in a community. Organized community action against noise includes more than mere complaint and depends not only on the intensity level of the noise but also on the leadership within the community and on the various psychological and attitudinal factors previously mentioned.

Although the likelihood of individual complaints and group action against noise sources can be estimated from acoustical measurement of the noise, as discussed above, such procedures are fallible, and numerous exceptions can be cited. New and different schemes of noise evaluation may allow more accurate prediction of complaints and community response than has been achieved in the past.

Two speculations about possible future community actions in response to noise may be worthy of note. Right or wrong, these speculations serve to illustrate how attitudes and beliefs might combine with actual exposure to noise to influence anti-noise actions.

In a recent survey, members of a sample of about 8,200 people who live near the approach and departure paths and within 12 miles of airports in seven major cities of the United States were asked whether they would be able to accept increases in noise exposure from aircraft operations. Fifty-four percent replied that they could not.

This, coupled with the fact that fear of aircraft crashes strongly enhances the annoyance produced by aircraft noise, leads to the speculation that substantial increases in aircraft traffic, along with a few crashes in populated areas, could result in vigorous community action against aircraft operations and those responsible for its regulation.*

It can also be speculated that if members of a community believe noise is necessary to an approved activity and if they believe people are free to move away from the noise, then they will be less likely to institute or support action against the source of noise than if they disapprove of the activity or believe there is no freedom to move to escape the noise. If this speculation is correct, then perhaps an increase in the total area or number of persons exposed to annoying noise levels in such an area would not necessarily result in an increase in support for antinoise actions.

There is one final point to be made. Complaints and group actions are difficult to predict from the physical characteristics of noise; loudness, perceived noisiness, annoyance, and disturbance of activities are more closely tied to the physical characteristics of the noise itself. However, whether or not one complains, the quality of one's life can be disturbed by noise.

Other Possible Psychological and Sociological Effects

Human Performance

If a task requires the use of auditory signals, either speech or nonspeech, then noise at any level sufficient to mask or interfere with the perception of those signals

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* Testimony from numerous witnesses at EPA public hearings indicates widespread dissatisfaction with the noise associated with aircraft operations around airports. This is also commented upon in Chapter 2.

will interfere with the performance of the task. When mental or motor tasks do not involve auditory signals, steady noises without special meaning do not seem to interfere with the performance of skilled mental or motor tasks unless noise level exceeds about 90 dBA. Even above these levels, performance is sometimes unaffected. On the other hand, irregular, unpredictable bursts of noise may influence performance when their noise levels are less than 90 dBA. *

The effects of noise on performance are often conceptualized in terms of arousal, distraction, and specific effects. Arousal of bodily systems can result in either beneficial or detrimental effects on performance. Distraction can be thought of as lapses of attention or diversion of attention from the task at hand; it can be the result of responses to the sound itself or of responses to the messages carried by the sound. Specific effects include auditory masking and certain patterns of muscular activation.

Many physiological and psychological responses to sound diminish or disappear when the noises are regular or predictable. Also, strategies can sometimes be learned so that detrimental effects of particular noises on specific tasks can be avoided. For these reasons, people sometimes achieve excellent performance or even temporarily exceed their normal performance in spite of the presence of noise.

Noises, however, are often not regular and predictable, adaptation is not always complete, and appropriate strategies to eliminate the effects of noise are sometimes not learned. Furthermore, the fact that distraction or disturbance may be the result

* An increase of 5 to 10 dBA above the existing noise level appears to cause attention and reaction by most exposed persons.

of the message carried by the noise rather than the result of the noise per se may be of little interest to the citizen. An ideal acoustical environment is one that does not disturb human performance either because of fundamental properties of noise that may be present or because of irrelevant messages carried by the noise. The trick, of course, is to eliminate disturbing noises while maximizing the chances that relevant messages carried by sound reach the appropriate listener.

Acoustical Privacy

Without opportunity for privacy, either everyone must strictly conform to an elaborate social code or everyone must adopt highly permissive attitudes. Opportunity for privacy avoids the necessity for either extreme. In particular, without opportunity for acoustical privacy one may experience all of the effects of noise previously described and, in addition, one is constrained because his own activities may disturb others. Without acoustical privacy, sound, like a faulty telephone exchange, often reaches the wrong number.

It would be helpful for both owner and renter and for both seller and buyer if standardized acoustical ratings were developed for dwellings. These ratings might include measures of acoustical privacy as well as other measures of acoustical quality. Such ratings would be particularly useful since the acoustical properties of a dwelling are not immediately obvious to the nonspecialist. If such ratings were available, the parties involved could balance the acoustical value of a dwelling in relation to such values as appearance, size, convenience, and cost.

Intersensory Effects

Background noise levels can influence the judgment of time. Very intense noise can also influence other sensory functions such as balance and vision. Fortunately, intensity levels sufficient to produce these effects are not normally encountered.

Mental Disorder, Anxiety, and Psychological Distress

There is some evidence that admissions to psychiatric hospitals are higher in areas with high noise levels than in quieter areas, but such evidence is not entirely convincing. There is no evidence that exposure to noise can result in mental illness. However, all of the facts clearly support the contention that noise can be a source of psychological distress through annoyance, disturbance of activities such as sleep and speech communications, and so on. Psychological distress, in turn, can contribute to a list of symptoms such as nausea, irritability, general anxiety, and changes in mood.

GENERAL PHYSIOLOGICAL EFFECTS *

There are general physiological responses to transient noise, and it has been proposed that there may be general physiological responses to persistent noise. It has also been proposed that noise can be a significant source of stress and can in this way increase the incidence of health problems. Each of these topics is discussed below.

Transient Physiological Response to Noise

There are three classes of transient general physiological responses to sound:

1. Fast responses of the voluntary musculature that are mediated by the somatic nervous system.
2. The slightly slower responses of the smooth muscles and glands that are mediated by the visceral nervous system.
3. The even slower responses of the neuro-endocrine system.

Responses of the Voluntary Musculature

Muscular responses to sound can be studied by visual observation of bodily movements or by electrical measurements of muscular activity. By these techniques it has been shown that people are equipped with an elaborate set of auditory-muscular reflexes that serve the basic functions of orienting the head and eyes toward a source of sound and of preparing for action appropriate to an object or event signalled by sound. These

* For a comprehensive review of current professional opinion on this subject, see the transcript of the EPA Public Hearing on Noise held in Boston.

reflexes operate at low levels of sound, where they can be detected by sophisticated electrical measurements, as well as at high levels of sound. Such auditory-muscular reflexes underlie muscular responses to sound that range from rhythmic movements and dance to the body's startle response to impulsive sounds such as gunshots or sonic booms.

The body's startle response to impulsive sounds can interfere with human performance and is one of the factors that underlie the annoyance produced by sudden noises. The startle response has been studied in detail and includes an eyeblink, a typical facial grimace, bending of the knees, and, in general, flexion (inward and forward) as opposed to extension of bodily parts. The startle response to a nearby gunshot, even when expected, may undergo various degrees of diminution with repetition, depending upon the individual, the rate of repetition, and the predictability of the impulse sound. Some individuals show little diminution of the response with repetition, others show marked reduction. The eyeblink and head movement persist even in experienced marksmen when shooting their own guns.

Auditory-muscular reflexes can have more subtle effects on human activity than those of the startle response. Interestingly, the greater the tension in a muscle, the greater its reflex response to sound. Therefore, the influence of auditory-muscular reflexes on the performance of a given task depends on posture and the pattern of muscular tension as well as on the movements required by the given task. For example, when a given task requires a movement of flexion and the resting posture heightens tension in the flexor muscles, then a burst of sound at an appropriate time can speed the required movement. Under other conditions, the burst of sound can greatly interfere with this movement.

In summary, the ebb and flow of muscular activity is closely linked to and influenced by the rise and fall of sound. The obvious effects of the startle response and other auditory-muscular reflexes often diminish with repetition of the sound stimulus. However, even after many repetitions these reflexes may continue to operate in a subtle manner, and their effects will depend on the details of posture and resting muscular tension, on the details of the task at hand, and on the physical properties of the sound stimulus.

Responses of the Smooth Muscles and Glands

In response to brief sounds, there is general constriction in the peripheral blood vessels, with a reduction in peripheral blood flow. There may be acceleration or deceleration of heart rate, changes in resistance of the skin to electrical current (an indication of activation of the peripheral visceral nervous system), changes in breathing pattern, changes in the motility of the gastrointestinal tract, and changes in the secretion of saliva and gastric juice. These responses are obvious when the noise level exceeds 70 dBA. For sounds below this intensity level, it is doubtful that the recording techniques have been sufficiently sensitive to decide whether or not these responses occur. In any case, they are either small or nonexistent. Some aspects of these responses diminish and seem to disappear with predictable repetition of the sounds, while others may not.

Some of these responses to sound are part of a pattern of response known as the orienting reflex or "what is it?" response. The orienting reflex disappears rapidly as the stimulus becomes known or predictable. Others of these responses to sound are probably part of a response known as the defense reflex, which prepares an organism to escape or accept injury or discomfort. Defense reflexes occur in response to warnings of painful stimuli, to painful stimuli themselves, or in response to very intense stimulation of any sense organ. Responses that are part of the defense reflex disappear more slowly with stimulus repetition than do those of the orienting reflex. Sometimes they may never completely disappear.

Neuro-endocrine Responses

Loud sounds as well as other intense stimuli, such as forced immobilization, forced exercise, cold, pain, and injuries, can activate a complicated series of changes in the endocrine system. These changes, in turn, can cause changes in hormone levels, blood composition, and a whole complex of other biochemical and physiological changes.

Possible Persistent Physiological Responses to Noise

It has been proposed that frequent repetition of the transient physiological responses to noise can lead to persistent, pathological changes in nonauditory bodily functions. Also, it has been proposed that such repetition of these transient responses might aggravate existing disease conditions. However, it is true that the transient physiological responses to sounds are often useful because they help to protect people from potentially harmful events. It is also appropriate that these responses diminish when repetition of the noise signifies that particular noises do not represent a threatening condition. The crux of the question is whether man is so designed as to adapt to nonthreatening noises that are also quite intense or whether the modern environment presents such ever changing noises that the transient physiological responses are chronically maintained.

At least some of the transient physiological responses to noise do appear to be chronically maintained. Furthermore, there is some evidence that workers exposed to high levels of noise have a higher incidence of cardiovascular disease, ear-nose-and-throat disorders, and equilibrium disorders than do workers exposed to lower levels of noise. However, it is also possible to explain these observations in terms of non-noise factors such as age, dust levels, occupational danger, or life habits.

Also, there is evidence from animal research that high sound levels can interfere with sexual-reproductive functions, can interfere with resistance to viral disease, and can also produce other pathological effects. These experiments, however, have often not been well controlled; i.e., fear, animal handling conditions, and so on have not been equated between noise-exposed and non-noise-exposed groups.* Further, rodents were used as experimental subjects, and these animals are known to have special susceptibility to the effects of certain sounds. Finally, the sound levels were well above those encountered by most people.

The evidence taken as a whole hints that chronic exposure to sufficiently variable or intense noise may contribute to nonauditory physiological and anatomical pathology. However, the case is far from proven and merits further research and investigation.

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* In addition to the EPA Hearing in Boston, see the transcript of the hearing held in New York City.

Stress Theory

The neuro-endocrine responses previously mentioned seem similar to the responses to stress. Responses to stress have general characteristics that appear in response to all stressors and special characteristics that are linked to specific stressors.

The response to stress, called the general adaptation syndrome, consists of three stages: an alarm reaction, a stage of resistance, and a stage of exhaustion. If a stressor is severe and is maintained for prolonged periods of time, an organism passes in succession through the stages of the alarm reaction, of resistance, and of exhaustion. In the extreme case, the end result is a breakdown of bodily function and death. Even in the less severe case, a price may be paid for continued stress during a prolonged stage of resistance. This price may include increased susceptibility to infection and, perhaps, specific diseases known as the diseases of adaptation. Such diseases may include, among others, some types of gastrointestinal ulcers, some types of high blood pressure, and some types of arthritis. Many medical authorities do not accept the theory that there are diseases of adaptation. Rather, they theorize that each disease has its own special set of causes.

Stress theory, even as presented by its strongest advocates, is complicated. These advocates speak of interactions between conditioning factors that set the scene for disease, specific reactions to particular stressors, and general reactions to non-specific stressors.

While it is plausible that frequent exposure to intense noise can act as a stressor, the details of its action as a stressor have not yet been identified, and its implications are unknown. There is evidence that suggests a certain amount of stress can even be beneficial.

IMPLICATIONS OF GENERAL PHYSIOLOGICAL RESPONSES TO SOUND

While physiological arousal in response to sound can be of great benefit when coping with possibly dangerous events, unnecessary arousal to irrelevant noises can provide a basis for annoyance and can interfere with performance of tasks. Noises that are of high level or are sufficiently varied may maintain chronic arousal and in this way may contribute to the incidence of nonauditory disease. However, if noise control sufficient to protect persons from ear damage and hearing loss were instituted, then it is highly unlikely that the noises of lower levels and duration resulting from this effort could directly induce nonauditory disease.

Of course, general psychological distress produced by noise can add to the overall stress of life and, in this way, may increase the incidence of nonauditory disease. However, at this time it is not possible to evaluate the contribution of noise in relation to all of the other sources of stress encountered in normal activities.

SUMMARY OF PSYCHOLOGICAL AND PHYSIOLOGICAL EFFECTS

It has not been demonstrated that people are having their lives shortened by exposure to audible noise. Perhaps the stress of continued exposure to high levels of noise can produce disease or make one more susceptible to disease, but, overall, the evidence is not convincing. The effects of noise on people have not been successfully measured in terms of excess deaths, shortened lifespan, or days of incapacitating illness. There are only hints that such effects might exist. Of course, there may be accidental deaths or injuries because warning signals were not heard or were misunderstood due to noise.

There is clear evidence that exposure to noise of sufficient intensity and duration can:

1. Permanently damage the inner ear with resulting permanent hearing losses that can range from slight impairment to nearly total deafness.
2. Result in temporary hearing losses, and repeated exposures to noise can result in chronic hearing losses.

It is also apparent that noise can:

1. Interfere with speech communication and the perception of other auditory signals.
2. Disturb sleep.
3. Be a source of annoyance.
4. Interfere with the ability to perform complicated tasks and, of course, can especially disturb those tasks that demand speech communication or response to auditory signals.

5. Adversely influence mood and disturb relaxation.

These latter effects are difficult to quantify, since they affect the essential nature of human life—its quality. But alone they are sufficient to require more efforts toward controlling the problem.

SOCIOLOGICAL IMPACT OF NOISE

The reactions of groups and communities of individuals arise, in part, from the aggregation of the varying individuals and personalized responses and from the interaction therewith of a wide variety of sociological influences. For example, due to ethnic background, one group of families may accept a noisy environment in their home that would be considered unacceptable by those of different cultural orientation. They may in fact create conditions that, while acceptable to themselves, are considered noisy by others.

This phenomenon must be taken into account in assessing the attributes of noise as a sociological problem. It also must be given careful attention in translating results of various studies on noise as related to a particular source and affecting a specific population (such as the variously cited studies on transportation noise mentioned elsewhere in this chapter and in other portions of this report) to other sources, situations, or populations. This caution was cited in Karl Kryter's recent work The Effects of Noise on Man (Academic Press, New York, 1970) in relation to possible national differences in tolerance to road noise. He further discusses the many factors in this regard that must be taken into account in assessing the validity of various studies and study techniques. *

The following discussion provides an overview of additional sociological factors that are important in the consideration of noise effects on community environmental quality. Roughly 130 million people live in metropolitan areas subject to the noises from transportation or construction projects, crowding and congestion, and widespread

* See especially his chapter devoted to Environmental Noise and Its Evaluation.

manufacturing activities.* Social surveys registering the public reactions to a variety of these noises have found people disturbed by such exposures to have increased from 23 percent in 1948 to 50 percent in 1961. Such annoyance is typically due to disruption of privacy, rest, relaxation, and sleep.

A close relationship exists between expressed annoyance and level of noise intensity. In community surveys based on 3500 people in widely separated areas, it has been found that the number of people expressing annoyance increased steadily as the noise level increased and that the number of complaints were a good indicator of the degree of annoyance. An English study of noise around Heathrow Airport indicated that 22 percent of the respondents said they were sometimes kept from going to sleep due to aircraft noise. This figure rose to 50 percent with an increase in noise levels.** A still greater proportion, also increasing with a corresponding increase in noise level, complained of being awakened by noise. A traffic noise survey in Sweden noted that the proportion of people annoyed increased linearly with increasing noise levels from 50 dBA on, based on a 24-hour energy average; it was also reported that symptoms such as headache, insomnia, and nervousness are associated with noise exposure.

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* Compared with the approximately 80 million possibly seriously affected by noise.

** For more details on later studies in London, see the transcript of the EPA Hearings on Noise held in Boston.

These studies and others have demonstrated that sounds at night are more annoying than those occurring during daytime. As discussed earlier in this chapter, noise interferes with rest and relaxation and especially with sleep. Complete withdrawal from the world around us, through sleep, is an obvious necessity for physical and emotional health, less complete withdrawal into the quiet of our homes may also be necessary.

As demonstrated throughout this Report, the assessment of the effects of noise on the population at large has been based on data from many sources and is presented in a variety of forms. The result has been a compilation of information (some highly quantitative and precise, some primarily descriptive in nature) on such things as community responses, physiological and annoyance measures, numbers of people "deafened", etc., all used to indicate the nature and scope of noise problems. In dealing with this vast array of data it is easy to lose sight of the fact that they all deal with basically the same problem and therefore should not be treated independently. Rather, it is extremely important to integrate these diverse findings by means of one or more unifying concepts. Perhaps one method of accomplishing this objective is to focus on its cumulative aspect.

Scientists concerned with hearing loss are in general agreement that the effects of noise are additive. The major source of disagreement is the specification of the minimum level(s) at which these effects become important. Any overall evaluation of the hearing loss problem in the nation must take into account exposures on the basis of lifetime experience rather than industrial, transportation, or household exposures.

Table 1-2 provides a sample of the conditions of noise exposure experienced by many members of typical U.S. urban communities. Since this information is included only for illustrative purposes, there is no attempt to specify age ranges or exposure data.

In a sense, the noise problem of today is both qualitatively and quantitatively different from what it was yesterday. Noise can be thought of as a localized and confined problem. For example, large cities have always been associated with noise since, by definition, they were the centers of activities involving industries, transportation, power facilities, large populations, etc. Certain industrial operations have long been associated with noise, as have large airports. Many persons living within cities have often considered noise as being a necessary evil that must be tolerated in exchange for the convenience of living either near places of work or in proximity to public transportation routes. The accelerated growth of suburban areas outside of most center cities and the mobility of our population have radically altered the scope of the noise problem. Population increase and greater mobility have combined in converting areas that were previously quiet into smaller versions of the inner city. Land usage has been changed to accommodate industry and transportation requirements associated with decentralization. The labor-saving devices that were possible only in industry several decades ago have been moved to the home environment. Because of new highways and small airports, motorized vehicles can now penetrate into regions that were only a short while ago considered remote.

With areas of the continental United States obviously remaining constant, the rise in the totals of noise sources, as well as in their power, has resulted in a

Table 1-2

LIFETIME EXPOSURE TO NOISE (ILLUSTRATION)

	Childhood	Youth	Maturity
Cap Pistols	x		
Firearms		x	x
Rock & Roll Music		x	
Transportation			
School Bus	x	x	x
Automobile	x	x	x
Train (subway, elevated)		x	x
Aircraft		x	x
Household Appliances	x	x	x
Construction Equipment	x	x	x
Community (roadside, flight path)	x	x	x
Recreational Vehicles		x	x

x = Exposure to noise source

considerable increase in the average sound levels produced throughout the nation. This factor, combined with an increased availability of major transportation activities and facilities, has made noise a much more pervasive problem than it was even a short while ago.

Many scientists and members of the professions concerned with noise are convinced that noise levels not intense enough to cause permanent damage cannot simply be disregarded as a nuisance that is a necessary waste product of technological progress. That view is shared by many members of the public at large, who see noise as adversely affecting the quality of life. The reasons for this widespread interpretation are partially rooted in the characteristics of sound and the types of effects associated with noise. Experimental findings have consistently demonstrated that when visual and auditory signals are concurrently presented, subjects tend to respond to the auditory signals first, presumably because of some attention-demanding quality. Researchers designing warning devices have made use of this characteristic for years.

Another characteristic of noise causing annoyance is that it affects people who are in the position of innocent bystanders. That is, in many instances those people responsible for producing noise are not the same as those severely affected by the noise; also, the receivers of the noise in these instances have no control over the noise source. It has been stated that noise annoyance is closely associated with the degree to which the noise producer is concerned with and doing something about the effect of noise on its receivers. Studies have substantiated this in that subjects showed significantly lower tolerance or greater attitudes of frustration after exposure to unpredictable noise than when the noise source was under the control of the subjects. This aspect of the problem is important because it has been repeatedly demonstrated that when there is no benefit to a person associated with an activity and yet there are adverse consequences to be suffered, there is little tolerance for those consequences. For example, if two people live near a highway and one uses it for commuting while the other walks to work, the walker is much more likely to complain about noise, air pollution, etc., due to automobiles than is the person who drives, all other things being equal. *

The problem is not new or unique to noise, as the following quote from James L. Hildebrand's Noise Pollution and the Law (Law Book Publishers, Buffalo, N.Y., 1970) says, "For hundreds of years, indeed throughout most of the history of the common law as we know it, courts have been struggling to reconcile the conflicting interests of two property owners—one who believes that his ownership entitles him to use his property as he wills and the neighbor who believes that his ownership entitles him to enjoy his property without annoyance. . . two major principles have evolved:

"First, each person must put up with a certain amount of annoyance.

"Second, . . . the gravity of the harm to the complainant should be weighed against the utility of the conduct of his troublesome neighbor.

"The first of these tells us what every city dweller experiences every day of his life. . . . The second is less easy to understand. . . in determining the utility of the defendant's conduct one must consider in addition to the social value of his conduct, its suitability and the impracticability of preventing or avoiding the annoyance."

The pervasiveness of noise, combined with the characteristics already noted, makes it a problem of special concern when psychological well-being is considered. Most competent medical practitioners, as well as those engaged in health research,

* Based on testimony of witnesses at several of the EPA Hearings.

agree that there is an absolute requirement for rest and recreational activities at regular intervals in order to maintain adequate mental and physical health. It is evident when we consider the quality of life that the need becomes of major importance to human welfare. Since the home environment is considered to be the principal haven for most persons to obtain such needed rest, the impact of noise thereon is a major consideration.

In considering noise within the home, it is useful to make the distinction between single-family dwellings and other houses. In multiple family buildings, the lack of acoustical provacy is a major source of difficulty. Acoustical privacy can be defined as the expectation that sounds generated within one household will not be broadcast to other households throughout the building. This particular problem deserves attention because of the changes in construction techniques that have been slowly evolving. There is a trend toward using lightweight construction having relatively poor sound insulating properties. If this trend continues (without modification of the sound insulating properties), the homes of the future will have far less acoustical privacy than did the homes of the past. Privacy, as well as annoyance, are difficult concepts for scientific investigators to objectively contend with. The two have been somewhat equated by indicating that annoyance due to noise may be thought of essentially as the resentment one feels toward an intrusion into his physical privacy. The existence of the problem, though, has been documented in a variety of community studies conducted in this country and abroad.

Noises in the home can be generally categorized into three sources: those generated by family members, building noises (fans, blowers), and those originating outside of but penetrating into the home. The mechanical helpers within the home are a major source of complaint by householders (see Chapter 2). Although washers, dryers, garbage disposer units, etc., have made household tasks easier to perform physically, they have exacted a psychological cost. The relatively long cycle time of many of these devices has resulted in not merely a noise nuisance but in a persistent one as well. Despite the fact that the family benefits from the primary noise sources within the home, such noises are often a source of conflict among family members engaging in incompatible activities; e.g., the housewife vacuuming the rug and her children who are studying.

The community noise studies cited already and discussed in Chapter 2 are in substantial agreement that noise serously affects many of the activities engaged in at home. It has been shown that noises in the home outnumbered all other disturbances. Rest and relaxation are difficult, and there is interference with TV viewing, listening to music, reading, conversation, and many other social and recreational activities. These and other investigations indicate that the home appears to be the recipient of noise from a great number of sources in the community. Among the major causes of complaint, the following have been cited most frequently: traffic, aircraft, industrial plants, construction, and neighborhood related sources such as dogs and powered lawn mowers.

When rest and recreation cannot be successfully accomplished at home, there is a tendency for people to seek these diversions elsewhere. This, along with other factors beyond the scope of this report, has led to an intensive use of the outdoors and has resulted in large recreational industries based activities such as camping, fishing, boating, and skiing. The function performed by recreation is primarily that of unwinding and relaxing as a necessary counterpoint to the often hectic day-to-day work and homemaking activities. Since the goal is identified basically with getting away from the usual annoyance, any interference with the achievement of this objective is, in the main, not well tolerated. Disturbances that are normally considered relatively minor thereby result in a sense of frustration well beyond that normally occurring.

Interference by noise with outdoor recreational activities is almost a universal phenomenon in that it occurs regardless of the time of day and in all seasons of the year. Winter vacations are now being disrupted by the advent of the snowmobile in the same way that motorboats have upset the tranquility of many of our lakes and rivers. The simple enjoyment of nature by hikers and families enjoying picnics is often interrupted by transportation noises generated by nearby roadways or aircraft. There is a growing trend of noise seriously disrupting the serenity of many formerly secluded retreat areas such as national park and forest areas.

Outdoor spectator events are also seriously affected by noise, especially that produced by aircraft. The Watergate concerts in the Washington, D. C., area have for years undergone regular interruptions as a result of overflights associated with National airport, with the enjoyment of the music being made extremely difficult by the almost continuous pattern of takeoffs and landings. As a result, there are plans to abandon Watergate as a concert site. These problems were repeatedly cited by witnesses at the various public hearings held by EPA during 1971 and are documented in the transcripts.

Among the activities most seriously affected by noise are those centered in public buildings. Recent studies concerned with aircraft noise in the community of Inglewood, California, provide an example. In the local churches, it was indicated that the conduct services was virtually impossible. The effects on several schools were so severe that new schools had to be built to serve the community. Other surveys have indicated that serious disruption of classroom activities has been a major effect of noise. Is it not reasonable to assume that the quality of education is going to suffer even when noise levels are not so great that they cause the closing of schools? Conditions suitable for adequate speech communication are necessary for classroom activities in which disruption by noise can readily lead to the necessity for repeating material, misunderstanding of assignments, and difficulty in concentrating on complex subject matter (which is especially vulnerable to noise interference). Activities in public libraries, theatres, and hospitals are also vulnerable to the disruptive attributes of noise. While acoustical treatment can be designed and applied to provide for satisfactory interior environments in such situations, they are extremely costly if added to existing buildings.*

Although the occupational noise exposure regulations promulgated under the Occupational Safety and Health Act are designed to control noise exposure within the work environment, this continues to be a major problem area, to be taken into account as part of the total daily noise exposure of a significant part of the total U.S. population.

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* Regarding problems of schools, see also the transcript of EPA Hearings in Noise held in Boston.

It is estimated that the number of workers in the U.S. exposed to noise potentially hazardous to hearing are in excess of 6 million and may be as high as 16 million. It is now becoming evident that many occupations should be considered among those in which noise is a hazard. In addition to the workers involved in the heavy industries traditionally associated with noise problems, construction workers, textile mill employees, truck drivers, and pilots of both fixed and rotary wing aircraft are exposed to excessive noise. The new computer-based organizations are not immune to this hazard either. Keypunch and paper tape devices and equipment such as the optical character readers and letter-sorting machines used in post offices produce noise that may ultimately affect the hearing of their operators.

It is important to note that workers exposed on the job to levels of noise considered hazardous do not spend the remainder of their time in a noise-free environment (as was assumed in the occupational noise limits established under the Occupational Safety and Health Act). Instead, after leaving work they may be exposed to the same noise levels at home and in the community as everyone else. Since there is fairly general agreement that total noise exposure is an important determinant of hearing loss, it might be conjectured that the aforementioned figures give a rather conservative estimate of the scope of the occupational hearing loss problem.

Based on testimony presented during EPA public hearings held in Chicago on July 29, 1971 the extent of hearing loss in the population is estimated as follows:

Hearing Loss (Moderate to Profound)

Age Range	Population Totals (in thousands)	Loss of Hearing Totals (thousands)	Noise-Associated Hearing Loss (thousands)
0-5	17,000	850	?
5-10	20,000	1,000- 1,400	*200
10-18	32,500	650- 975	**150
18-65	113,000	2,260	2,000 (Approx)
Over 65	20,000	4,000	400-600
TOTALS	202,500	8,700-11,135	2,750-2,950

* Most common cause is explosions from toy caps (20% sensory-neural hearing loss).
** Firearms and toy caps (based on approximately 20% sensory-neural hearing loss).

For several years, many investigators have expressed concern about the possible adverse consequences of music heard at greatly amplified sound levels. Entering freshmen college students have been found to have hearing disorders that were attributed to exposure to music played at intense levels. In a series of audiometric examinations given to more than 7,000 students ranging from sixth graders to college freshmen, the findings indicate a steady increase in hearing loss at high frequencies, as measured by a screening examination. While only 3.8 percent of the sixth graders failed this test, approximately 10 percent of the 9th and 10th graders and more than 30 percent of incoming college freshmen failed. A test of the next freshman class (Fall, 1969) yielded the most disturbing findings of all: 61 percent of them failed the audiometric screening test. There is evidence that the hearing acuity of young persons 21 years of age and under is becoming prematurely reduced possibly because of voluntary exposure to sounds that are at a damage-risk level. These implications lead to the speculation that the current population of young people will encounter much more serious hearing problems in their middle years than the present group of 50 to 60 years olds. *

One other direct consequence of noise is a possible increase in the occupational rate. A British study indicates, and it seems reasonable to suppose, that if high noise levels increase, the number of errors during work will increase. The increased levels will also cause errors in safety measures and, consequently, may cause a higher rate of accidents than would occur in quieter conditions. Another possible cause of accident is the masking of an auditory alarm. Since danger signals often take this form, it can be reasonably expected that some such signals will be masked in environments typical of heavy industry operations, construction activities, and mid-city traffic during shopping and commuting hours.

While examining the effects of noise on people and groups, it is easy to lose sight of an evident but important fact. The "average" person or "typical" group simply does not exist. It should be noted that responses to noise by individuals, as well as by classes of people, differ markedly from one another. A segment of the population (estimated from 2 to 10 percent depending upon the source) is considered to be highly susceptible to noise at almost any level, while some individuals (possibly 20 percent of the population) barely respond to noises considered intense by others. The

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* By way of contrast, testimony received at the EPA Hearing on Noise Associated with Agriculture, Denver, indicated that children from farms, who were exposed to farm machinery noise, had a higher percentage of hearing impairment than any other children from urban communities.

following factors have been found to be the most important, from a sociological view, in enhancing or decreasing noise acceptability:

1. Feeling about the necessity or preventability of the noise.
2. Feeling of the importance of the noise source and the value of its primary functions.
3. Types of living activities affected.
4. Extent to which there are other things disliked in the residential environment.

H. O. Parrack, in the Handbook of Noise Control, 1957, provided data on the characteristics of people more likely to complain about noise. He noted that they were generally of higher socioeconomic status, were highly educated, and were likely to have political affiliations. He also found that those people engaging in mental as contrasted to physical occupational pursuits were more likely to complain about noise. This latter finding is consistent with that of the London noise survey and many others. The recently issued study by TRACOR, Inc. (a NASA report entitled Community Reaction to Airport Noise, 1971) indicated that, on the average, complainants are older and more affluent and have a higher education level than noncomplainers.*

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* There are indications, however, that the lack of complaint is not a true measure of response, as brought out in testimony regarding Logan Airport, at the EPA Hearing in Boston, Mass.; and further that those of lower socio-economic status, while not "complaining" are personally disturbed or have adverse social reactions to the noise source.

Prof. A. C. McKennell (of the University of Southampton, England) in a recent article entitled "Complaints and Community Action", which appeared in Transportation Noises—A Symposium on Acceptability Criteria, evaluated the results of many community surveys in the following terms: "We know a certain amount about the characteristics of the reactions of communities to events which deeply affect them. A small, middle class group actively protesting in the presence of an apparently indifferent majority is a common occurrence. It is when these activists groups gain the support of the larger, normally acquiescent majority, that serious community conflict can result. Under these conditions, what starts as a specific issue often sparks off a more generalized local conflict."

The day when planners could concern themselves solely with technical and economic considerations is past. In a paper entitled "Predicting the Future", which also appears in the previously cited symposium volume on transportation noises, Prof. R. A. Bauer of the Harvard Graduate School of Business notes: "If we are moving into a period in which individual citizens increasingly expect to be freed from various forms of environmental nuisance and if all citizens groups are tending more and more to take an active role in the decision making process, then it is probable that complaints and effective organized protests will occur at lower levels and frequency rates of noise exposure than in the past." He further stated that, "For a variety of convergent reasons, we appear to be entering a period in which people will be more disposed to organize for direct participation in policy decisions affecting them."*

As a counterforce to this pressure exercised by the community, associations and organizations representing the noise producers can be expected to act concertedly. In this manner, large and politically powerful groups with differing beliefs and objectives can be expected to press for their interests. This type of situation requires that all the facts relevant to the issues at hand be brought into the arena of public discourse and be used in the decision making process, in an orderly manner.

There is an upsurge of activity regarding enactment by states and cities of new regulatory provisions on noise. Many states are currently considering legislation relating to control of noise. This activity is clear indication of the increasing importance of noise as a sociological and environmental quality consideration. Vigorous statements at EPA public hearings concerning the lack of corrective action on the part of the Federal government were received from mayors and other elected local officials and from numerous congressmen. Such statements reflect the awareness of the respective constituencies of the general noise problem and the widely held view that there is little or no recourse, short of court action or acts of Congress, to the solution of this major problem. This, in spite of the extensive investment of the Federal government

* There are clear implications in this as to the importance of the Environmental Impact Statement provisions of PL-91-190 (Sec. 102(2)c) and the noise nuisance control features of PL-91-604 (Sec. 402(c)).

and industry in aircraft noise control research (as brought out in EPA hearings in Chicago and Washington) indicates the need for more rapid action to control noise.

THE EFFECTS OF NOISE ON WILDLIFE AND OTHER ANIMALS

Acoustic signals play a major role in animal species survival in terms of maintaining viable population dynamics and an individual animal's growth behavior. For example, a single startle event may stop the brooding cycle of wild game birds for an entire season. Continuous noise may mask the detection and avoidance relationship between prey and predator causing huddling or panic-behavior or may induce population dissipation and migration. Unfortunately, a thorough search of the scientific literature from 1950 to the present reveals an almost complete lack of information concerning the effects of noise on wildlife. Scientific literature dealing with the effects of noise on laboratory and farm animals is sparse but can provide some clues regarding the possible effects on wild animals.

Extreme caution should be used in interpolating from experimental data obtained on animals receiving acute high level sound exposures when estimating probable results to be expected from animals experiencing lower sound levels for longer terms or variable durations. Also, it should be recognized that experimental animal data may not always be relevant to humans.

It is important to note that audible frequency ranges vary widely from organism to organism. This might be expected to be a significant factor in studies to determine the effects of sound on the organism. However, little or no mention of this is found in the available scientific literature nor is there any evidence of concern about this factor.

The sound pressure levels that have been used to study laboratory animals were mostly high or intense, and the duration of exposure in most cases was typically acute rather than chronic. A danger in generalizing from acute high or relatively high intensity level studies to chronic low levels of stimulation is that there may be no relationship at all. The longest exposure duration in studies reviewed was 150 days. This should probably be considered a chronic exposure; however, the next longest exposure was 42 days, which would hardly qualify as a chronic exposure except perhaps for organisms with relatively short lifespans. The levels of stimulation were as high as 160 dB, with most in excess of 100 dB and with few below 90 dB. These are higher levels than those animals would normally be exposed to around most airfields, industries, highways, or other man-made sources that may invade their habitats.

Studies using laboratory animals have demonstrated loss of hearing after exposures to sound pressure levels of 90 dB or less, depending upon the animals studied and upon the frequency characteristics of the sound. Spectra varying from pure tones to narrow and broad band noise have been used. Most of the studies conducted have utilized high intensities of sound, usually of narrow- or broadband noise.

Effects of Noise on Wildlife

A thorough search of the scientific literature from 1950 to the present reveals an almost complete lack of information regarding the effects of noise on wildlife. However, there have been a number of selective studies to determine the effects of noise on particular fish and insects. These studies have established that intrusive sounds can affect the locomotor patterns of fish and, if sufficiently intense, can also result in their death. Studies of insects indicate that their life span and reproductive capacity may be affected by exposure to certain sounds.

Effects of Noise on Laboratory Animals

The best documented effect of noise on laboratory animals, as on man, is the production of loss of hearing or damage to the auditory system. Brief exposures to intense sound or prolonged exposures to moderate levels of noise can cause hearing loss. Impulse sounds are sounds in which the pressure from the sound wave rises to its maximum intensity quickly (within a few millionths of second). If sufficiently intense, such sounds can damage the ear before protective mechanisms (the aural reflex) can help compensate for the pressure increase.

Loss of hearing due to noise exposure has been demonstrated in a variety of animals such as guinea pigs, rats, chinchillas, dogs, and cats. Histologic studies have revealed damage to the inner ear, such as destruction of hair cells and, in some cases, disruption of supporting cells and damage to the basilar and tectorial membranes.

Nonauditory effects of exposure to noise have been demonstrated in guinea pigs, mice, rats, and rabbits. There is evidence that noise influences stress responses in an animal, producing neural and hormonal changes affecting urinary, adrenal, and reproductive functions.

In summary, high levels of noise stimulation of laboratory animals for fairly short durations have produced results suggestive of significant effects on such things as sexual function, blood chemistry, auditory function, and seizure susceptibility.

Effects of Noise on Farm Animals

There has been a considerable amount of speculation concerning detrimental effects of noise on domestic animals of economic importance such as horses, cattle, swine, poultry, and especially mink. However, controlled studies typically reveal little or no effect other than startle response to sudden loud sounds. Sound in itself apparently produces responses ranging from momentary alerting and searching reactions to (rarely) signs of panic or fright. In general, panic reactions occur when a visual stimulus, such as a low-flying airplane, occurs alone or in conjunction with the loud sound. The larger farm animals (horses, cattle, and swine) appear to adapt readily to high levels of noise. Several studies have revealed that sonic booms and simulated sonic booms have little effect on mink, despite many large claims against the government for noise-related losses.

Poultry may not adapt as well as do the large farm mammals. Loud noises have been demonstrated to disrupt broodiness (cessation of egg laying and initiation of incubation) in turkeys, producing a rapid return to egg production. Little effect on the hatchability of chicken eggs as a result of sonic boom exposure has been shown. In general, insufficient research on effects of noise on farm animals precludes drawing any firm conclusions. However, sounds that are meaningful to a particular animal seem to communicate specific information that results in changes in behavior and internal physiological states.

Possible consequences of some of the behavioral changes effected by noise are difficult to evaluate. Decreased exploratory behavior, immobility, and things of like nature could have significant consequences if they occur under conditions of chronic stimulation and the exposed animals do not adapt out over time. Any panic type behavior, such as piling up or huddling, could well lead to problems of survival of an animal. Also, avoidance behavior could restrict access to food or shelter and could therefore adversely affect an animal's, or even a specie's, chances for survival.

The prey-predator situation could be drastically changed. The animal that depends on its ears to locate prey could starve if auditory sensitivity acuity decreased, or the animal that depends on hearing to detect and avoid its predators could be killed. Reception of auditory mating signals could be diminished, therefore affecting reproduction. Masking of these signals by noise in an area could also produce the same effect. Detection of sounds of the young by the mother could be hindered, leading to increased rates of infant mortality or decreased survival rates. Distress or warning calls may not be received, again significantly affecting survival.

In view of the potential economic impact of noise effects on farm animals, it would appear worthwhile to study in more detail the effects of noise on such things as fertility, egg laying, weight gain, and health, under precisely controlled conditions and in realistic, chronic exposures. In any such investigations, the frequency characteristics of stimuli to be used should be carefully selected to correspond to the audible range of hearing of the animal to be studied, in order to enhance the likelihood of valid and realistic results.

Summary of Effects on Wildlife and Other Animals

With the exception of the extensive and systematic body of literature exploring the effects of noise upon auditory structures and hearing, well controlled and well designed experiments substantiating nonauditory effects of noise on animals are rare. In the case of wildlife, such studies are virtually nonexistent.

The uncertainties, ambiguities, and even conflicts in reports of nonauditory physiological, metabolic, sexual, and other physical effects of noise suggest the need for a thorough and clearly defined research program to systematically study the effects of long-term, low level chronic noise exposure in animals. Concurrently, and with careful examination of possible physiological and psychological effects of noise on animals, the effects of noise on true wildlife in its native habitat requires detailed investigation.

EFFECTS OF SONIC BOOM AND SIMILAR IMPULSIVE NOISES ON PROPERTY

The effects of impulsive noise will be discussed here mainly in terms of the effects produced by sonic booms. However, the discussion is applicable to the sounds of chemical explosions and to other impulsive noises if the appropriate physical parameters are known.

The Federal government has carried out a comprehensive series of observations on the effects of sonic booms produced by supersonic aircraft flights. Three of the series were observations at cities in the Midwest. The cities, dates, and total number of overflights producing booms were as follows: St. Louis (1961-62), 150; Oklahoma City (1964), 1253; Chicago (1965), 49. Another series of experiments was carried out at Edwards Air Force Base in California (1966). Most of the results summarized in the following discussion are drawn directly from the report of the Sonic Boom Panel of the International Civil Aviation Organization, which included data from the four series of tests.

Nature of Sonic Booms and Other Impulsive Noises

Impulsive noise has its origin in transient events that generate sound pressure waves jumping abruptly to some peak value, then decaying slowly with time and, finally, (for a sonic boom) abruptly jumping again. The pressure jumps of sonic booms are shock waves and are audible as two sharp bangs separated by a short time interval.

A rise in the pressure of the air may always be observed immediately in front of any solid object, e.g., an aircraft, that is in motion relative to the surrounding air. At subsonic speeds, the pressure decreases rapidly with distance away from the aircraft. However, when the relative velocity between the aircraft and the surrounding air is greater than the local speed of sound, not only is the air ahead of the aircraft compressed, but a coneshaped shock wave is formed with the aircraft at the vertex. As the shock spreads out, the shock cone intersects the earth's surface and is heard by the observer as a sonic boom. It should be emphasized that sonic booms occur in the wake of a supersonic aircraft at all times when it is traveling faster than the speed of sound and not just at the instant when the aircraft passes from a subsonic to a supersonic speed.

The intensity of the sonic boom and the region on the ground over which the sonic boom will be observed (known as the boom carpet) are dependent on atmospheric conditions and airplane characteristics. The volume, weight, length, lift characteristics, altitude and Mach number of the aircraft affect both the amplitude and duration of the boom. The total width of the boom carpet is, typically, 20 to 80 miles. Outside of the carpet, the passage of the aircraft is heard only as a low-pitched rumble.

When the effects of the sonic boom on structures are being considered, it should be noted that most of the mechanical energy of the boom is contained in a band of low, inaudible frequencies. A convenient measure, for discussing the effects of sonic booms is the number of boom-person exposures—the experience of one sonic boom by one person. It is used as a measure of the times a sonic boom is experienced, either on different occasions by the same recipient or on the same occasion by different recipients.

Response of Structures to Sonic Booms

Sonic booms can induce transient vibrations in various types of structures. The manner in which a given structure vibrates is basically the result of the pressure signature distributed over the entire structure. The structural response will depend on the structure's location, size, shape, type of construction, manner of assembly, and state of maintenance and on the specific form of sonic boom pressure signature and its variation over the structure. The resonance characteristic of the structure will also have major influence. Seismic transmissions—vibrational energy transmitted through the earth—may also play a minor role in exciting the vibrations.

It follows, then, that structural response to sonic booms will be highly variable among structures, and unpredictable for a particular structure. But the response of a large collection of structures, such as the buildings in a community, will be fairly predictable in statistical terms.

Physical Effects on Buildings

It appears that the structures most susceptible to sonic boom loads are buildings, residential, public, commercial, or otherwise. By and large, the damage caused by sonic booms will be confined to brittle secondary structures, such as window glass and plaster. There is, however, a small probability of a greatly magnified boom (as from aircraft turns and accelerations) striking a building with an exceptionally weak or faulty primary structure.

Studies involving flights of aircraft over instrumented and monitored structures have been completed for a number of residential and commercial building structures and for a variety of window configurations. The results of these studies are presented in Table 1-3.

Table 1-3

STUDIES AND SURVEYS ON SONIC BOOM

COMMENT	NOMINAL PEAK PRESSURE	RESULTS
Laboratory Test: plate glass windows 7'x7'x1/4" and normal construction mounting	960 N/m^2	No damage
Laboratory Test: residential sash window	144 - 960 N/m^2	No damage
Field Test: (White Sands) with 20 different type of residential and commercial structures and 1200 supersonic overflights	158 N/m^2	No damage
Field Test: residential and commercial buildings and pre-test structural survey monitoring. (St. Louis, Wallops Station, Oklahoma City, Edwards AF Base)	288 N/m^2	No damage
Field Test: Flights controlled, but no monitoring of building structures (St. Louis, Oklahoma City, Edwards, Chicago)	48 - 154 N/m^2	Some damage claimed

Between 1961 and 1965 field studies of sonic boom effects were conducted by systemmatic supersonic overflights of three cities: St. Louis, Oklahoma City and Chicago.

As an illustration of the type of damage reported, the information in Table 1-4 is presented from an analysis of the complaint reports in the St. Louis area.

Table 1-4

PERCENT OF VALID CLAIMS FOR CATEGORY OF DAMAGED ELEMENT

Type Element Damaged	Percent of Units Damaged
Glass only	37.0
Plaster only	22.0
Glass and Plaster	11.0
Bric-a-brac	18.5
Tiles and fixtures	7.5
Other structural damage	4.0

Evaluations were made of a portion of the complaints received, and it was judged by competent engineers and architects that about one-third of the alleged damage incidents were valid. The validated complaints included those in which the sonic boom was interpreted as a possible triggering mechanism in the presence of other factors affecting structural integrity.

Measured vibrational accelerations and displacements in all monitored structures indicate that such occurrences as door closing, door slamming, and pedestrian traffic create accelerations in the structure of the same order of magnitude as those measured due to sonic booms. In addition to the statistical nature of glass breakage, some inconsistency between laboratory and community data undoubtedly existed due to the willingness of claims adjusters to allow small claims rather than to pursue the investigation to proof of damage cause.

Cost of Damage to Buildings

In the foregoing discussion, the physical nature of the sonic boom damage problem has been treated. Another measure of the extent of damage is the number of claims filed. In this connection, Concorde 001 carried out 43 supersonic flights over France under conditions different from expected commercial flight operations in that, for example, a great number of focused booms were generated during supersonic maneuvers. Furthermore, during these flights, 27 focused booms due to transonic acceleration reached the ground. For 40 million boom-person exposures, 56 claims were lodged and are presently being processed. The fianancial settlement of claims judged to be justified is not presently known.

In the last decade, military aircraft have logged over 15,000 hours of supersonic flight training time over the continental United States. Typical peak overpressures under the flight path are 96 N/m^2 (2 lb/ft^2), although overpressures two to four times greater may arise during maneuvering. Of the paid damage claims resulting from Air Force training flights, 65 percent were for glass and 18 percent were for plaster damage.

The previously mentioned sonic boom tests in three cities —account for the overwhelming bulk of the systematic study of boom-person exposures in published reports to date. The data on boom-person exposures, numbers of complaints, claims filed, and, finally, value of damage awarded are given in Table 1-5. The data is analyzed and reduced on the basis of boom-person exposures in Table 1-6. Perhaps the most useful yardstick of structural damage is the amount of money paid out in settlement of damage claims per million boom-person exposures in these three highly publicized tests. For these surveys, this averages to about $220 per million boom-person exposures.

Care must be taken in applying the above estimate of damage costs per million boom-person exposures in other contexts; for example, at other average boom intensities. The samples of costs underlying the estimate vary by more than a factor of two; thus, no consistent pattern of costs among the cities has emerged. (Errors in consistency in estimating the population affected in the different cities may be a factor). Also, structural damage susceptibility, varying building codes, repair costs, reimbursement policies (whether lenient or strict) probably vary widely among cities and counties.

Effect of Sonic Booms on Natural Structures and Terrain

Earth Surfaces

Sonic booms apply moving pressure loads to the earth's surface. On land there are two major effects. The first, and largest, is the static deformation that travels with the surface load, and the second is a train of Rayleigh surface waves that travel at a different speed.

The ground response to sonic booms in terms of soil particle movement is comparable to that associated with the footsteps of a man. The effective areas covered on

Table 1-5

SONIC BOOM DAMAGE DATA

Boom dates	Metro-politan population	Total SS over-flights	Median peak over-pressure N/m^2 (lb/ft^2)	Boom-person exposures (millions)	Number of com-plaints	Number of claims filed	Number of claims paid	Value of claims paid
St. Louis, 1961-62	*2,600,000	150	86 (1.8)	390.0	5,000	1,624	825	$ 58,648
Oklahoma City, 1964	+512,000	1,253	58 (1.2)	642.0	15,452	4,901	289	123,061
Chicago, 1965	6,221,000	49	86 (1.8)	304.5	7,116	2,964	1,442	114,763
Total	9,333,000	1,452	++84 1.76	1,336.5	27,568	9,489	2,556	$296.472

*Metropolitan area as given in National Geographic Atlas, 1963 edition, rounded off to nearest thousand population.

+Greater St. Louis population affected by boom.

++Average.

Table 1-6

ANALYSIS OF SONIC BOOM DAMAGE DATA

	Complaints per million *BPE	Claims per million BPE	Paid-out claims per million BPE	Paid-out damage per million BPE
St. Louis	12.8	4.16	2.11	$151
Oklahoma City	24.1	7.63	.45	192
Chicago	23.4	9.75	4.74	377
Weighted average	20.6	7.10	1.91	$222

*Boom person exposures

the ground are, of course, different; the boom-induced motions are correlated over distances on the order of miles, whereas footstep-induced motions decay within several feet. Earthquake tremors that are measurable with sensitive instruments but imperceptible to humans are also of this magnitude. Sonic-boom-induced particle velocities are, on the average, approximately two orders of magnitude (that is, a factor of 100) less than the damage threshold accepted by the U.S. Bureau of Mines and other agencies for blasting operations.

Further significant findings of the sonic boom tests were that the disturbances were limited to a thin surface of the earth and that no evidence of focusing of seismic energy was observed. Although reports have been received concerning cracked concrete driveways and broken underground pipes due to sonic booms, investigations produced no scientific support for such allegations.

Avalanches

Of particular concern is the possibility of avalanches being triggered by sonic booms. A series of 18 flights that generated nominal peak pressures up to 500 N/m^2 were conducted over a snow covered area exhibiting potential avalanching conditions. No avalanche or effect on the creep behavior of the snow layers resulted. However, the snow conditions were such that the U.S. Forest Service rated the possibility of avalanche to be low. The results, therefore, are inconclusive.

Landslides

There have been reports of landslides and cliff failures attributed to sonic booms. However, these reports have not been documented at this time.

Water Surfaces

In deep water, a moving underwater pressure field accompanies the boom carpet over the surface. Theoretically the pressure wave formed just beneath the surface of calm water is almost identical to that of the wave in air, both in the amount of peak pressure and in wave form, but it is rapidly attenuated with depth. Furthermore, the pressure jumps disappear and are replaced by slowly varying pressures. It does not seem probable that a pressure field in water could cause structural damage.

Summary of Effects of Sonic Boom

- Laboratory and controlled overflight experiments with monitored structures were generally negative regarding sonic boom damage from peak pressures up to 960 N/m^2 (20 lb/ft^2).
- Controlled overflights with unmonitored structures subjected to a range of nominal peak pressures from about 48 to 154 N/m^2 (1 to 3.2 lb/ft^2) resulted in damage claims, predominantly for glass, on the order of one per 100,000 population per flight, i.e., 100,000 boom-person exposures, with about one in three being judged valid.
- Flight test series in Oklahoma City, Chicago, and St. Louis resulted in over 1 billion boom-person exposures. The associated property damage resulted in paid out claims averaging about $220 per million boom-person exposures. Numerous small claims were paid without investigation or inspection.
- On the average, frequency of paid claims for glass damage far exceeded that for plaster damage.

- Ground motion due to sonic boom is small, but measurable (two orders of magnitude less than U.S. Bureau of Mines damage threshold for blasting operations.)
- Although no direct evidence exists, sonic booms may trigger avalanches if unstable snow conditions exist.
- Although no documented evidence exists, unstable terrain features could be affected by sonic booms.
- A structure may accumulate damage (often not visible) from vibration, weathering, and aging that eventually terminates its life. The sonic boom could be another such cumulative contributor.
- An uncertainty concerning the effects of the sonic boom is how it compares with the structural aging effects due to the existing environment.
- Sonic boom pressures over water are rapidly attenuated and converted to slowly varying pressures and probably have no effect on structures.

In summary, the effects of sonic boom on ground motion must be further explored.

PHYSICAL EFFECTS OF NOISE ON STRUCTURES AND PROPERTY

There is little data available regarding the effects of acoustical energy on structures other than aircraft, in which case high frequency, high intensity noise has been implicated in metal fatigue in certain components. High intensity, low frequency acoustical energy, such as associated with pulsejets and other high intensity pulsation sources, has been observed to set structural components such as windows, light aluminum or other sheet metals into sympathetic vibratory motions. There is little valid information regarding the transition zone between acoustical energy and vibratory response phenomena and possible effects on structures, machinery, and equipment. Since shock and vibration do play a major role in certain types of mechanical deterioration and equipment failures or malfunctions (in which noise generation may be a symptom of the occurrence), it is evident that a complex relationship exists.

The heavy concentration of construction equipment in certain urban areas may produce a combination of vibratory energy transmission through soil and supporting structures, which could conceivably affect fragile structures such as glass and certain particularly susceptible materials including plastics and thin aluminum panels. Further investigation is needed on the exact nature of this problem.

CHAPTER 2

SOURCES OF NOISE AND THEIR CURRENT ENVIRONMENTAL IMPACT*

A characterization of the sources of environmental noise and an assessment of their impact on the quality of life is central to the formulation of a balanced environmental noise abatement program. Clearly, such a program must be predicated on a quantitative understanding of the contribution of each of the broad array of noise-producing devices. Most people are aware, at least qualitatively, of the impact of aircraft noise on airport communities, and many are aware of the numerous diesel trucks presently on our roads. But noise from other types of vehicles, construction and industrial operations, and appliances are also recognized as a problem in various segments of society. People will, however, assess the relative and absolute impact of these sources differently. Such impressions are generally closely tied to an individual's life style and experience and cannot be used as the basis for the establishment of national policies. An objective and quantitative description of noise sources

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* This chapter is based upon material prepared by the staff EPA Office of Noise Abatement and Control as a result of testimony received during public hearings and upon data contained in EPA Technical Information Documents NTID300.1, "Noise From Construction Equipment and Operations, Building Equipment, and Home Appliances" (EPA contract 68-04-0047, Bolt, Beranek and Newman); NTID300.2, "Noise From Industrial Plants" (EPA contract 68-04-044, L. S. Goodfriend Associates); and NTID300.3, "Community Noise" (EPA contract 68-04-0046, Wyle Laboratories); NTID300.13, "Transportation Noise and Noise From Equipment Powered by Internal Combustion Engines (EPA contract 68-04-0048, Wyle Laboratories).

and effects is needed to establish priorities and to cast the problem of environmental noise in proper perspective. More important is the need to determine the average cumulative noise exposure of typical individuals in our complex society.

Sources may be characterized individually and in the aggregate. To assess relative importance and as a basis for impact evaluation, it is generally adequate to determine a simple measure of the noise level (e.g., dBA) of a source at a particular distance. For example, by comparing the A-weighted sound levels of appliances at a 3-foot measuring distance, one can tentatively conclude that refrigerators generating 42 dBA are likely to be a far less serious problem than vacuum cleaners generating 72 dBA. Further, noise levels at other distances and in other situations characteristic of personal exposure may be estimated by accounting for changes in level as sound propagates through the air and structures.

Characterizing noise levels in a more collective sense is also of use in assessing impact. People tend to respond differently to the noise characteristics of a distant highway or construction site than to a readily identifiable single incident such as a passing truck. Highways for example, are typically characterized by a nearly continuous background level, with fluctuations owing to vehicle spacing and the various source levels of each vehicle. Single events are different in that they may intrude excessively in otherwise quiet environments, and annoyance is strongly related to both the peak level and duration of exposure.

One step further than aggregating vehicles into highways is to consider the noise generating in the community. This means the combination of all sources creating a total noise environment. The value of considering community noise as a whole, rather than evaluating each source in isolation, is twofold. First, human behavior is not arithmetically additive, reactions to individual acoustic stimuli do not provide a simple measure of the reaction to concurrent stimuli. Secondly, the myriad sources around us make the synthesis of a community noise profile difficult. To acquire an indication of realistic community situations it is more useful to have a total noise picture, established from actual field measurement.

As with noise source levels, the community impact must be treated quantitatively, and in terms that can be readily interpreted. It is not necessarily of great interest that a piece of construction equipment may generate as much as 95 dBA at 50 feet. What is of interest is that this noise level will contribute to the hearing loss of construction workers and other people exposed daily for several hours, will prevent intelligible conversation, and could affect the sleep of people living nearby. Also of great significance is the number of people disturbed in these ways and the extent of their disturbance. In a sense, the magnitude of the noise problem is proportional to the number of people whose lives are significantly degraded by noise.

It is neither practical nor desirable to identify and characterize all sources of environmental noise. Every piece of machinery, from a jet aircraft to an electric clock, produces sound; but not all of these sounds are of sufficient significance to merit study. Furthermore, the appropriate depth of treatment varies with the significance of the source. To ensure that the most significant sources of environmental noise are treated, the following categories of sources are identified and analyzed in this chapter.

1. Transportation systems
2. Devices powered by internal combustion engines
3. Industrial plants
4. Construction equipment
5. Household appliances and building equipment.

Transportation systems include aircraft, road and rail vehicles, ships, and such recreational vehicles as snowmobiles and all-terrain vehicles. The second category includes such devices as gasoline-powered lawnmowers and chain saws, which are not treated elsewhere. Although industrial plants have traditionally received attention because of occupational noise problems, they may also generate noise that is propagated to the community. Construction equipment and operations are responsible for intense levels of noise, though they are not as ubiquitous as certain other sources. Numerically, probably the most widespread source of noise is household appliances and building equipment, which includes 1 billion home appliances, as well as electric tools, and heating, ventilation, and air conditioning machinery. As a prelude to a discussion of these sources, community noise is treated in general. The chapter is concluded with an evaluation of the total impact of noise on the environment and a comparison among the various source categories.

COMMUNITY NOISE

The description of community noise requires inclusion of all of the noises in the outdoor acoustical environment. The outdoor noise environment varies from the quiet suburban areas to the din of traffic in the downtown city canyon and it generally varies with time of day in each location, being relatively quiet at night and noisier in the late afternoon during the 5 p.m. rush. Its effects may be experienced by people either in or out of doors. Thus, the task of describing community noise is to determine the variations in the outdoor noise environment with time and place throughout the community so that the descriptions are relevant to noise effects on people.

Description of the Outdoor Noise Environment

A physical description of a sound must account for its frequency characteristics, magnitude, and temporal pattern. A sound level meter, when used with the A-weighting characteristic, accounts for the frequency characteristics of a noise and magnitude of outdoor noise by weighting the amplitude of the various frequencies approximately in accordance with a person's hearing sensitivity as illustrated in the example in Figure 2-1.

Because the A-weighting is not a perfect solution for the accounting of man's perception of the frequency characteristics of a sound, other scales have been developed that attempt to better quantify loudness and noisiness. One of these, the tone-corrected Perceived Noise Level, better accounts for the ear's frequency response function and certain other characteristics of the noises; that is broadband noises containing strong high frequency pure tones (e.g., whine in jet noise). Presence of such tones results in a higher Perceived Noise Level. This scale requires complex measurement and analysis in its quantification. However, because it is somewhat more exact than the A-weighting in relating the physical characteristics of a sound to perceived noisiness, particularly for aircraft noise, it has become a major

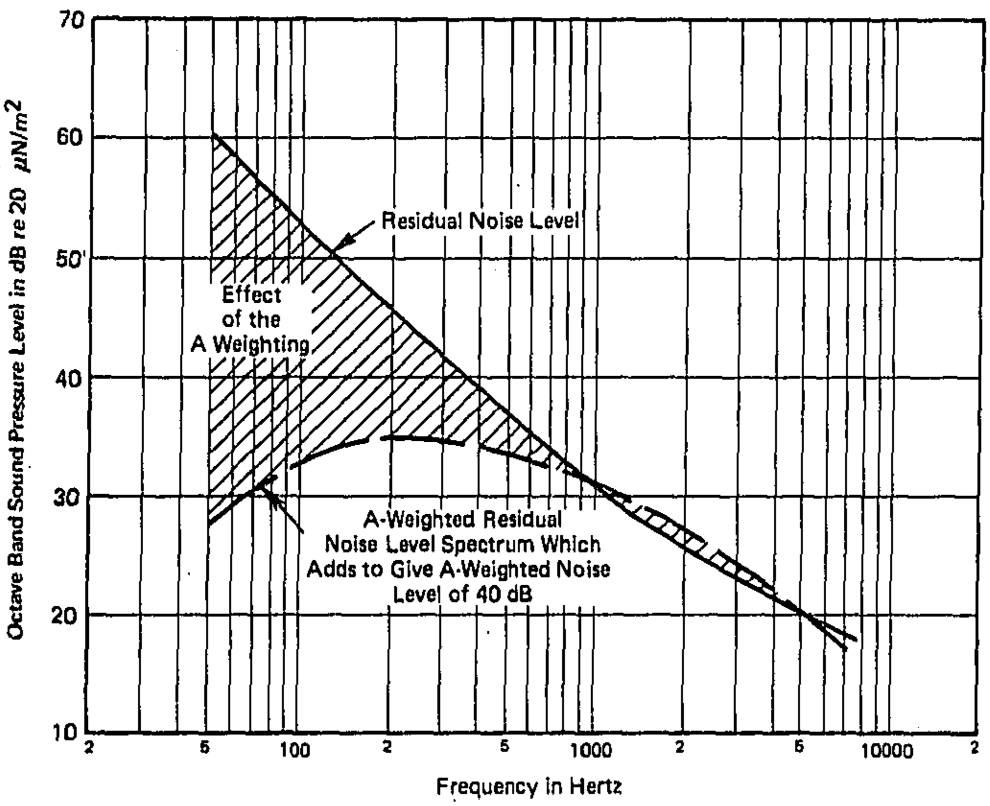

Figure 2-1. A Typical Octave Band Spectrum of the Outdoor Residual Noise Level in Late Evening in a Normal Suburban Neighborhood

element in the noise scale used for certifying aircraft. For most sounds, the Perceived Noise Level exceeds the A-weighted noise level by 13 dB, the difference ranging between 11 and 17 dB, depending upon the amount of the correction for pure tones. The complex Perceived Noise Level is used in this report only for describing aircraft noise, since the A-weighted sound level adequately describes the outdoor noise environment in a community.

To complete the description of the outdoor noise environment at a specific location, it is necessary to account for the temporal pattern of the A-weighted noise level. The temporal pattern is most easily observed on a continuous graphic-level recording, such as the two samples illustrated in Figure 2-2. The first striking feature of these two samples is that the noise level varies with time over a range of 33 dB, which is greater than an eightfold range of noisiness.*

The second major feature of the samples is that the noise level appears to be characterized by a fairly steady lower level, upon which is superimposed the increased levels associated with discrete single events. This fairly constant lower level will be termed the residual noise level for purposes of this report. The continuous noise heard in the backyard at night when no single source can be identified, and which seems to come from all around, is an example of residual noise. Distinct sounds that are superimposed on the residual noise level, such as aircraft overflight, cars, and dogs barking (Figure 2-2), can be classified as intrusive noises. Further, they can be separated into intrusive noises from outside the neighborhood, such as aircraft and the cars on boulevards and local neighborhood noises, such as dogs barking and local cars passing by.

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* A change of approximately 10 dB represents a doubling, or halving, of perceived loudness or noisiness of a sound. Thus, a 33-dB range of variation represents more than 2x2x2, or eightfold, range of possible variation in loudness or noisiness.

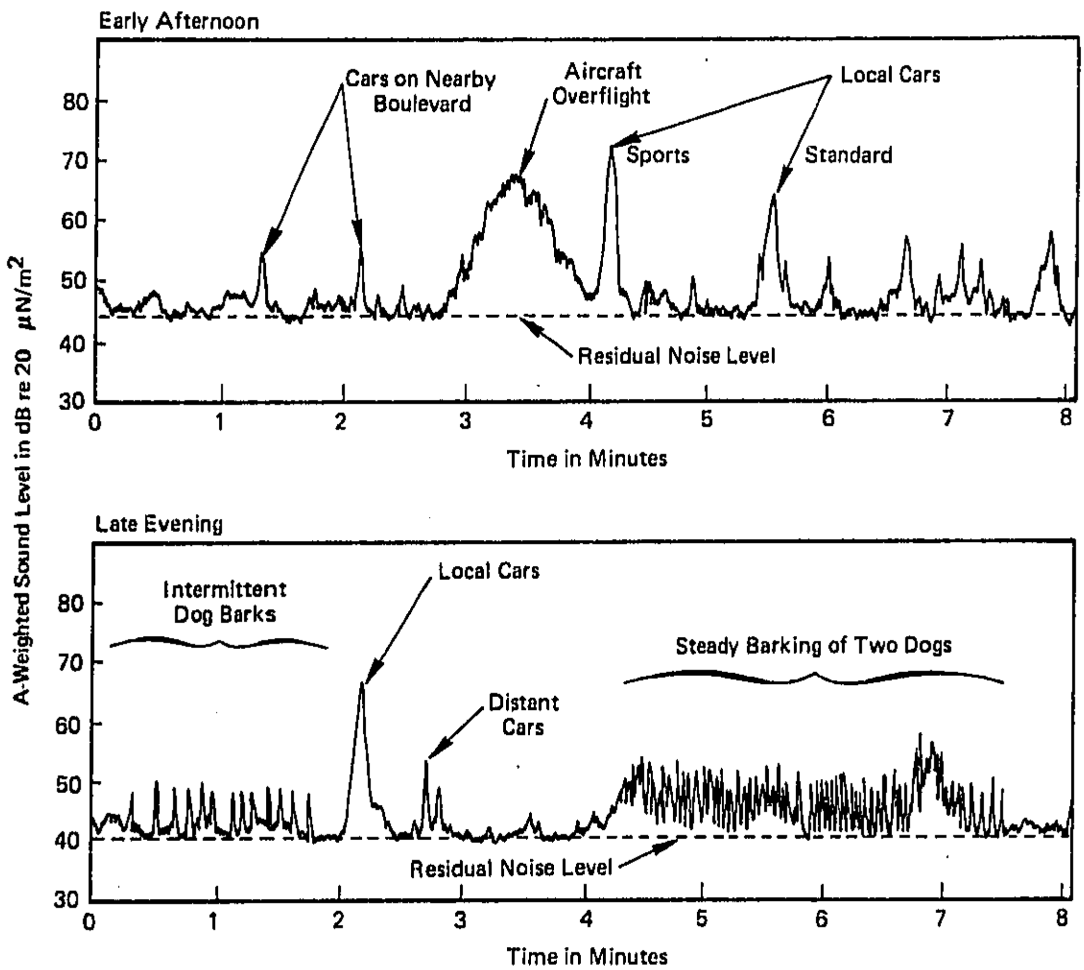

Figure 2-2. Two Samples of Outdoor Noise in a Normal Suburban Neighborhood with the Microphone Located 20 Feet From the Street Curb.

The third feature in these two samples is the difference in the noise level-time patterns among the various sounds. The noise level of the aircraft in this example is above that of the residual noise level for approximately 80 seconds, whereas the noise levels from the passing cars are above the residual noise level for much shorter durations, ranging between about 5 and 20 seconds. Clearly, if the noise associated with these single events were of sufficient magnitude to intrude on an individual's activities — conversation, thinking, watching television — the duration factor might be expected to affect the degree of annoyance. Similarly, it might be anticipated that the number of times such an event occurred would also affect the degree of annoyance.

The details presented in a 24-hour recording such as Figure 2-2 aids in understanding the nature of the outdoor noise environment at any neighborhood location. However, to quantify an outdoor noise environment so that it can be compared with others, it is often necessary to simplify its description by eliminating much of the detail. One way of accomplishing this simplification is to measure the value of the residual noise level and the values of the maximum noise level for specific single-event sounds at various times, using either a simple sound level meter or the continuous graphic-level recording of its output.

Another method of quantifying the noise environment is to determine the statistical properties of the noise level, through use of a statistical analyzer in conjunction with a sound level meter. The data from the statistical analyzer can be used to determine the percentage of time the value of the noise level remains between any two set limits. Alternatively, the data can be used to obtain a cumulative distribution in terms of the level exceeded for a stated percentage of the time.

Both the direct reading and the statistical methods have been applied to 24-hour recordings of the outdoor noise level at a typical suburban residential location. The results are illustrated in Figures 2-3 and 2-4. The variation of the hourly and the day, evening, and nighttime values of the various statistical measures, together with the minimum and maximum values read from a continuous recording, are summarized in Figure 2-3. The period histograms, showing the percentage of time that the level was in any stated level interval, are shown in Figure 2-4.

The maximum noise levels are often much greater than the highest statistical measure, L_1, which is the value exceeded 1 percent of the time. Consequently, for many communities in which the residual noise level (L_{90}) is relatively low and the statistical distribution is skewed far from the normal distribution, one must monitor almost continuously to determine the maximum environmental noise level.

All of the statistical measures in Figures 2-3 and 2-4 show the typical daytime-nighttime variation in noise level. In this example, the residual noise level drops sharply after midnight, reaching a minimum value between 4:00 and 5:00 a.m., and rises between 6:00 and 8:00 a.m. to its almost constant daytime value. This time variation of the noise is generally well correlated with the amount of activity and particularly well correlated with the amount of vehicular traffic in urban areas, which is generally considered to be the basic source of the residual noise. For this report the level exceeded 90 percent of the time, L_{90}, will be used as the statistical measure of residual noise where there are no identifiable stead-state noises present. The median noise level (L_{50}) is a useful measure of the "average" noise environment in the sense that one-half of the time it is quieter and one-half of the time it is noisier than L_{50}. The dashed line in Figure 2-3, labeled L_{eq}, is the Energy Equivalent Noise Level (L_{eq}) affected by both the duration and the magnitude of all the sounds occurring in the time period. Its value equals that of a steady-state noise that has the same

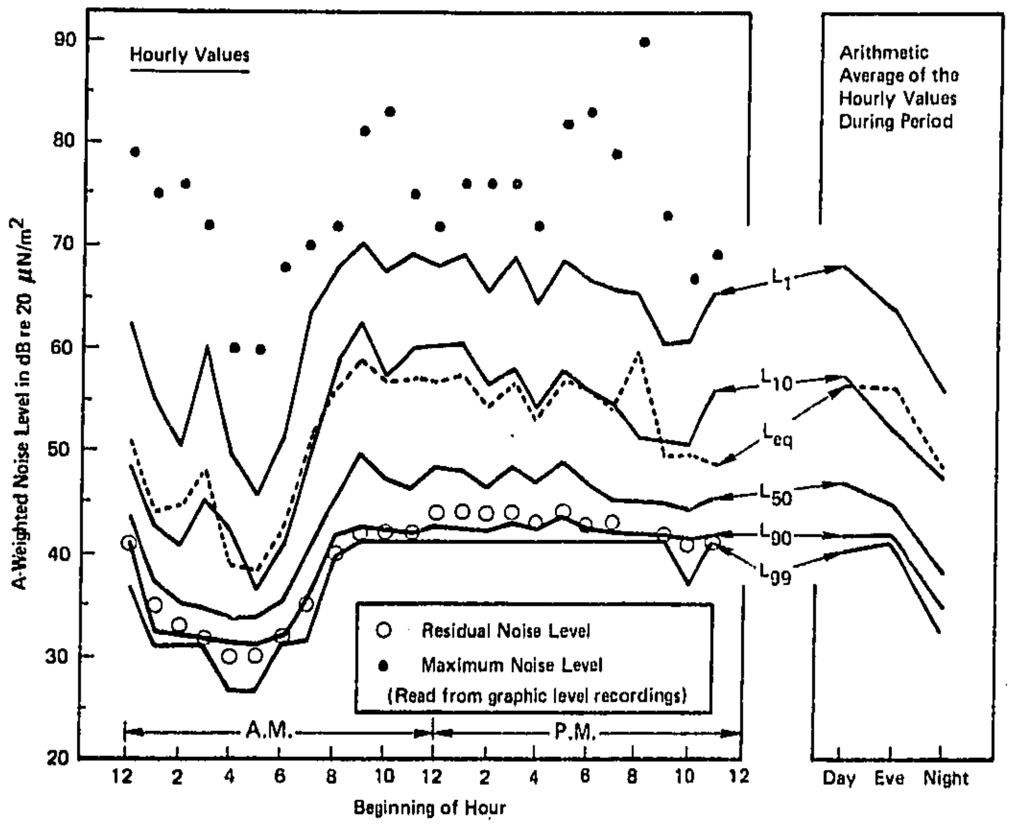

Figure 2-3. Various Measures of the Outdoor Noise Level.

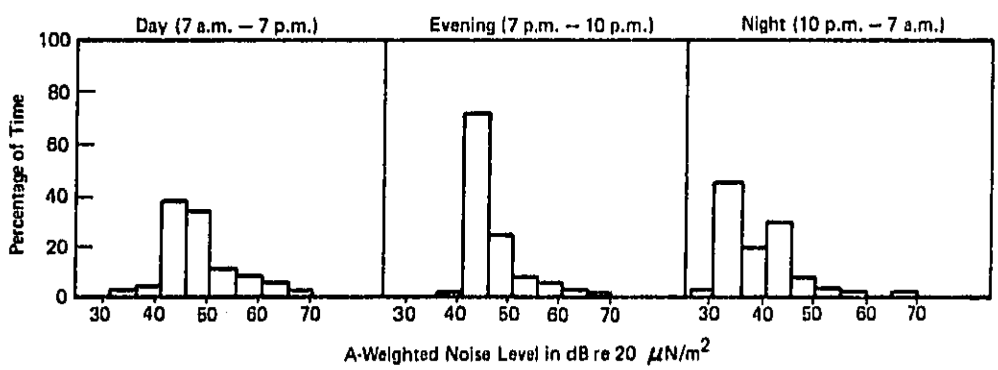

Figure 2-4. Histograms of the Percentage of Time Noise was in Each 5-dB Interval for Three Time Periods.

energy during the period analyzed as that of the actual time-varying noise. The energy equivalent noise level is one of the most important measures of the outdoor noise environment for the purpose of correlating noise and community reaction. These statistical measures simplify the quantification of the outdoor noise level and will be used in this report to compare the outdoor noise environments in various places. However, they must be supplemented by other observations if the character of the outdoor noise environment is to be understood beyond the simple statistics of the noise levels.

Range of Outdoor Noise Environments

To define the range of outdoor noise environments encountered by people in their normal activities, a series of 24-hour outdoor noise recordings was made at each of 18 sites, as part of the research for preparation of this report. This exploratory measurement survey was designed to sample noises in all types of locations, with major emphasis on the suburban and urban residential areas, and to include examples of the more significant noise problems. Thus, the survey presents a preliminary cross-section of the noise environment, but since it was not designed to be weighted by population density, it cannot give a true statistical picture of the noise environment in terms of a national baseline.

The range of daytime outdoor noise levels at the 18 locations is presented in Figure 2-5. The locations are listed from top to bottom of the figure in descending order of their daytime residual noise levels (L_{90}). The noisiest location, outside a third-story apartment overlooking an eight-lane freeway, is at the top of the list with its daytime residual noise level of 77 dBA, and the rural farm is next to the bottom of the list with its daytime residual noise level of 33 dBA. That all citizens do not enjoy the same quality in their noise environment is exemplified by the case of the owner of the third-story apartment near the freeway who has trouble renting because of the noise from the freeway.

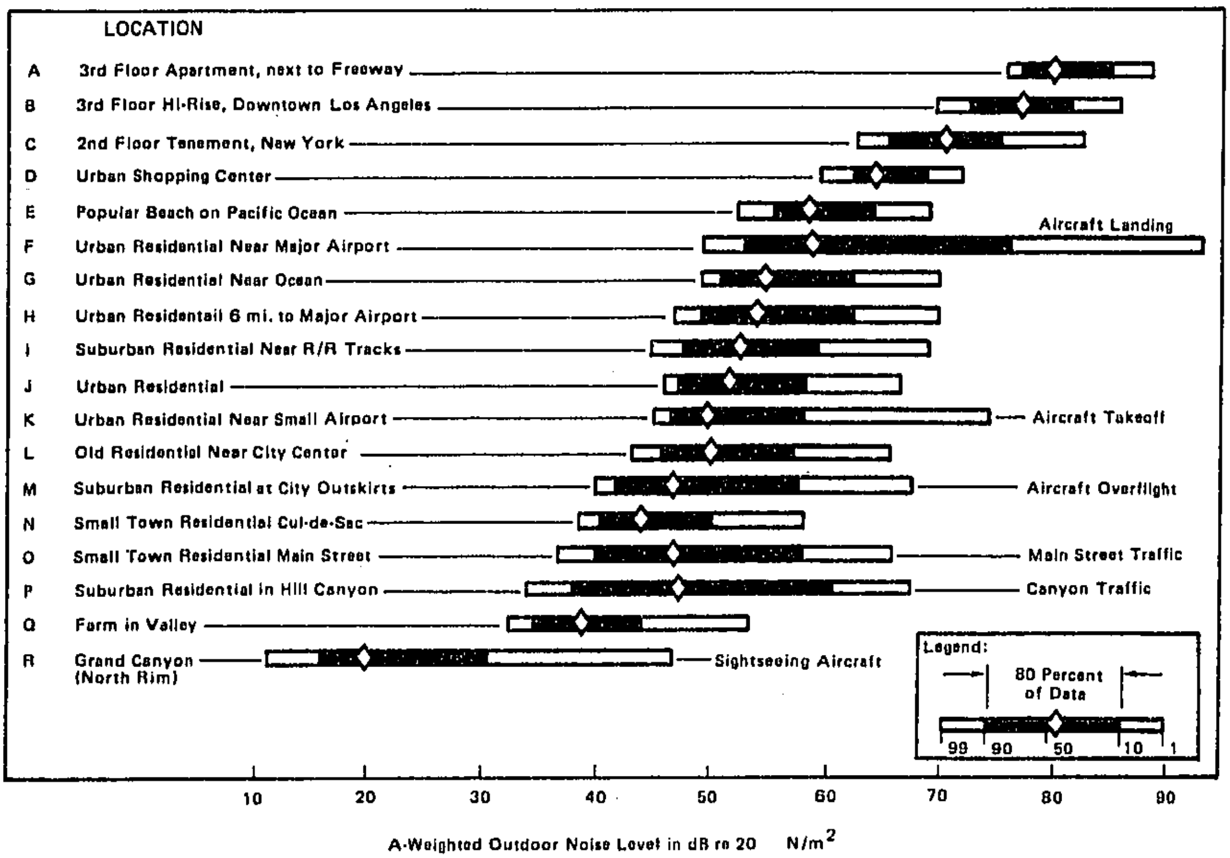

Figure 2-5. Daytime Outdoor Noise Levels

The Grand Canyon measurement was made at a remote camping site on the north rim. Even in this remote location, crickets raised the outdoor residual noise level to approximately 32 dBA for a few hours in the evening and early nighttime. For the remainder of the 24 hours, the residual noise levels were extremely low. The outdoor daytime residual noise level (L_{90}) of 16 dBA is close to the internal noise threshold of the field measurement system and should be representative of the quietest locations in this country. The difference between this extremely low residual noise level and the much higher noise levels in the city is representative of the contribution of man and machine to the outdoor noise environment. In this small sample of measurement locations, the average residual and median noise levels are over 20 dB greater in the city than in the detached residential housing areas for both daytime and nighttime, as seen in the comparisons in the first two columns of Table 2-1.

In this survey, the nighttime noise was less than that measured during the daytime, as is generally the case, except in summer when crickets abound. The average of the differences between the daytime and nighttime residual noise levels at each of the 11 locations in the residential areas is 5.8 dB. A similar comparison of the differences between the maximum daytime and minimum nighttime residual noise levels showed a difference of 13 dB, averaged over the same 11 locations. The comparison between maximum and minimum levels gives full weight to the quiet nighttime period, which was illustrated in Figures 2-3 and 2-4 examples of a normal suburban residential neighborhood.

The average value of the daytime residual noise level is 45 dBA for this limited number of measurement locations. This value lies on the borderline between the daytime residual noise level ranges chosen to represent normal suburban and urban residential areas, as given in Table 2-2. Since the qualitative descriptions of these 11 residential locations included four descriptive categories that ranged from quiet

Table 2-1

COMPARISON OF AVERAGE DAYTIME AND NIGHT TIME OUTDOOR NOISE LEVELS

General Category	Average Daytime (7 a.m.-7 p.m.)			Average Nighttime (10 p.m.-7 a.m.)			Difference Between Day and Night	
	Range dBA	Arithmetic Mean dBA	Standard Deviation dB	Range dBA	Arithmetic Mean dBA	Standard Deviation dB	Average Difference dB	Standard Deviation of Difference dB
Residual Level (L_{90})								
City (4 Locations)	61 to 77	69.1	6.1	51 to 69	60.8	6.3	8.3	2.1
Suburban and Urban Detached Housing Residential (11 Locations)	38 to 53	45.6	4.6	35 to 46	39.8	4.1	5.8	3.6
Median Noise Level (L_{50})								
City (4 Locations)	64 to 80	73.0	6.23	55 to 75	65.5	7.2	7.5	3.0
Suburban and Urban Detached Housing Residential (11 Locations)	44 to 59	50.9	4.1	38 to 50	44.2	4.3	6.7	2.6

Table 2-2

QUALITATIVE DESCRIPTORS OF URBAN AND SUBURBAN DETACHED HOUSING RESIDENTIAL AREAS AND APPROXIMATE DAYTIME RESIDUAL NOISE LEVEL (L_{90})

Description	Typical Range dB(A)	Average dB(A)
Quiet Suburban Residential	36 to 40 inclusive	38
Normal Suburban Residential	41 to 45 inclusive	43
Urban Residential	46 to 50 inclusive	48
Noisy Urban Residential	51 to 55 inclusive	53
Very Noisy Urban Residential	56 to 60 inclusive	58

suburban residential to noisy urban residential, it is not surprising that the average residual level for these locations is close to the average of the four categories in Table 2-2.

Intruding Noises and Community Reaction

There are two basic types of identifiable intruding noises that increase the outdoor noise level above the residual noise level — steady or quasi-steady-state noises and intermittent single-event noises. A steady or nearly constant level noise intrusion may result from a nearby freeway, industry, or air conditioner. The intermittent single-event noise is exemplified by the noise from an aircraft flyover, a single car passby, or a dog barking.

Constant-Level Noise Intrusions

One of the best known examples of constant-level noise intrusion is the noise environment within a busy city. The high daytime noise levels within the city make it difficult to have an outdoor conversation at normal voice levels. For example, if the outdoor noise level is 76 dBA, a condition commonly encountered in cities, it is necessary to talk in a raised voice to achieve intelligibility at a 2-foot distance.

The maximum distances for intelligible conversation at various voice levels have been calculated in accordance with the data in Chapter 1 for the outdoor daytime median noise levels (L_{50}) measured at each of the 18 locations in the exploratory survey. The median noise level (L_{50}) rather than the residual noise level (L_{90}), has been selected for evaluating the effects of the outdoor noise environment on speech communication since the median noise level more nearly represents the typical noise environment for most communication situations. The calculated distances, summarized in Figure 2-6, illustrate the restrictions in voice communication distances due to city noise.

Similar calculations show that the maximum distance for normal voice conversation outdoors in a noisy urban residential area is 3 to 5 feet, according to the range of noise levels for this category in Table 2-2. Also, the noise associated with the "very noisy urban residential" area of Table 2-2 is sufficiently high to restrict the amount by which doors and windows can be opened if one is to retain a desirable indoor noise environment. *

The noise levels associated with the "quiet suburban residential" area of Table 2-2 permit barely intelligible normal voice conversation at distances ranging between 30 and 50 feet. However, if the noise level is so low that the distance for intelligible conversation in normal voice approaches the distances between neighbors, it becomes difficult to have a private conversation. For example, with a 50-foot distance between neighbors, the median noise level required to obtain privacy would have to be on the order of 46 to 50 dBA, depending upon orientation of the talker relative to the neighbor and assuming no barriers exist. This median noise level range is approximately that of the normal suburban community.

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* A general estimation of building interior noise levels could be made on the basis of a reduction of exterior levels by about 7 dBA with windows open and 15 dBA with them closed, in the direction facing the noise source, and assuming average residential structures.

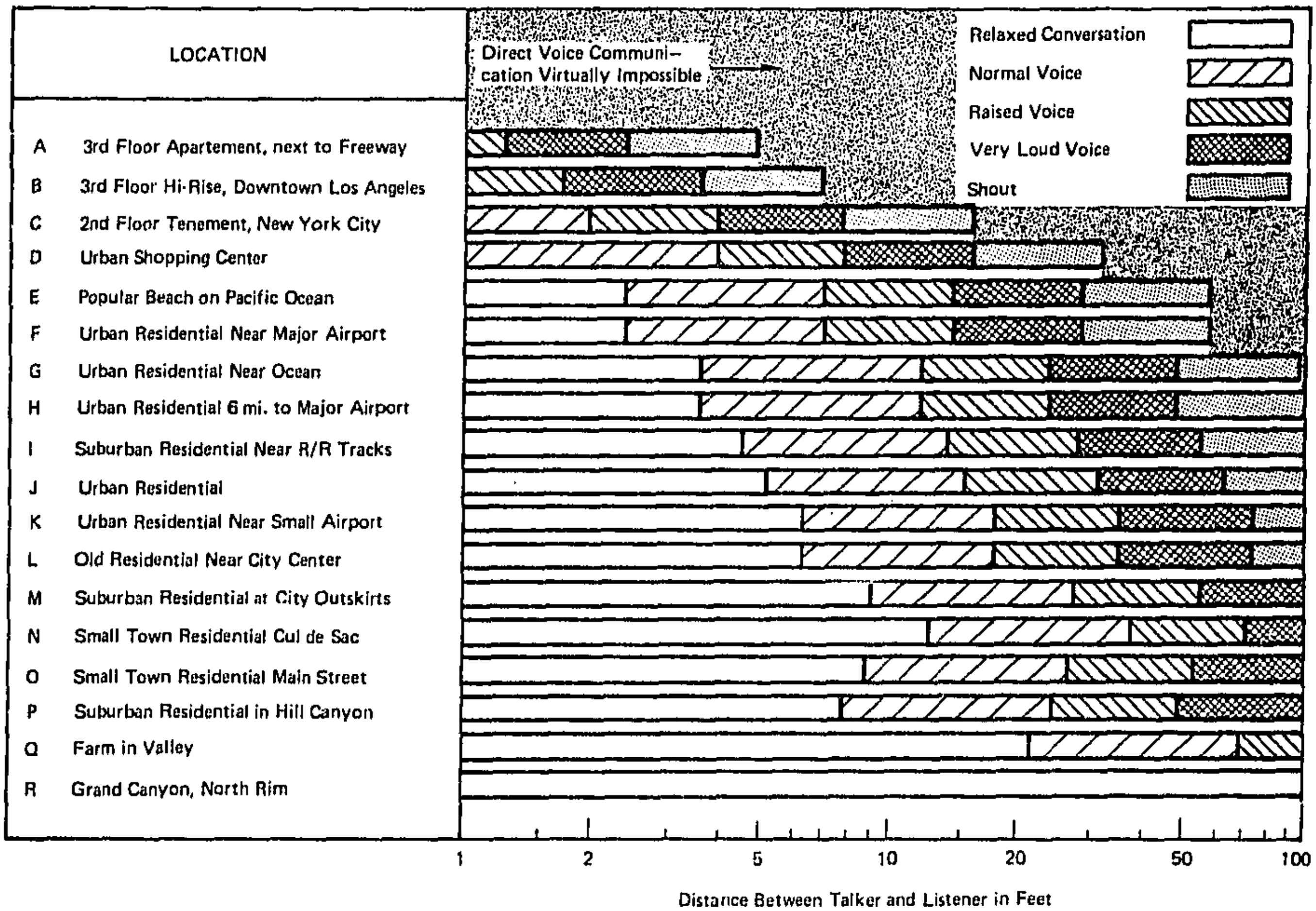

Figure 2-6. Estimated Maximum Distances Between Talker and Listener That Permit Intelligible Conversation and Those That Enable Relaxed Conversation When the Outdoor Noise Level Equals the Daytime Median Noise Level.

The considerations of speech intelligibility and privacy suggest that there are both maximum and minimum bounds to the outdoor noise levels that are compatible with reasonable enjoyment and full use of patios, porches, and yards. The upper bound for speech intelligibility appears to be in the range of the "very noisy urban residential" category of Table 2-2, and the lower bound for speech privacy is a function of the distance and shielding between neighbors.

Intermittent Single-Event Intriduing Noises

At many points in typical communities, the noise environment is made up of a series of transient noise events, such as caused by vehicular traffic. Many of these single-event noises interfere with speech and other activities for brief intervals of time. However, their impact is not as easily quantified in terms of speech interference as are constant level noise intrusions.

One method for estimating the magnitude of the intrusion for single-event noises is to have people rank the acceptability of a series of noises at different levels. One of the most comprehensive recent studies of the subjective judgment of single-event noises was performed using vehicle traffic noises, and the results are summarized in Figure 2-7. This data is consistent with the apparent general acceptance of maximum levels that result from standard passenger automobiles driven on residential streets.

When a single event is of sufficient magnitude and duration, it will add to the total noise energy in the hour, increasing the value of L_{eq}. Depending on the duration, it will also increase L_1 and L_{10}. These effects are illustrated in Figure 2-8, which shows the values of L_{eq}, L_{10}, and L_1 relative to the value of the residual noise level for daytime at each of the 18 locations. For most of the locations, L_{10} is approximately 10 dB greater than L_{90}. At the seven locations where significant intruding noises were

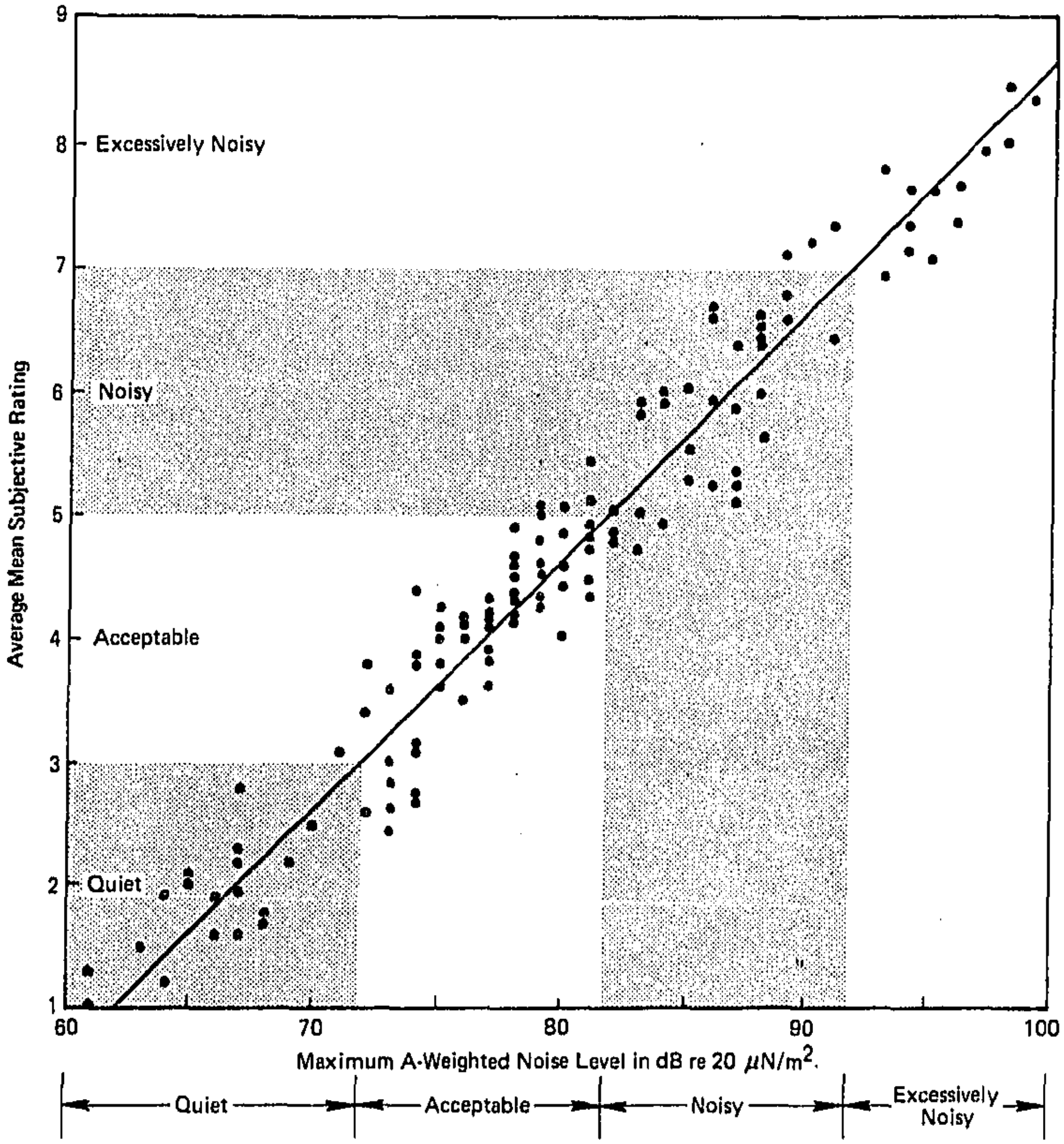

Figure 2-7. Average Mean Subjective Rating as a Function of Maximum Noise Level in dBA for the British Experiment at the Motor Industry Research Association Proving Grounds

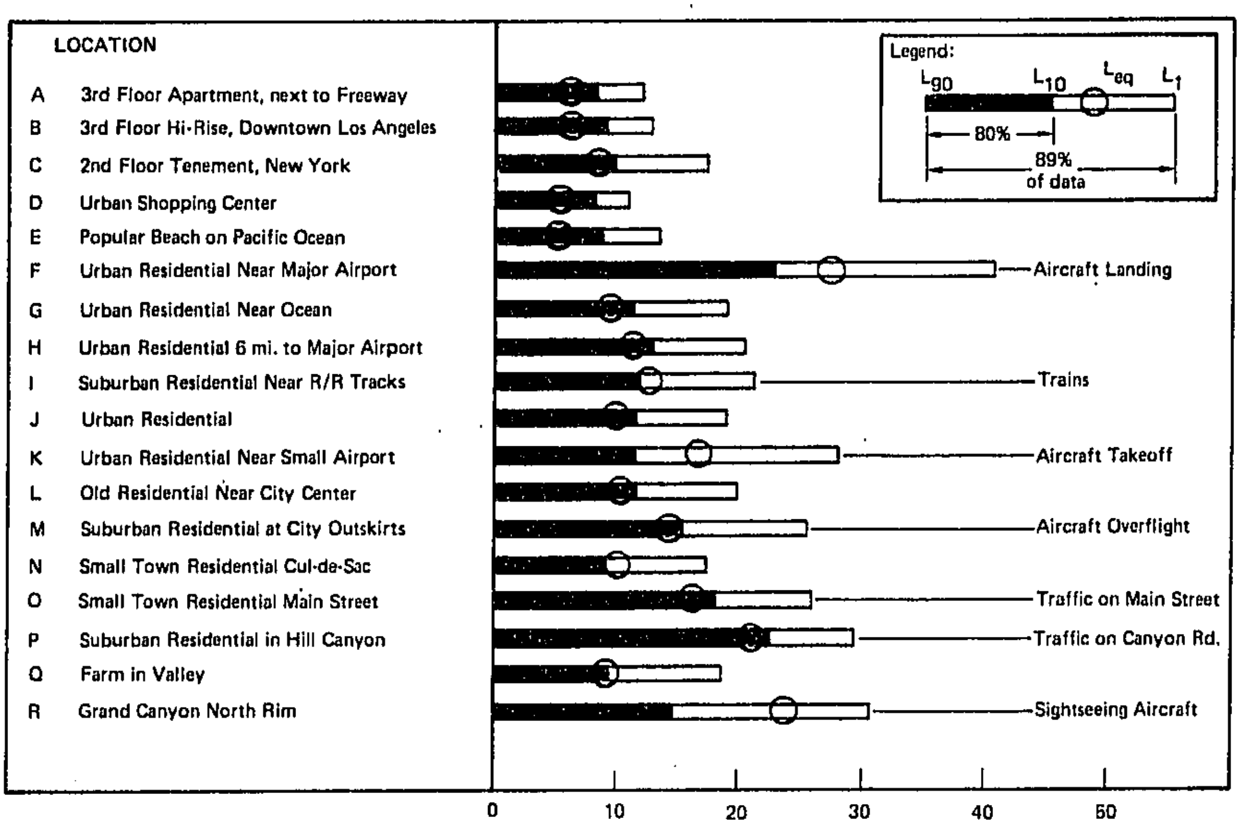

Figure 2-8. Difference Between A-Weighted Outdoor Noise Levels and the Residual Noise Level, L_{90}, in dB

noted, both L_1 and L_{eq} tended to be significantly higher relative to L_{90} than at locations where significant intruding sources were not noted. However, L_{10} showed increases in only four of the cases.

These increases in L_{eq} and L_1 are characteristic of the outdoor noise environments at locations where significant single-event type noise intrusions are experienced. In many cases, these noise intrusions will interfere with speech and other activites for short time periods, even though the median noise level is satisfactory.

Community Reaction to Noise

The advent of commercial jet aircraft initially increased the maximum noise levels at some locations around major airports by 10 to 20 dBA. These increases in noise caused widespread complaints and various forms of legal action from citizens living in neighborhoods near these civil airports. This situation paralleled earlier history of military jet operations by the Air Force after World War II, although only a few Air Force operational bases were close to cities and towns. Unfortunately, the civil airports, which accounted for the majority of the early commercial jet operations, were located near the major cities they served. Further, they were becoming surrounded by homes constructed in the post-WWII building boom. As jet thrust ratings, jet aircraft operations, and airports continued to increase, the airport noise problem tended to spread through the wider areas of the community and to more communities.

The U.S. Air Force and other governmental agencies began to investigate the effects of aircraft noise on people in communities in the early 1950's. This early research resulted in a proposed model for relating aircraft noise intrusion and the probable community reaction. This model, first published by the U.S. Air Force (Handbook of Noise Control, Vol. II, "Noise and Man," WADC TR-52-204), accounted for the following seven factors:

1. Magnitude of the noise with a frequency weighting for hearing response
2. Duration of the intruding noise (10 times the logarithm of the relative duration)
3. Time of year (windows open or closed)
4. Time of day noise occurs
5. Outdoor noise level in community when the intruding noise is not present
6. History of prior exposure to the noise source and attitude towards its owner
7. Existence of pure tone or impulsive character in the noise.

Corrections for these factors were generally made in 5-dB intervals, since many of the initial relationships were based solely on the intuition of the authors (Rosenblith and Stevens), and it was considered difficult to assess the response to any greater degree of accuracy. This method was incorporated in the first Air Force Land Use Planning Guide in 1957 ("Procedures for Estimating Noise Exposure and Resulting Community Reaction From Air Base Operations," WADC TN 57-10) and was later simplified for ease of application by the Air Force and the Federal Aviation Administration (FAA).

Many other methods have been proposed for describing repeated single-event type noise, with primary application to airport noise problems. Most of those methods represent an evolution of the community noise reaction model and consider at least some of its principal factors. Three of the methods for calculating the magnitude of noise intrusion are summarized in Table 2-3.

The Composite Noise Rating (CNR) was introduced in the early 1960's and has been widely used by Federal agencies. The Noise Exposure Forecast (NEF) is a recent evolution of the CNR and is proposed as its successor by the FAA. It essentially updates the CNR by substitution of the tone- and duration-corrected Effective Perceived Noise Level (EPNL) scale used for aircraft certification, instead of the Perceived Noise Level (PNL) scale of the earlier CNR. Thus, the NEF accounts for both duration and pure tone content of each single-event sound, whereas the CNR accounted for neither.

Table 2-3

FACTORS CONSIDERED IN EACH OF THREE METHODS USED FOR DESCRIBING THE INTRUSION OF AIRCRAFT NOISE INTO THE COMMUNITY*

Factor	Composite Noise Rating (CNR)	Noise Exposure Forecast (NEF)	Community Noise Equivalent Level (CNEL)
Basic measure of single event noise magnitude	Maximum perceived noise level	Tone-corrected perceived noise level	A-weighted noise level
Measure of duration of individual single event	None	Energy integration	Energy integration
Time periods during day	Daytime (7 AM-10 PM) Nighttime (10 PM-7 AM)		Daytime (7 AM-7 PM) Evening (7 PM-10 PM) Nighttime (10 PM-7 AM)
Approximate weighting added to noise of single event which occurs in indicated period	Daytime 0 dB Nighttime 12 dB		Daytime 0 dB Evening 5 dB Nighttime 10 dB
Number (N) of identical events in time period	10 log N		10 log N
Summation of contributions	Logarithmic		Logarithmic

*See Chapter 1 for additional details.

The Community Noise Equivalent Level (CNEL)* was recently introduced by the State of California for monitoring purposes. It is based on the A-weighting to avoid the complexity of the computer calculations required to obtain EPNL and, thus, cannot contain a pure-tone weighting. It also differs from the NEF by inclusion of the evening time period weighting, in addition to daytime and nighttime. However, despite these structural differences, the difference between the absolute values of CNEL and NEF for specific locations near airports is approximately constant at 35±2 dB. Thus NEF-30 is approximately equivalent to CNEL-65.

The CNEL has been applied to a series of community noise problems to relate the normalized measured CNEL with the observed community reaction. The normalization procedure followed is the Rosenblith/Stevens method, with a few minor modifications. The correction factors added to the measured CNEL to obtain the normalized CNEL are given in Table 2-4. Two examples of the application of these factors to the measured values of the Equivalent Noise Levels (L_{eq}) of the intruding noise are given in Table 2-5. The examples are drawn from the results at two locations in the survey and illustrate an approximate procedure for calculating CNEL from the measured averages of L_{eq} in the daytime, evening, and nighttime periods, accounting both for the weightings of 0, 5, and 10 dB, respectively, and for the duration of each of the periods. The results of 55 case histories are summarized in Figure 2-9, with an approximate NEF and CNR scale shown for reference. The data is normalized to the descriptions in Table 2-4, which have a correction of zero. The distribution of the cases among the various sources impacting areas of the community are listed in Table 2-6.

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* CNEL has been adopted for use in this report. However, this use should not be interpreted as an endorsement by the EPA since neither CNEL nor any other method has been sufficiently validated to determine their adequacy in predicting present and future community reaction to noise.

Table 2-4

CORRECTIONS TO BE ADDED TO THE MEASURED COMMUNITY NOISE EQUIVALENT LEVEL (CNEL) TO OBTAIN NORMALIZED CNEL*

Type of Correction	Description	Amount of Correction to be Added to Measured CNEL in dB
Seasonal Correction	Summer (or year-round operation)	0
	Winter only (or windows always closed)	-5
Correction for Outdoor Residual Noise Level	Quiet suburban residential or rural community (remote from large cities and from industrial activity and trucking)	+10
	Normal suburban residential community (not located near industrial activity)	+5
	Urban residential community (not immediately adjacent to heavily traveled roads and industrial areas)	0
	Noisy urban residential community (near relatively busy roads or industrial areas)	-5
	Very noisy urban residential community	-10
Correction for Previous Exposure & Community Attitudes	No prior experience with the intruding noise	+5
	Community has had some previous exposure to intruding noise but little effort is being made to control the noise. This correction may also be applied in a situation where the community has not been exposed to the noise previously, but the people are aware that bona fide efforts are being made to control the noise.	0
	Community has had considerable previous exposure to the intruding noise and the noise maker's relations with the community are good	-5
	Community aware that operation causing noise is very necessary and it will not continue indefinitely. This correction can be applied for an operation of limited duration and under emergency circumstances.	-10
Pure Tone or Impulse	No pure tone or impulsive character	0
	Pure tone or impulsive character present	+5

Source: "Supporting Information for the Adopted Noise Regulation for California Airports," Report WCR 70-3(R), January 29, 1971.

Table 2-5

TWO EXAMPLES OF CALCULATION OF NORMALIZED COMMUNITY NOISE EQUIVALENT LEVEL

Factor	Aircraft Landing Noise in Noisy Urban Residential Community(1)			Traffic Noise in Old Residential Area Near City Center(2)		
	Day	Eve.	Night	Day	Eve.	Night
Energy Equivalent Noise Levels (Leq) in dB(A) for Time Period	80	83	75	56	57	53
Duration and Time of Day Correction Factor	-3	-4	+6	-3	-4	+6
Subtotals Which are added Logarithmically to Obtain CNEL	77	79	81	53	53	59
Community Noise Equivalent Level	84			61		
Additional Corrections from Table 2-4						
Seasonal	0			0		
Residual Noise Level	-5			0		
Experience & Attitude	0			-5		
Pure Tone or Impulse	5			0		
Total Additional Corrections	0			-5		
Normalized CNEL	84			56		
Actual Reaction	Extensive Lawsuits and Political Pressure			No Reaction		

(1) Location F in Figures 2-5 and 2-8.

(2) Location L in Figures 2-5 and 2-8.

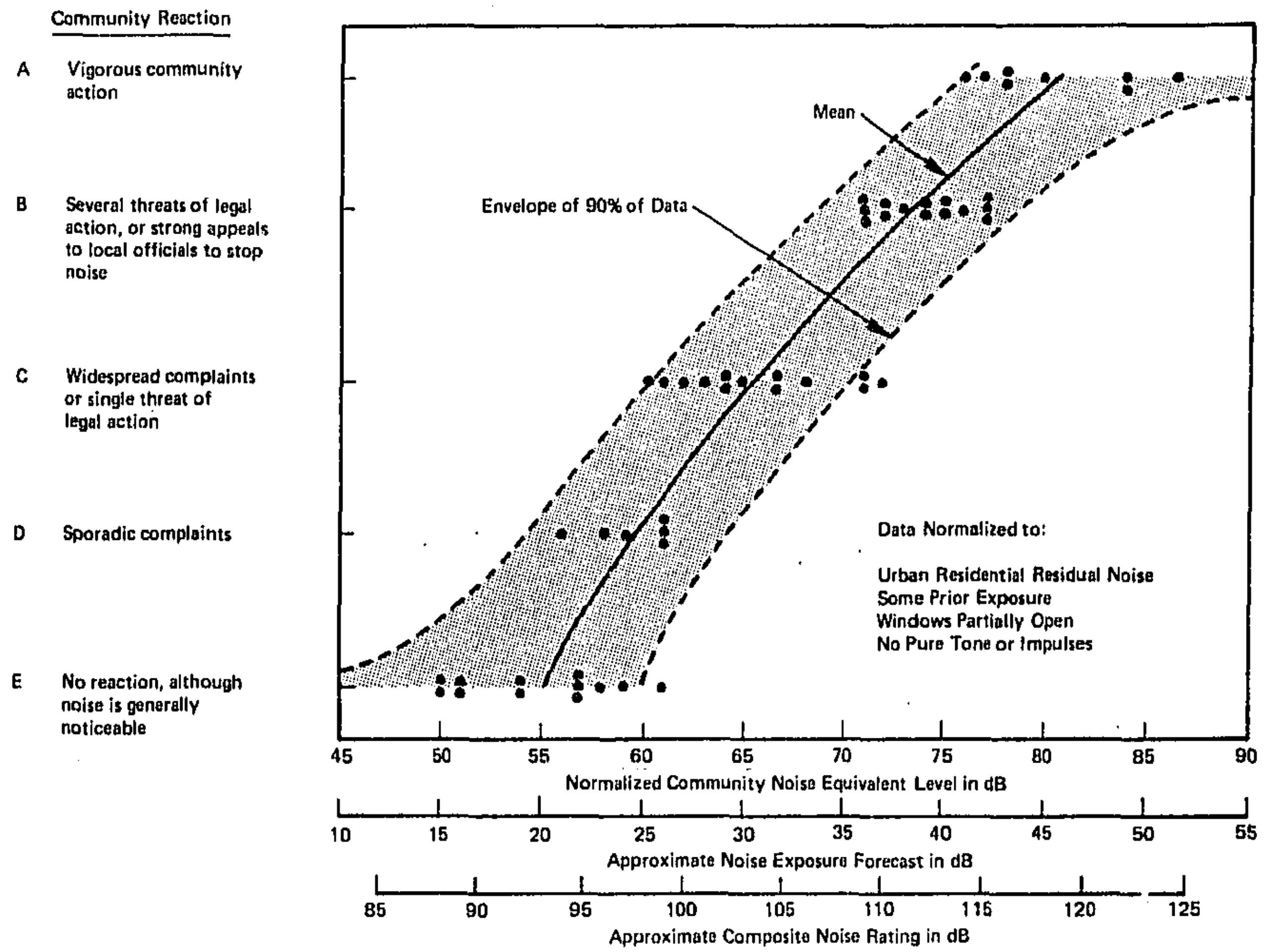

Figure 2-9. Community Reaction to Intrusive Noises of Many Types as a Function of the Normalized Community Noise Equivalent Level

Table 2-6

NUMBER OF COMMUNITY NOISE REACTION CASES AS A FUNCTION OF NOISE SOURCE TYPE AND REACTION CATEGORY

Type of Source	Community Reaction Categories			Total Cases
	Vigorous Threats of Legal Action	Wide Spread Complaints	No Reaction or Sporadic Complaints	
Transportation vehicles, including:				
Aircraft operations	6	2	4	12
Local traffic			3	3
Freeway	1			1
Rail		1		1
Auto race track	2			2
Total Transportation	9	3	7	19
Other single-event or intermittent operations, including circuit breaker testing, target shooting, rocket testing and body shop	5			
Steady state neighborhood sources, including transformer substations, residential air conditioning	1	4	2	7
Steady-state industrial operations, including blowers, general manufacturing, chemical, oil refineries, et cetera	7	7	10	24
Total Cases	22	14	19	55

The data points for "no reaction" response in Figure 2-9 correspond to a level ranging between 50 and 61 dB, with a mean of 55 dB. This mean value is approximately 7 dB above the mean value assumed in categorizing the daytime residual noise (L_{90}) level for a residential urban community, which is the baseline category for the data in the figure. This difference of 7 dB between the mean reaction line and L_{90} is only approximately 2 dB greater than the average difference between the outdoor median noise level (L_{50}) and the residual noise level, as shown in Table 2-1. Consequently, from these results it appears that no community reaction is usually expected when the normalized CNEL of the intruding noise is approximately equal to the daytime outdoor median noise level (L_{50}). This conclusion is not surprising; it simply suggests that people tend to judge the magnitude of an intrusion with reference to the noise environment existing without the presence of the intruding noise source.

The data in Figure 2-9 indicates that widespread complaints may be expected when the normalized value of CNEL exceeds the outdoor residual noise level by approximately 17 dB, and vigorous community reaction may be expected when the excess approaches 33 dB. Thus, the normalized CNEL community reaction relationship appears to be a reasonably accurate and useful tool in assessing the probable reaction of a community to an intruding noise.

This community reaction data has also been used to test the effect of the various normalizing factors in Table 2-4 on the degree of correlation between the community reaction and the normalized CNEL. The factor most necessary in the normalization to bring the data closer to a common line is the duration correction. The next most important factor is the residual noise level correction. Less important, but still significant, are the corrections for time of day, pure tone/impulse, and prior experience/attitude, the lack of which resulted in standard deviations of 4.6, 4.3, and 4.0 respectively. No change occurred by removing the seasonal factor, which was only applicable to three of the 55 cases.

The data for the 55 cases was also compared with a version of the CNEL modified by replacing the day-evening-night corrections of the standard CNEL with the day-night corrections of the NEF calculation procedure. The resulting mean line was altered by less than 1 dB from that given in Figure 2-9, and the standard deviation was only 0.1 dB greater than before, an insignificant difference. Thus, these 55 cases can support the adoption of either type of time period weighting, in combination with the energy equivalent A-weighted noise level and the other correction factors in Table 2-4, for the prediction of community reaction to noise.

The normalized CNEL scale can also be compared with the results of social surveys, such as those taken in London and in the U.S., showing that people are usually at home when they are annoyed by noise. As might be anticipated, disturbances of activities related to speech intelligiblity are the most frequently reported as sources of annoyance.

Figure 2-10 shows the average annoyance reaction found in the London Airport Survey as a function of CNR and approximate normalized CNEL. Figures 2-11 and 2-12 show the relationships of those "very much annoyed" and those "only a little, or not annoyed" with data from the same survey. Also shown in Figure 2-11 is a data point from Sweden and a tangent line through the most important range of community reaction.

These results demonstrate that a majority of the citizens are greatly annoyed when the noise is sufficient to produce a vigorous community reaction in accordance with the data in Figure 2-9. This survey also shows that a small but significant percentage of the population is still greatly annoyed at the CNEL 44 value, where no community reaction is expected. Thus, the true impact of intrusive noises as measured by individual or personalized annoyance goes deeper than that indicated by the community "no reaction" point.

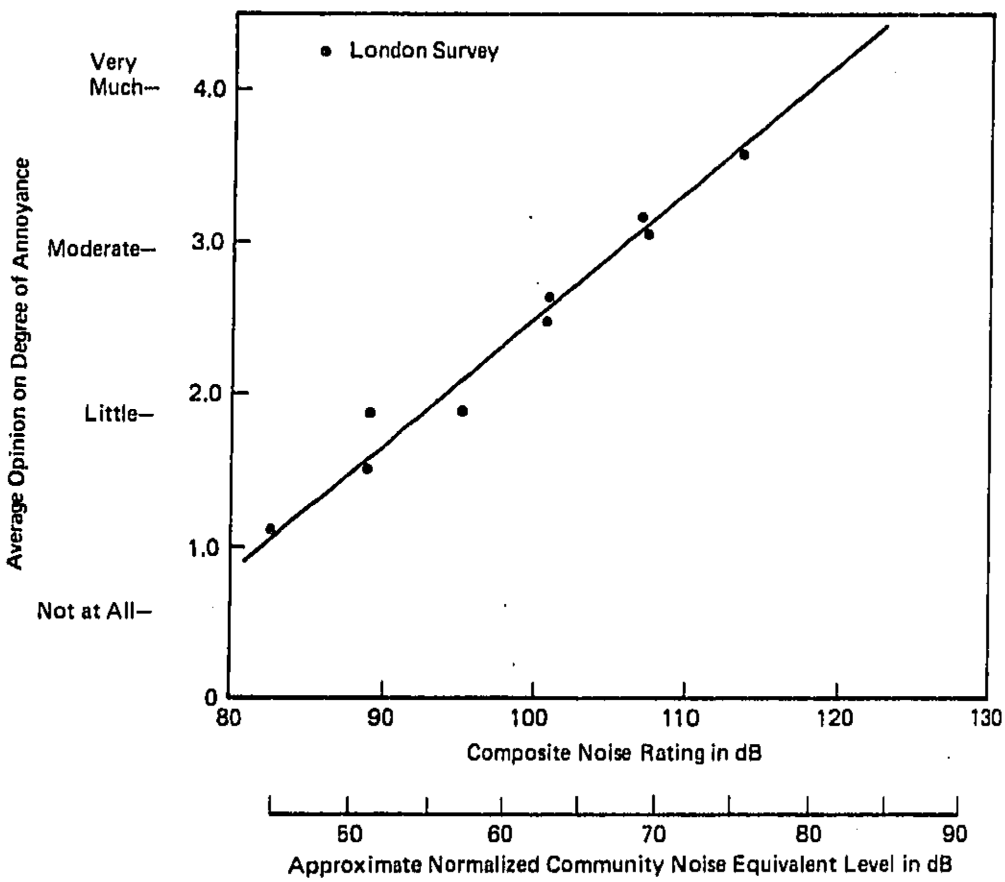

Figure 2-10. Relationship Between Average Expression of Annoyance to Aircraft Noise and the Composite Noise Rating

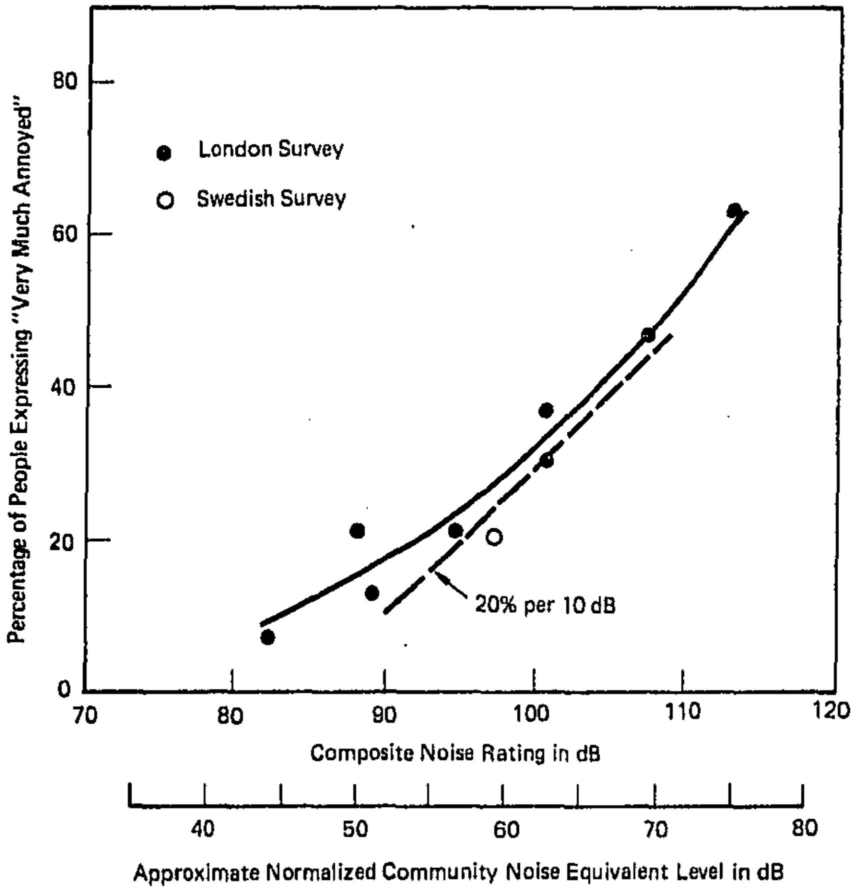

Figure 2-11. Percentage of People Expressing "Very Much Annoyed" as a Function of Composite Noise Rating

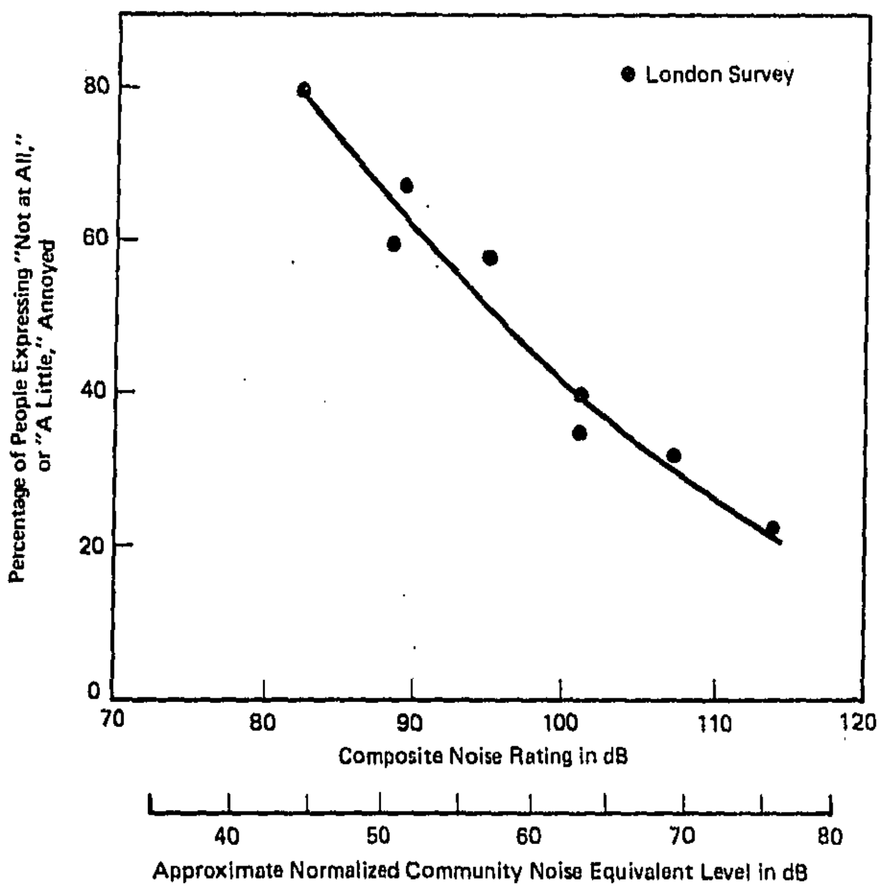

Figure 2-12. Percentage of People Expressing "Not At All" or "A Little" Annoyed as a Function of Composite Noise Rating

The preceding material relates to community reaction as evidence of an aggregation of individual responses. There are no good measures, however, of the impact of noise in terms of effects on individual hearing and generalized response.

The Growth of Noise

There have been dire predictions that the noise in our environment is increasing by as much as 1 dB per year, or 10 dB per decade. Clearly, such a growth rate, if true, would lead to severe consequences. To place this issue in perspective, it is useful to examine the possible changes in both the intruding noises and the residual noises over the past few decades.

There has been considerable growth in the number of miles of urban freeways and thruways since 1950 accompanied by an increase in noise in neighborhoods adjacent to the freeways. Similarly, there has been a significant increase in commercial air travel since 1950. This increase, together with an increase of the noise level of jet aircraft relative to propeller aircraft, and the building of homes around existing civil airports has precipitated complex noise problems.

The amount of land estimated to lie within the CNEL-65 (approximately NEF-30) contours is illustrated in Figure 2-13 for both freeways and airports. CNEL-65 is a convenient value to choose for this type of impact assessment because at a normalized CNEL of 65, widespread complaints are expected, with more vigorous reactions at the higher values occurring inside the contours. These estimates show that in 1970 approximately 2000 square miles of land were bounded by CNEL-65. The actual land use within these impact boundaries (airport property and freeway property have been excluded) is not known. However, if it is assumed, as a reasonable estimate

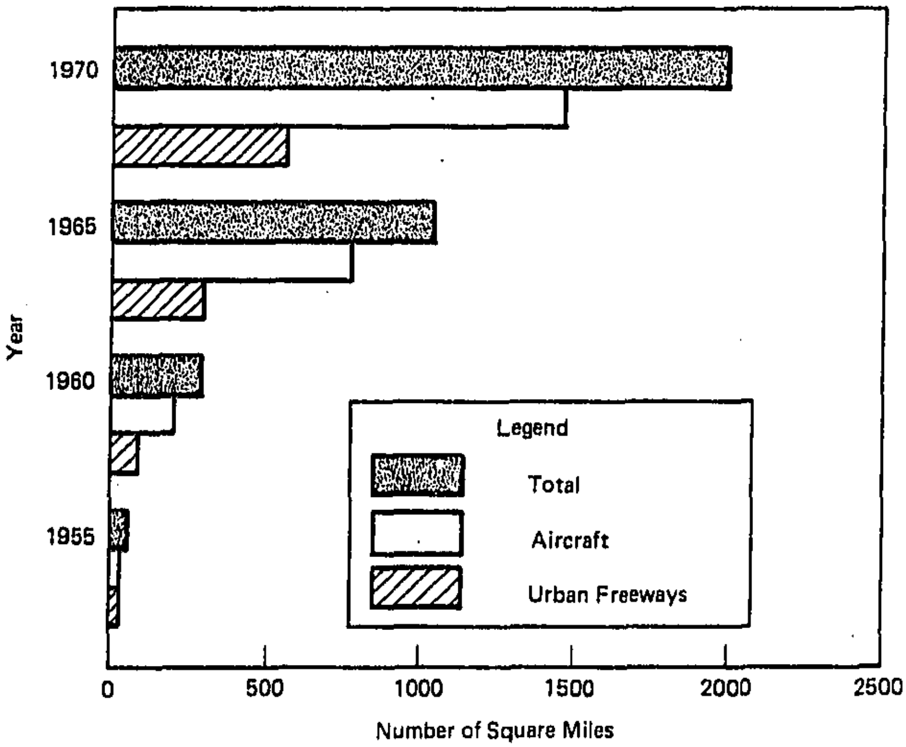

Figure 2-13. Approximate Growth in Aircraft and Freeway Noise Impacted Land Area, Enclosed by CNEL 65

based on general observation, that the average use is like the average urban land use, approximately 10 million people would be expected to live in these areas. These areas are conservative estimates of the impact, since an intruding noise source causing a normalized CNEL of 65 dB in an urban residential community is expected to result in widespread complaints. Clearly, the noise impact extends beyond the estimated boundaries in an urban residential community and even further in a quieter suburban community. In addition, the growth of construction activity within cities and the location of new industrial plants in the suburbs and rural areas brings increased noise to each affected area. The number of noisy devices, such as power lawnmowers and motorcycles, has increased from a few hundred thousand units in 1950 to over 20 million in 1970. Similarly, the introduction and use of recreational vehicles, chain saws, and fully equipped campers has introduced a new element to wilderness areas. Even at a remote location on the north rim of the Grand Canyon, noise from a small propeller driven private aircraft has been found to have a maximum level of 70 dBA, a 54-dB intrusion above the residual noise level (these operations being the cause of considerable complaints).

The increasing number of sources producing high noise level intrusions gives clear evidence of the significant growth of noise over the last two decades. Although the majority of this growth occurred in specific areas in which freeways or airports were located adjacent to the communities, a significant number of new single-event sources were added to all areas, from the wilderness to urban residential communities.

The question remains of whether the additional intrusive noisy sources, together with any changes in the noise characteristics of all other sources, have changed the outdoor residual noise levels in the residential areas in which land usage has not significantly changed. The answer is elusive without the existence of a statistically significant survey of residential noise environments. To obtain a current estimate, the data for the 11 residential locations in the survey, Table 2-1, has been combined with data for 17 typical residential locations from another recent survey, to give a better composite of an average urban residential noise environment. Since neither survey was undertaken with the intent of statistically sampling a city, and there are only 28 locations in total, the results should be considered indicative only of central trends. The available past data consists of the results of four surveys covering the last 34 years and beginning with the 1937 Bell Telephone Company extensive survey of noise in residential areas in Chicago, Cleveland, and Philadelphia. The comparison of results is given in Figure 2-14.

Each survey was different in method, objective, and instrumentation; and none compare identical locations. Most were also different in methods of reducing and reporting data. Therefore, it is necessary to adjust the data to a common base for comparison. The data for the 1937 and 1968 surveys was published in terms of the median outdoor noise level (L_{50}) and that of the 1954 survey in terms of an energy mean of the noise environment. All three results have been corrected to the residual noise level (L_{90}) by subtracting the average difference of 5 dB found between the median and residual levels in the current data. The mean and 50-percent range for the residual noise levels of the 1947-1948 and 1971 surveys are shown as originally presented.

Disregarding the 1954 results, the means of the other four surveys lie between 46 and 50 dBA, with a grand average of 46.9 dBA. This value is also close to the average value of 45.5 dBA calculated for the four categories described in Table 2-2 (quiet, normal suburban, urban, and noisy urban residential areas).

The mean value of the 1954 data is 7.7 dB below the 1971 results and 7.9 dB below the average of the other four surveys. This survey was designed to investigate the effect of aircraft noise at many locations under aircraft flight tracks up to 12 miles

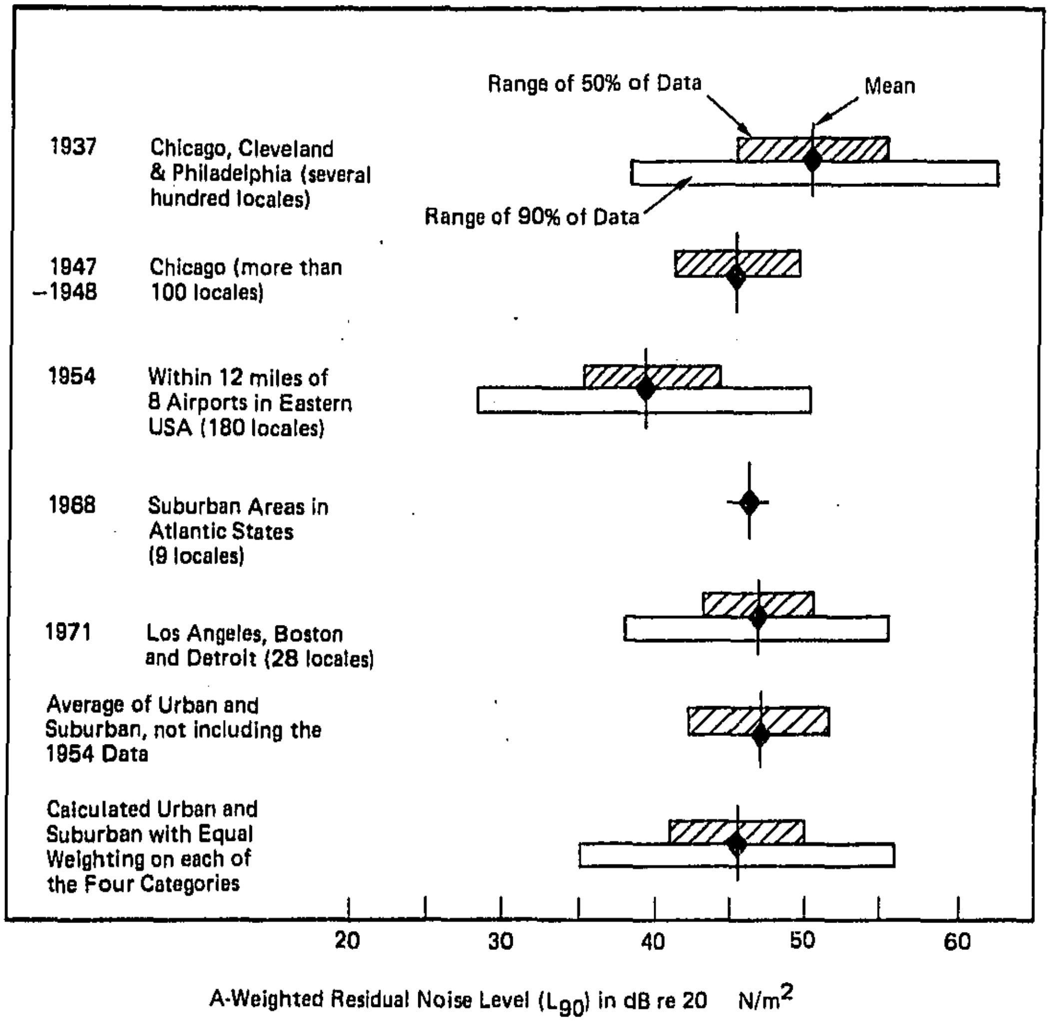

Figure 2-14. Comparison of Five Surveys of Outdoor Noise Levels in Residential Areas in the United States Between 1937 and 1971

from each of eight airports and included rural as well as suburban and urban locations. It is probable that the principal reason for the low values reported by the 1954 survey is that its mix of locations gave significantly more weight to the quiet rural and suburban areas than to the urban and noisy urban residential areas. Similarly, the 1937 survey included city apartment dwellings as well as suburban and urban residential areas with detached dwellings. This difference in emphasis probably resulted in higher emphasis on the "very noisy urban residential" category and explains why this data has the highest reported mean value for the residual noise level.

Thus, it is considered that the 1937 survey was biased to slightly noisier areas that the 1954 survey was significantly biased to the quieter areas, and that the three remaining surveys are probably somewhat similar in their distribution of locations. Within this perspective, it is concluded that where land use has not changed, there is no strong trend toward an increase in the average suburban and urban residential area residual noise levels over the past 34 years. Further, it appears that the only increase that can be inferred from this data is 2 dB in over two decades, based on the difference between the 1947-1948 and 1971 results.

This conclusion is also supported by a comparison of two locations in the 1971 Los Angeles data that was directly comparable to measurements made in 1955 and 1959. At a normal suburban neighborhood location, where no significant change in land or road use has occurred over 16 years, the two measurements of the residual noise level agreed within 1 dB. In the other case, the 1971 measurements in a residential urban area were approximately 2 dB higher than in 1959, due at least in part to the construction nearby of a major freeway.

It can be further concluded that the average outdoor residual noise level in an area with a constant land usage probably changes slowly with time as has been true over the past few decades in the area studied. If the land use is changed, such as from quiet suburban residential to urban residential, a normal suburban residential to noisy urban residential, the outdoor residual noise level can increase significantly (10 dBA or more), approximately in accordance with the values in Table 2-2. Even if the noise level for given categories of land use do not change, rapid change in the land use of specific areas has significantly increased the number of people affected by urban type noise.

More important in this review is the fact that outdoor noise levels throughout a major portion of the day are not satisfactorily indicated by the residual noise level but rather by the character and intensity of intruding noises. The outdoor noise level at any location increases significantly as new intruding noise sources, such as freeways, power plants, a jet aircraft overflight paths, or construction equipment, are added. The general increase in environmental noise is associated with the spread of areas infringed upon by such intruding noise sources.

Summary

The preceding discussion leads to several significant observations regarding the nature of noise and the methods of measuring its magnitude. Although many of these conclusions must be regarded as tentative because of the lack of statistically sound community noise baselines, the general trends appear straightforward and give useful perspective for the overall nature of the problem. The following points are significant:

- The outdoor daytime residual noise level in a wilderness area, such as exemplified by the Grand Canyon rim, is on the order of 16 dBA, on the farm 30 to 35 dBA, and in the city 60 to 75 dBA.
- Areas in which the daytime outdoor median noise level exceeds the range of 56 to 60 dBA, categorized as "noisy urban," are not well suited to detached residential housing, since normal voice conversation outdoors is limited to distances of less than 6 to 10 feet between talker and listener. Also, when the

noise level is above this range, it is not possible to have relaxed conversation in a living room at a distance of 10 feet with windows or sliding glass doors fully opened.

- Areas in which the daytime outdoor median level exceeds 66 dBA are not suited to apartment living unless the buildings are air conditioned, so that the windows may be kept closed to enable relaxed conversation indoors. If the outdoor median noise levels are above 71 dBA, special sound proofing is necessary to preserve the indoor noise environment, even with windows closed.
- The outdoor residual noise level in suburban and urban residential communities serves the useful function of providing speech privacy between neighbors. It appears that considerations of speech privacy requirements will set the lower limit of a desirable residual noise level in each type of community.
- The limited available data from community noise surveys conducted over the past 34 years indicates that little increase has occurred in the residual noise level, except where land usage has changed. Where such change has occurred, the noise has generally increased, probably in accordance with the expected change between land use categories in Table 2-2, such as plus 10 dB from quiet suburban residential to urban residential, or plus 20 dB from quiet suburban residential to very noisy urban residential. A significant spread of noise has occurred in this manner because of the large growth of urban and suburban areas, and their populations, in the last 20 to 30 years.
- A significant increase in noise in the past 20 years has resulted from the rapid growth of commercial avaiation and from its use of jet aircraft that are about 10 to 20 dB noisier than the older, smaller piston engined aircraft. A somewhat less but still significant, increase in noise has resulted from the construction and use of freeways located within urban and suburban residential areas. It is

estimated that at least 2000 square miles of urban and suburban area have been severely impacted by noise from these two major sources, with lesser degree of impact extending over a much larger area.

- The rapid increase in the use of noisy recreational vehicles and home lawn care equipment powered by poorly muffled internal combustion engines has contributed to noise in both wilderness areas and residential neighborhoods.
- The community reaction scale based on the normalized CNEL appears to give reasonable predictions of community complaints, with 90 percent of the data within ±5 dB of the mean relationship between the normalized magnitude of the intruding noise and the degree of community reaction.
- The data indicates that no community reaction should be expected when the normalized CNEL of the intruding noise is approximately 2 dB above the daytime median noise level, or equivalently, approximately 7 dB above the residual noise level. However, some social surveys indicate that when the intruding noise equals this level, approximately 18 percent of the population is "very much annoyed" although 43 percent are only "a little," or "not at all annoyed."
- The significant complaint reactions from the 55 community reaction cases and the approximate percentage of the population "very much annoyed" and "only a little" or "not at all annoyed" from the London study are given in Table 2-7.

Table 2-7

SUMMARY OF EXPECTED COMMUNITY REACTION AND APPROXIMATE ANNOYANCE AS A FUNCTION OF NORMALIZED COMMUNITY NOISE EQUIVALENT LEVEL

Expected Community Reaction	Approximate Difference Between Normalized CNEL and Average Day-time Residual Noise Level (L_{90}) in dB		Approximate Percent Very Much Annoyed	Approximate Percent Little or Not Annoyed
	Mean	Range of Data		
No reaction	7	2 to 13	20	45
Sporadic complaints	11	8 to 13	26	37
Widespread complaints	17	12 to 24	37	26
Threats of legal action	26	23 to 29	60	14
Vigorous action	33	28 to 39	87	7

TRANSPORTATION SYSTEMS

One of the most significant byproducts of our increasing population and economic growth is the increasing demand for improved modes of transportation. These demands have been met by the development of more efficient, larger, and faster transportation systems. The transportation industry represented, in total, approximately 14.5 percent of the gross national product in 1970 and employed approximately 13.3 percent of the total labor force. This major section of the nation's economy is defined, for this report, as the sum total of the:

- Commercial aircraft and airline industry
- General aviation industry
- Highway vehicle industry
- Recreational vehicle industry
- Railroad and urban mass transit industry
- Commercial shipping industry.

The economic structure of this industry and the general division and magnitude of the transportation services provided are illustrated in Figure 2-15, and the rapid growth of several segments of the transportation system since 1950 is summarized in Table 2-8. While there are many important sources of intrusive noise, transportation vehicle noise tends to dominate most residential areas. In fact, the cumulative effect of the increase in noise intrusion by transportation vehicles is, to a large extent, responsible for the current general concern with noise. This discussion briefly treats the general nature of transportation system noise sources and considers their overall impact in the United States today. Aircraft, one of the more dominant sources of noise in the transportation industry, will be considered first.

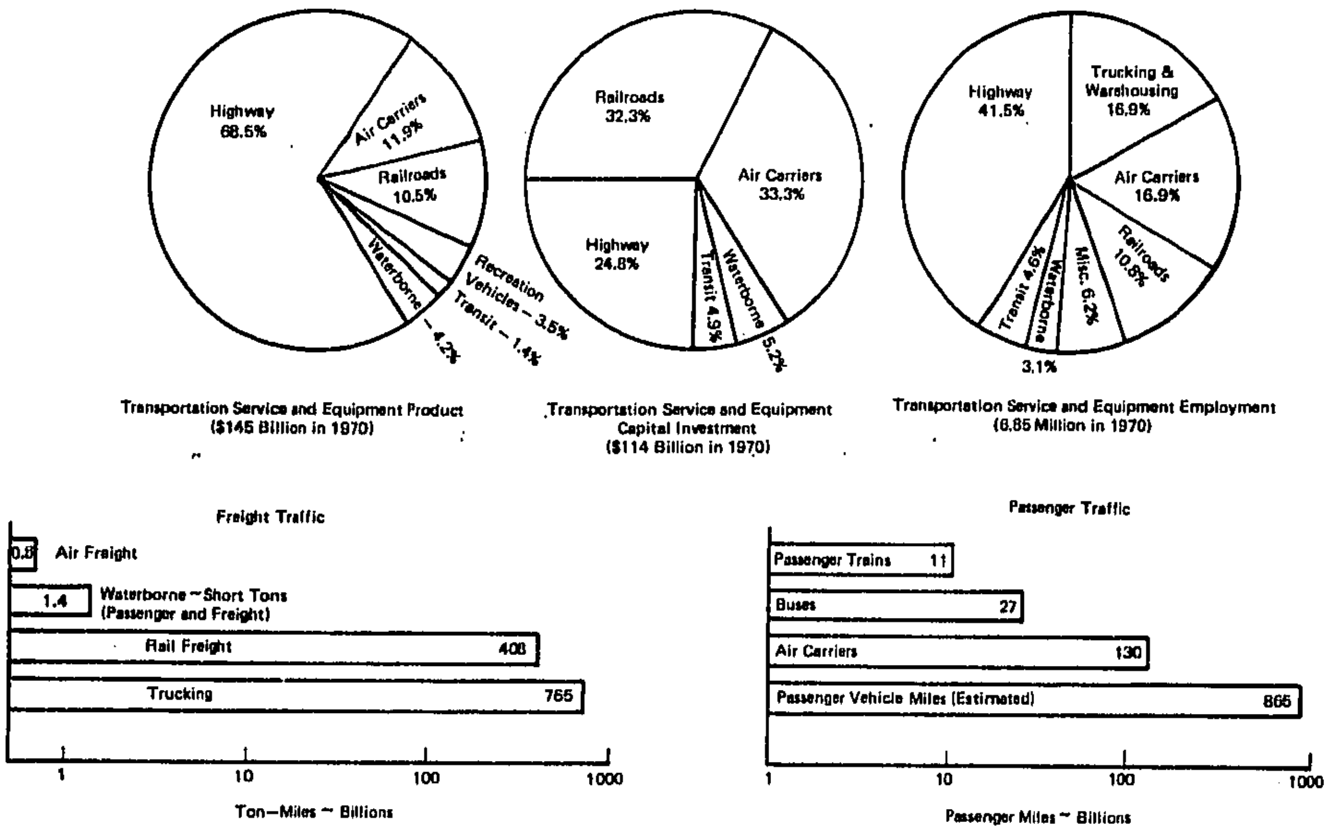

Figure 2-15. General Characteristics of the Transportation Industry in 1970

Table 2-8

GROWTH IN THE TRANSPORTATION SYSTEM, 1950-1970

Source	1950	1960	1970
Population (in millions)	151	181	204
Passenger Cars (in millions)	40.4	61.7	87.0
Trucks and Buses (in millions)	8.8	12.2	19.4
Motocycles (in millions) (Highway) – Registered	0.45	0.51	2.6
Motorcycles (in millions) (Off-road)	-	-	1.0
Snowmobiles (in millions)	0	0.002	1.6
2-3 Engine Turbofan Aircraft	0	0	1,174
4-Engine Turbofan Aircraft	0	202	815
General Aviation Aircraft	45,000	75,550	128,900
Helicopters	85	830	3,260

Commercial Aircraft

The increase in air travel during the last decade is closely related to the introduction and growth of the commercial jet aircraft fleet. The advantages of jet-powered passenger airplanes have led to a gradual phasing out of the older propeller-driven commercial aircraft. Only a small percentage of piston-powered aircraft now remain in the fleet, and the turboprop aircraft in use are primary short range twin-engine types used on light traffic routes. There were a total of 10.7 million operations of commercial aircraft in 1970. Military jet aircraft, not considered in this report, have about one fourth as many operations. Due to this lower level of operation and the generally remote location of most military airfields, the noise impact from military aircraft is substantially less than for commercial aircraft.

Figure 2-16 summarizes the category of commercial fixed-wing aircraft in terms of type, application, passenger capacity, and range of typical noise levels. The original commercial jet aircraft were powered by turbojet engines. These engines have been largely replaced by quieter and more powerful turbofan engines. The new types of commercial jet aircraft have recently been introduced and are powered by advanced technology turbofan engines that are much more powerful and quieter than earlier engines.

Although the current V/STOL aircraft fleet is inherently part of both the commercial and general aviation fleet, its unique capability of operating from small airfields or from urban centers tends to distinguish it in terms of noise impact from the remainder of the aviation transportation industry. The present V/STOL fleet consists predominantly of helicopters.

The STOL fleet is not yet a significant reality but is currently undergoing considerable Federal and industry study. The principal objective of STOL aircraft is to move much of the intercity air transportation (short haul) away from the congested major-hub airports and toward urban communities. Tentative noise goals have been proposed for aircraft operating from the projected peripheral STOL ports, but as yet a community-compatible noise goal has not been defined for the intracity heliports now in operation or for those that will serve as city-feeder terminals for the STOL ports.

Figure 2-17 shows the typical structure of the present and proposed V/STOL fleet, the typical range of noise levels for these aircraft, and their major applications. Of the current total of 3260 vehicles, approximately 1900 are based in urban areas. The most significant increase of usage in recent years has been by civil government agencies. In particular, the number of city police helicopters is rapidly increasing, with a total of about 150 vehicles in present use. Commercially operated helicopters, currently about 2100, are predominantly used for charter air service operations, with only about 15 vehicles on regularly scheduled intracity air carrier routes.

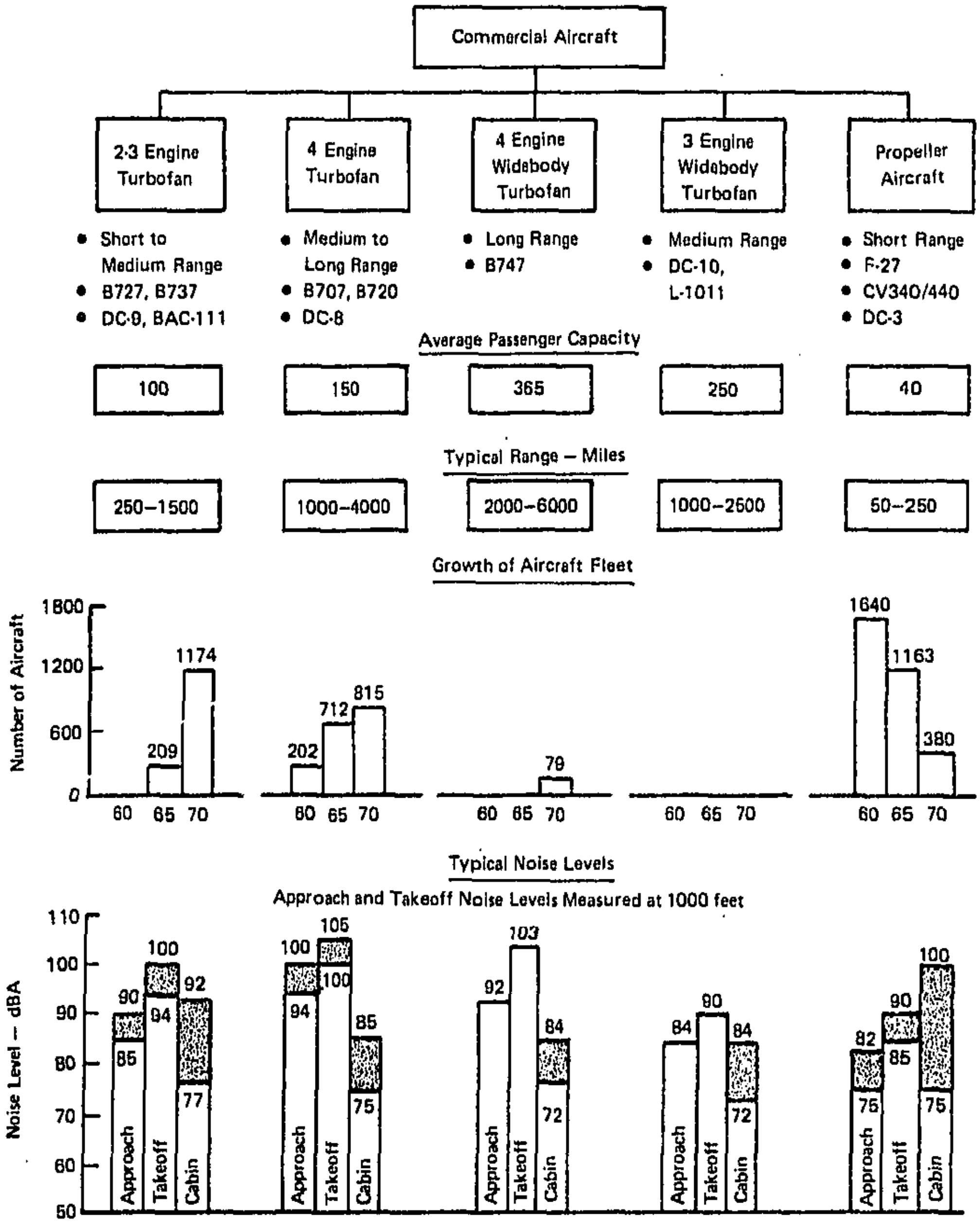

Figure 2-16. Characteristics of Commercial Aircraft

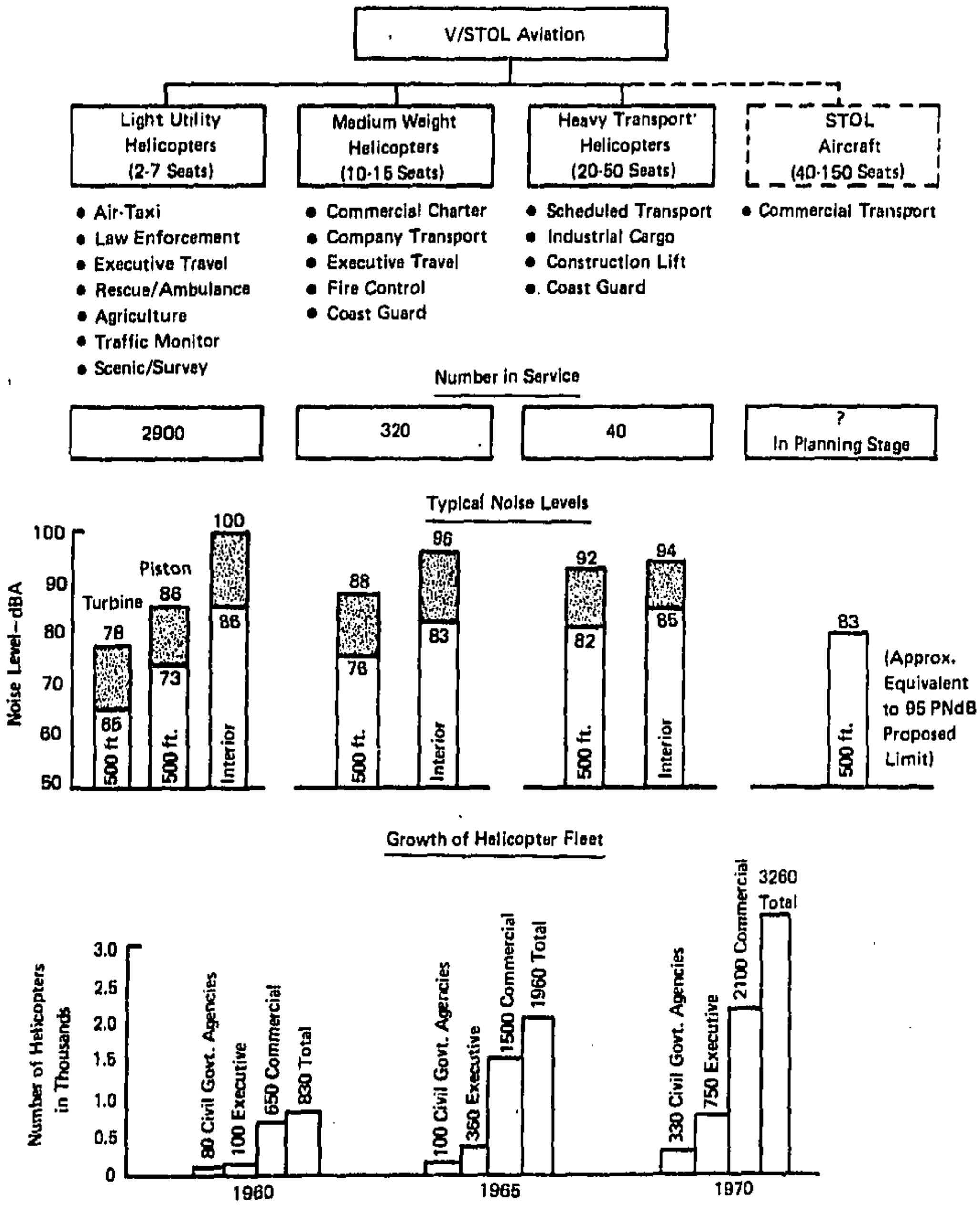

Figure 2-17. Characteristics of V/STOL Aircraft

Jet Aircraft

The noise associated with jet aircraft is primarily generated by the processes that take place both within and outside the engine. The dominant source of noise from the early turbojet engines was the jet noise generated by the turbulent mixing of the high velocity exhaust jet and the surrounding air. Sound power increases rapidly with increasing jet velocity; therefore, high noise levels are associated with the high velocity exhausts of turbojet engines.

The turbofan engines that have replaced the turbojets offer substantial jet exhaust noise benefits because they take in larger quantities of air and expel this air at lower jet velocities. However, with reduced levels of jet noise and with the increased size and power of the fan, its whine was elevated from a secondary to a primary noise source, particularly for landing or approach power.

For the four-engine turbofan aircraft, powered by early models of turbofan engines, the engine thrust, and thus the jet exhaust velocity, is higher during takeoff than during approach. Consequently, the low frequency roar of the jet is significantly higher at takeoff than at approach. However, the high frequency fan noise is relatively insensitive to engine power setting and thus becomes clearly dominant at approach engine conditions. This type of aircraft generates higher noise levels than most of the aircraft in the commercial fleet today. For the two- to three-engine turbofan aircraft, the jet noise is lower because of slightly reduced jet velocities, and the high frequency fan noise is considerably reduced due to fundamental improvements in fan design.

The new Boeing 747 four-engine turbofan aircraft are powered by new technology engines that incorporate several advancements, with respect to propulsion efficiency and reduced noise generation. The low jet exhaust velocity made possible with these new engines has resulted in a significant reduction in jet noise so that fan noise now dominates both during takeoff and approach operations. Despite the considerable technological advances incorporated in the fan design, the discrete frequency fan whine forms the major obstacle to achieving significant noise reduction. The newest three-engine turbofan widebody aircraft (DC-10 and L-1011) use similar engines, but with additional improvements in fan noise reduction. The net result is a 10-EPNdb to 13-EPNdB reduction in noise for these latest designs over the earlier turbofan aircraft.

The noise level in the interior of jet aircraft is dominated by a different noise source. Because these aircraft travel at high speeds, the pressure fluctuations generated by the turbulent mixing that occurs in the boundary layer between the aircraft fuselage and the surrounding air becomes significant. These fluctuations cause the fuselage walls to vibrate and radiate noise into the aircraft interior.

The growth of community noise levels due to commercial aircraft operations is closely related to the introduction of the commercial jet aircraft in 1958 and the growth of air travel during the following decade. First, the jet aircraft were noisier on approach and takeoff than piston-engined aircraft they replaced. Secondly, although the number of major airports has increased only slightly since the late 1950's, the quantity and frequency of air travel has grown many times over. Finally, vast new residential communities have been established in the vicinity of nearly all busy airports. This combination of expanding air travel and residential growth has resulted in a growing airport-community noise problem.

To assess the effect of aircraft noise on the community, the previously described NEF method has been widely used. This method, developed initially as a land-use planning guide, gives a single number rating of the cumulative noise produced in the vicinity of an airport by aircraft operations, taking into account factors such as the total mix of aircraft utilizing the airport, subjective noise levels generated by each aircraft class, flight paths, and number of operations in day and night periods. Contours of constant values of the NEF index provide a measure of the total impacted area. A criterion level of NEF-30 is normally used to indicate the approximate outer boundary of the impact area. NEF-30 contours are shown in Figure 2-18 for a representative one-runway airport and average commercial aircraft fleet mix.* For simplicity, the aircraft are assumed to operate in the same direction on the single runway, and the contour combines the effects of takeoffs and landings. Operations by four-engine, low-bypass-ration turbofan standard aircraft (Boeing 707 and 720, McDonnel-Douglas DC-8) are responsible for 69 percent of the total impact area, while comprising only 23 percent of the total number of operations.

Helicopters

The helicopter is unique in that its noise signature is characteristically different from that of all other common noise generators: a distinctive, low frequency throbbing sound. Due to this characteristic, it is extremely difficult to control noise intrusion into the passenger cabin or into buildings because sound-insulation methods are notably inefficient in the low frequency range. This problem is further complicated by the fact that low frequency sound propagates through the atmosphere more readily than high frequency sound. Thus, helicopter noise can be distinguished at greater distances than most other sources of equal source noise level.

Interior Levels for Commercial Jet Aircraft

Passengers on jet aircraft are exposed to moderately high noise levels from the time of boarding the aircraft to landing. The interior noise levels during cruise typically range from 79 to 88 dBA, depending on the seat location, with a typical value of 82 dBA. During takeoff and landing operations, the noise levels are up to 12 dBA

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* A simplified method for estimating NEF contours, for use by persons without technical training is available from the Department of Housing and Urban Development, in "Noise Assessment Guidelines," Report No. 2176, August, 1971.

Representative Large Airport (1970)

Commercial Aircraft Type	Number of Operations/Day
B727-100, B737, DC-9	140
B727-200	40
B707, B720, DC-8	108
DC-8 (Stretched)	18
B747 (Jumbo)	6
Propeller Aircraft	54
	366*

*Total operations, 86.3% of which occur during daytime (0700-2200 hours) and 13.7% of which occur during nighttime (2200-0700 hours).

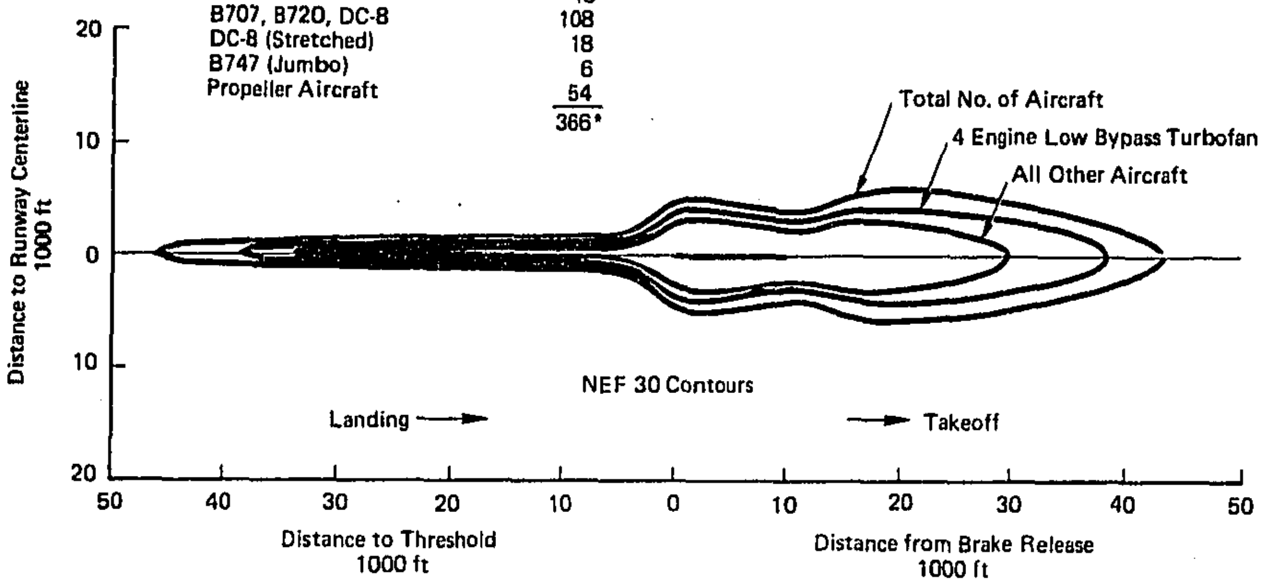

Figure 2-18. NEF-30 Contours for Representative (Single Runway) Airport

higher, but only for periods of up to 1 minute during each operation. The noise level inside many helicopters ranges between 90 and 100 dBA, representing a definite risk of hearing damage for the constant traveler.

General Aviation Aircraft

General aviation refers to all civilian aviation activity other than that of the commercial air carriers. Within this broad definition, general aviation includes a wide variety of aircraft uses; Figure 2-19 summarizes this fleet mix and provides information on the number of aircraft and typical range of noise levels produced. The general aviation fleet has grown rapidly during the last 15 years and will continue to do so for the next 10 to 20 years. During 1970, these aircraft flew an estimated 25.5 million aircraft hours, conducted 153 million operations, and carried a total of 220 million passengers. The composition of the fleet has changed over the last 10 years from mostly small, single-engine propeller types to a more complex fleet mix.

The noise associated with general aviation propeller aircraft, both piston and turboprop types, is produced primarily by the propellers, with dominant fundamental tones typically in the range from 50 to 250 Hz. Higher harmonic tones may also be significant, depending on the propeller blade shape and operating conditions. The broadband and discrete frequency noise generated above approximately 250 Hz consists of higher propeller noise harmonics, discrete frequency noise from the engine and exhaust, and exhaust broadband noise.

The noise characteristics of jet-powered general aviation aircraft, or executive jets, are similar to those of commercial jet aircraft. Although the engines are much smaller than those used to power commercial jet aircraft, the jet noise levels are comparable to those of existing two- and three-engine turbofan commercial jets. However, some recent executive jets are powered by turbofan engines with substantially lower sound levels.

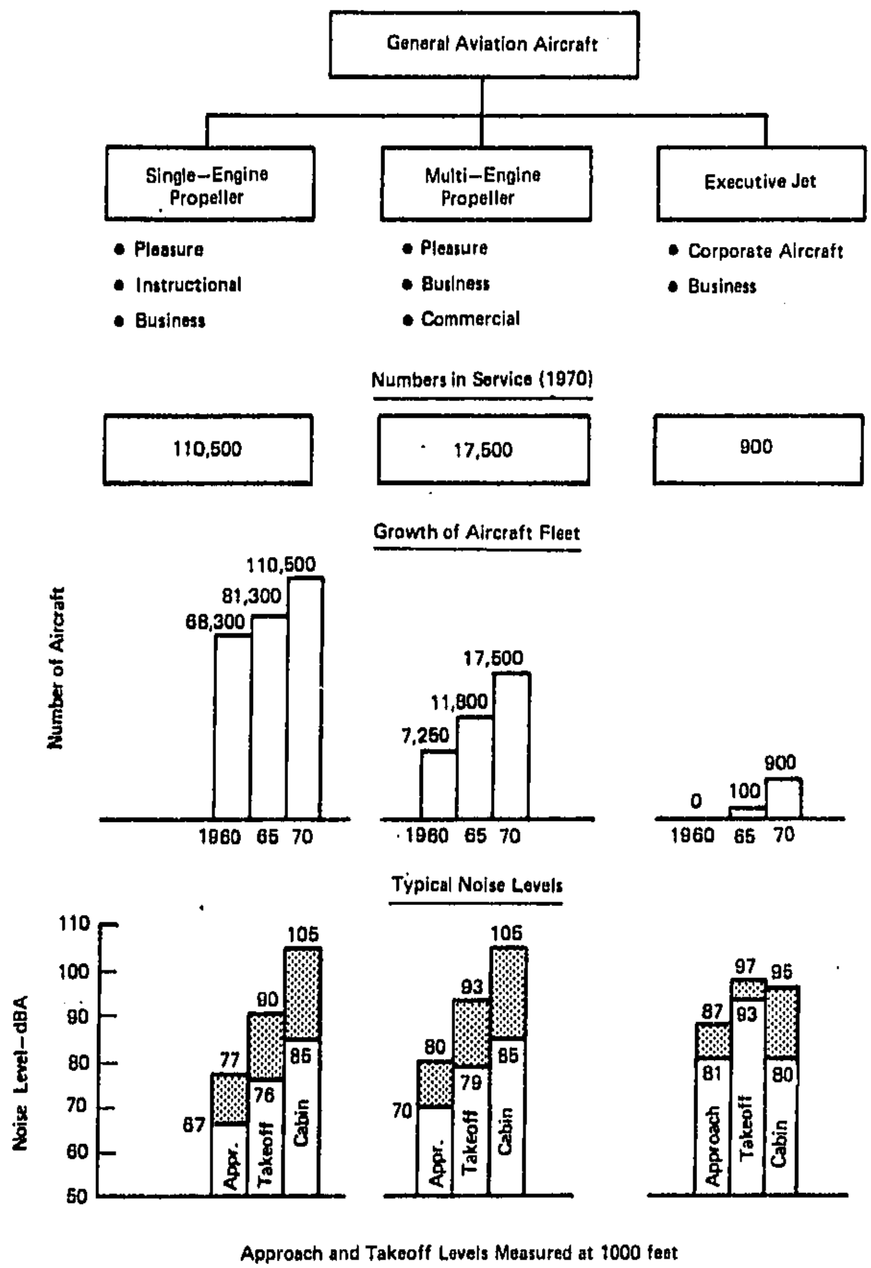

Figure 2-19. Characteristics of General Aviation Aircraft

The operator or passenger in a general aviation propeller aircraft is subjected to noise levels of about 90 dBA, which is 5 to 15 dB higher than in a commercial jet. These higher levels are the result of the typical close spacing of engines and propellers to the cabin and the small space and weight allowance for acoustic treatment in general aviation aircraft. Internal levels inside executive jets are comparable to those in commercial jets.

Highway Vehicles

Highway vehicles include automobiles, trucks, buses, and maintenance and utility vehicles. Motorcycles are treated in the discussion of recreation vehicles. Traffic studies of highway vehicle usage in typical urban areas show that about 1600 to 2300 trips are made by automobile drivers and passengers every day for every 1000 people, while 200 to 400 truck trips are made for every 1000 people. Approximately 40 to 45 percent of the latter terminate in residential areas. This urban travel represents about 52 percent of the estimated 3 billion highway-vehicle-miles traveled in 1970. The general characteristics, numbers, growth patterns, and range typical noise levels for highway vehicles are summarized in Figure 2-20.

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

1. Rolling stock: tires and gearing
2. Propulsion system: engine and related accessories
3. Aerodynamic and body noise.

Tires are the dominant noise source at speeds greater than approximately 50 mph for both trucks and automobiles. Tire noise levels increase with vehicle speed and also depend upon variables such as the road surface, axle loading, tread design, and wear condition. Changes in any of the variables can result in variations in noise level of up

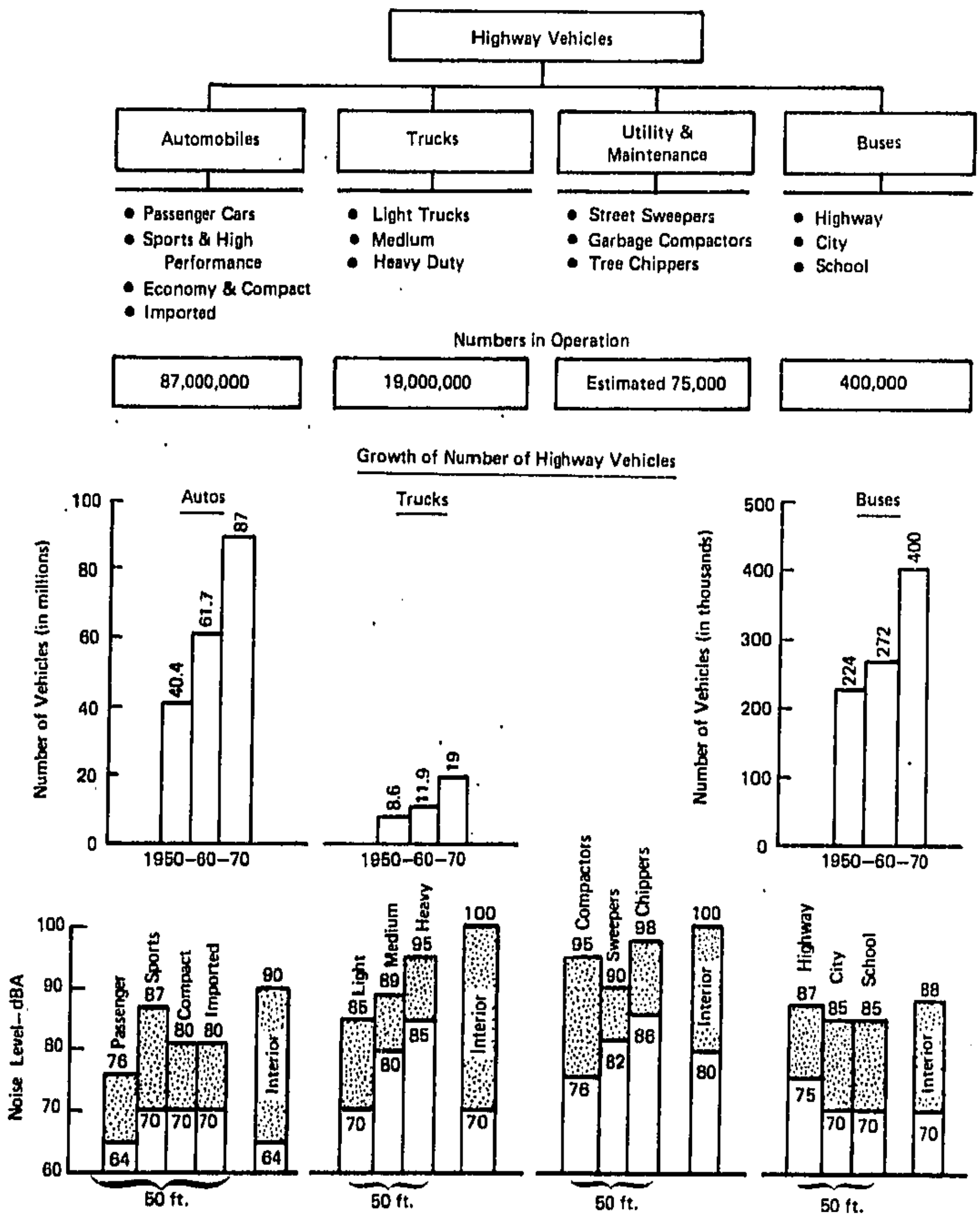

Figure 2-20. Characteristics of Highway Vehicles

to 20 dB at constant vehicle speed. Truck tires are generally noisier than automobile tires because of their size and other design constraints. Engine generated noise is normally the dominant noise for trucks and automobiles at speeds below 45 and 35 mph, respectively. This noise is radiated directly from the engine exhaust and intake openings and from the vibrating engine casing. The third source of highway vehicle noise includes noise produced by turbulent aerodynamic flow over the body and rattling of loose mechanical parts.

Automobiles constitute the largest number of highway vehicles. While not as noisy as trucks, buses, and motorcycles, their total contribution to the noise environment is significant due to the number in operation – 87 million in 1970. Of the 19 million trucks in operation, only 2 to 3 percent are powered by diesel engines. However, these trucks are generally 8 to 10 dB noisier than gasoline powered trucks and 12 to 18 dB noisier than automobiles. Due to their heavy rate of usage, trucks produce noise levels that tend to increase with truck age. This situation is worsened by the tendency to overhaul trucks with replacement mufflers that are inferior to the original equipment. Figure 2-21 summarizes the dominant noise sources for automobiles and trucks and indicates a typical example of noise levels for each source component.

Utility and maintenance trucks often generate a unique noise signature because of the auxiliary functions they perform. The noise of the garbage truck during its compacting operation is the classic example.

Although buses share many basic design characteristics with trucks, they are generally quieter due to their increased packaging space (which allows larger mufflers) and enclosed engine compartment. At highway speeds, passenger buses produce noise levels primarily in the 80 to 87 dBA range at 50 feet. The pedestrian standing at the curb experiences comparable levels as the bus passes him during low speed acceleration.

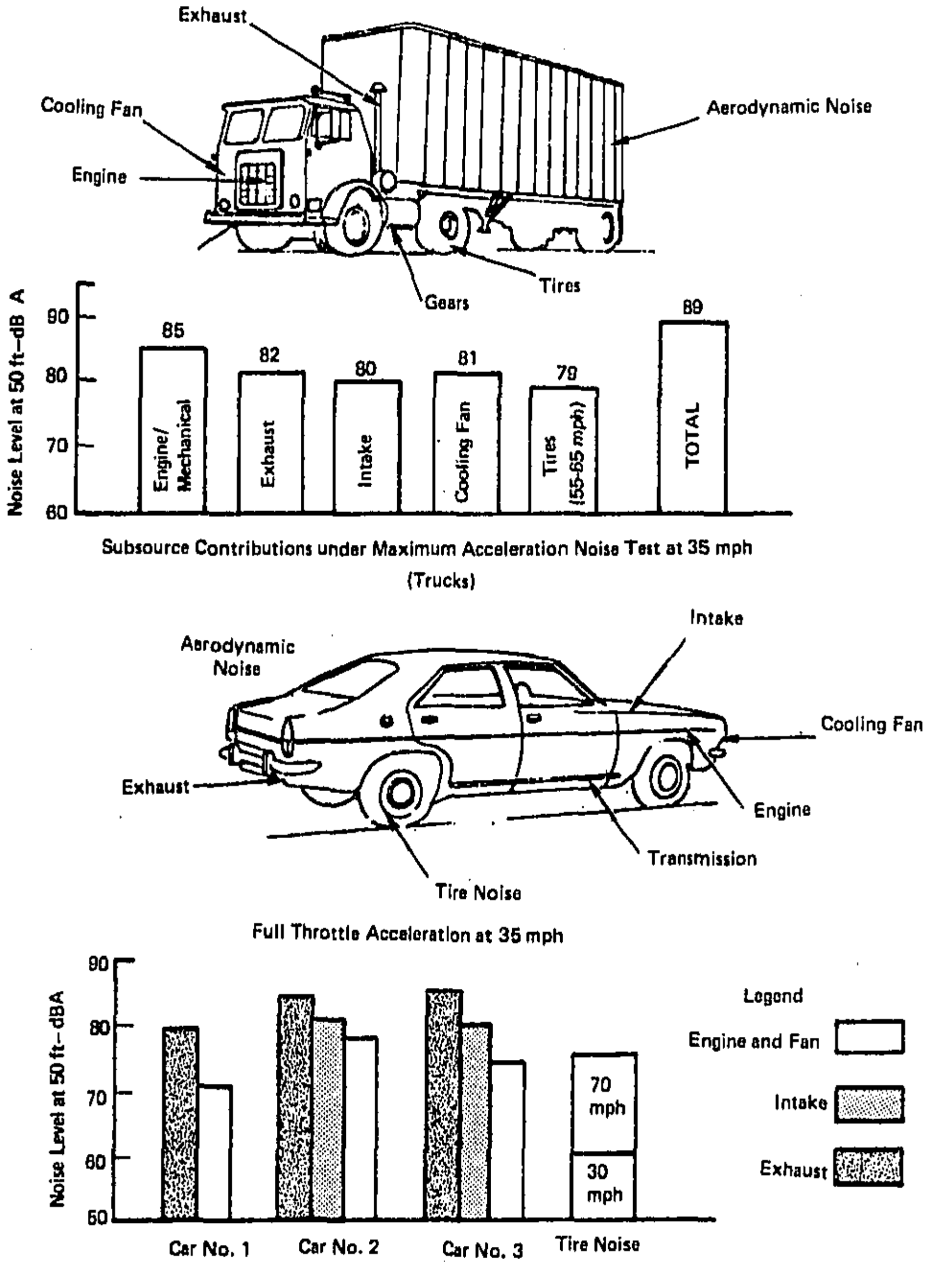

Figure 2-21. Noise Sources for Highway Vehicles

Highway Vehicle Noise in the Community

Vehicular traffic generally establishes the residual noise levels in most urban and suburban communities. This residual noise level varies throughout the day, based on the average density of noise sources in a given community. However, in the immediate vicinity of a major arterial highway or freeway, the noise level is much higher. Its actual value is dependent upon traffic flow rate, average vehicle speed, distance to the traffic lane, and the ratio of trucks to automobiles on the highway. For a typical eight-lane freeway, average daytime traffic flow rates can be on the order of 6000 to 10,000 vehicles per hour. For this condition, the median noise level beyond 100 feet from the flowing traffic is equivalent to that from a continuous line of noise sources. Typical median traffic noise levels near a major freeway are about 75 to 80 dBA at 100 feet from the roadway and about 60 to 65 dBA at 1000 feet.*

Superimposed on this median traffic noise level are the intrusive or single-event noises from individual trucks, cars, and motorcycles that are normally 15 to 25 dBA above the residual noise levels on neighborhood streets. However, at the high traffic flow rates typical for freeways, these individual single events are less distinguishable from the overall roar of the total traffic flow.

Interior Levels for the Passenger

At highway speeds, the interior noise levels in the majority of the larger American passenger cars are in the 65 to 70 dBA range, with the air conditioner off and windows up, whereas the smaller economy and compact cars have somewhat higher levels ranging between 70 and 82 dBA. However, some of the small cars with noisy air conditioners, or with the windows open, generate internal noise levels in the range of 80 to

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* Information on estimation of noise effects from highways is also contained in the HUD "Noise Assessment Guidelines," cited regarding NEF values.

90 dBA. Buses, by virtue of their rear engine design and adequate allowance for interior sound package treatment, provide interior noise levels in the range of 72 to 80 dBA.

Recreation Vehicles

Recreational vehicles, as defined here, include all types of motorcycles, snowmobiles, all-terrain vehicles, and pleasure boats. There has been a remarkable growth in the number of these vehicles in the last 10 to 20 years, which is a reflection of the greater amount of leisure time and of the availability of these vehicles at attractive prices.

Over 90 percent of the 2.6 million motorcycles in the United States are used for pleasure and are operated in residential and recreational areas. This number is expected to increase to 9 million by 1985. Nearly 80 percent of the 1.6 million snowmobiles in use today are operated primarily for pleasure by families in rural communities. Boating, enjoyed by an estimated 44 million persons in 1970, presents the most widely employed form of recreational travel. Figure 2-22 summarizes the general characteristics of this category in terms of growth patterns and range of typical noise levels.

The noise output of recreational vehicles, although dependent upon speed, is primarily a function of their mode of operation. For example, many off-road-motorcycles and some snowmobiles are capable of speeds of 80 to 100 mph but are most often operated at low speed in the lower gears, with medium to high engine power output. Thus, except when cruising at constant speeds or coasting downhill, they are operated at high throttle settings near their maximum noise output. This high noise level is frequently considered synonymous with high power by the recreational user.

The major contributing source of noise from these vehicles is the exhaust system. This exhaust noise is often increased by operators who modify or remove their exhaust

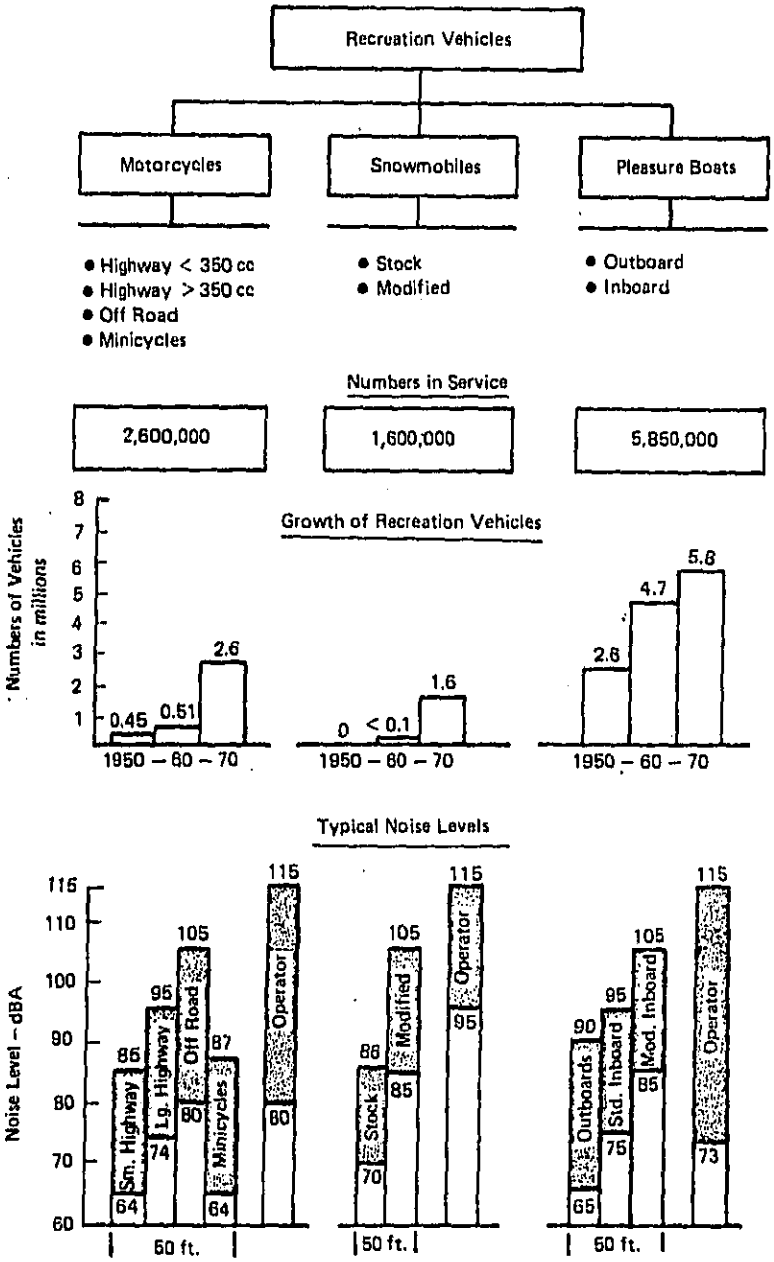


Figure 2-22. Characteristics of Recreation Vehicles

muffler in a misguided attempt to produce more engine power. Of secondary, but significant, importance in these vehicles is the noise radiated from their intakes and engine walls. Generally, intakes are not silenced and engines are either partially or totally unshielded. As a result of this lack of silencing, some of these vehicles create noise levels as high as 100 to 110 dBA at 50 feet. Pending state legislation to regulate the noise produced by off-road machines has caused manufacturers to reduce the maximum noise levels of vehicles in current production to 92 dBA.

The type of pleasure vehicle that currently reflects the most significant noise reduction technology in its basic engineering design is the outboard-powered pleasure boat. The power plants on most of these boats represents the most effectively silenced application of the widely used two-stroke internal combustion engine.

Motorcycles

The noise levels produced by many motorcycles increase rapidly with cruising speed. Typical noise levels at 50 feet range from 59 to 69 dBA at 20 mph to 78 to 86 dBA at 60 mph. Typical noise exposure levels at the operators ear range from 85 to 90 dBA for the quiet highway cycles to 110 dBA for the large off-the-road motorcycles and modified large highway motorcycles. A typical example of the principal contributing sources of noise for motorcycles is given in Figure 2-23.

Snowmobiles

The noise levels produced by snowmobiles are largely dependent upon their age, because of a trend to improved designs. Current production models are generally in the range of 77 to 86 dBA, measured at 50 feet, under maximum noise conditions. The noise level of older or poorly muffled machines ranges from 90 to 95 dBA, with racing machines generating levels as high as 105 to 110 dBA at this same distance. The noise from new machines normally ranges from 95 to 115 dBA at the operator position but

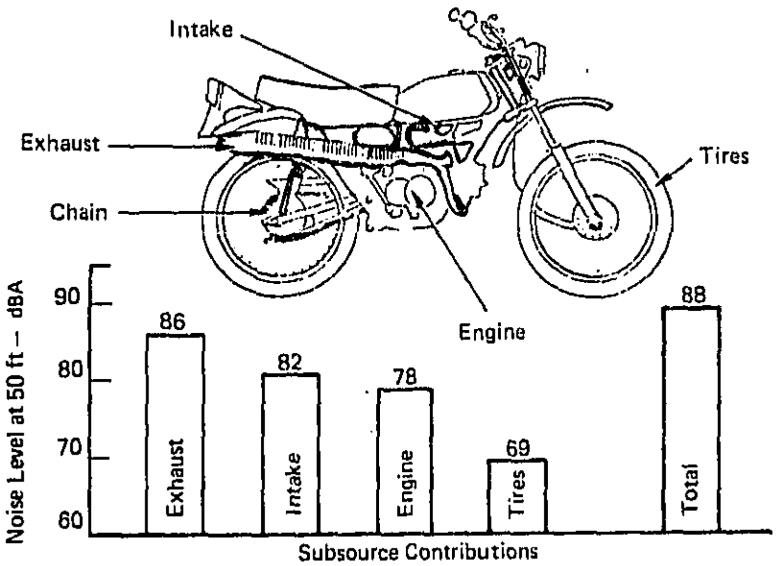


Figure 2-23. Motorcycle Noise Sources

can be higher on racing machines. A typical example of the principal contributing sources of noise for snowmobiles is summarized in Figure 2-24.

Pleasure Boats

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

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

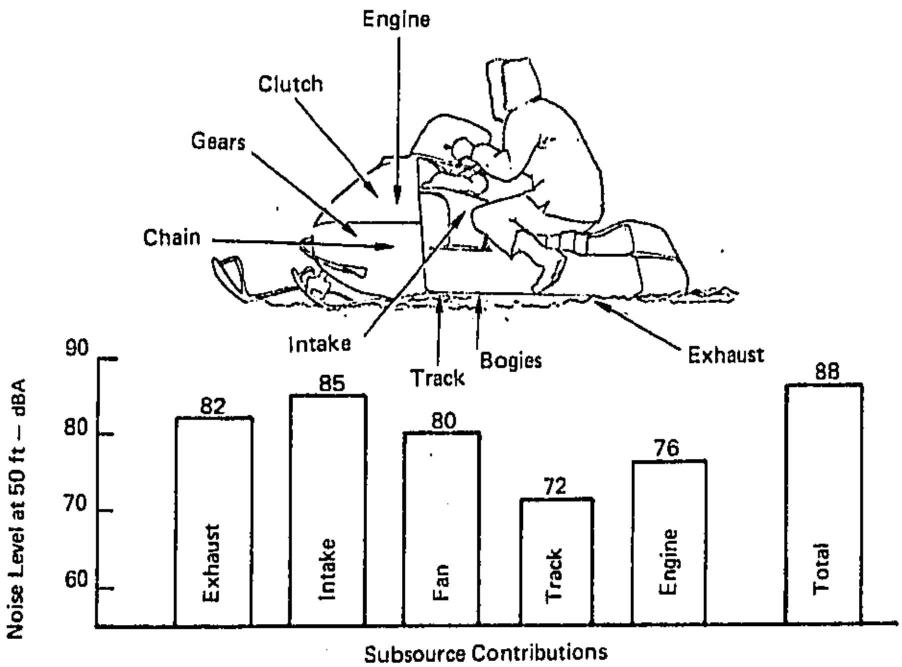


Figure 2-24. Snowmobile Noise Sources

inboard engines are typically lower; but the exhaust, even though released under water, is still the major noise source. In the medium and smaller outboard engine sizes, the engine and intake, though acoustically shielded, produce almost as much noise as the exhaust.

The typical noise exposures for operators of outboard boats are also high. These exposures range from 84 dBA for 6-horsepower units to 98 to 105 dBA for 125-horsepower units measured at the driver position under accelerating conditions. At cruising speeds, operator levels on all boat types (inboard and outboard) range from 73 to 96 dBA.

Dune Buggies, All-Terrain Vehicles and Other Off-Road Vehicles

The major source of noise output in the remainder of those vehicles considered under the recreation classification is predominantly exhaust. Because of the unregulated nature of these vehicles and their use, the owners tend to attempt the achievement of maximum power output through the use of tuned and unmuffled exhaust systems.

Rail Systems

Rail systems are defined here as consisting of:

1. Railroads. Long distance freight and passenger trains and high speed intercity trains.
2. Rail Transit Systems. Rapid transit subways and elevated systems, streetcars, and trolley lines.

The characteristics of rail systems are summarized in Figure 2-25.

Approximately 10,000 freight and passenger trains operate daily, hauling 40 percent of all freight tonnage. Urban rapid transit systems operate over 22,000 trips per day and transport approximately 2.3 billion passengers a year over 1070 miles of line, using about 11,650 rapid transit rail cars and trolley coaches. Each application has required development of specialized vehicle systems that differ significantly in their noise characteristics.

Railroads

Noise in railroad systems is made up of the contributions from locomotives and the train vehicles that the locomotives haul.

Locomotives. Ninety-nine percent of the 27,000 locomotives in service in the United States in 1971 were diesel-electric, and the majority of the remainder were electric. Approximately one-half of the locomotives are used for main line hauling.

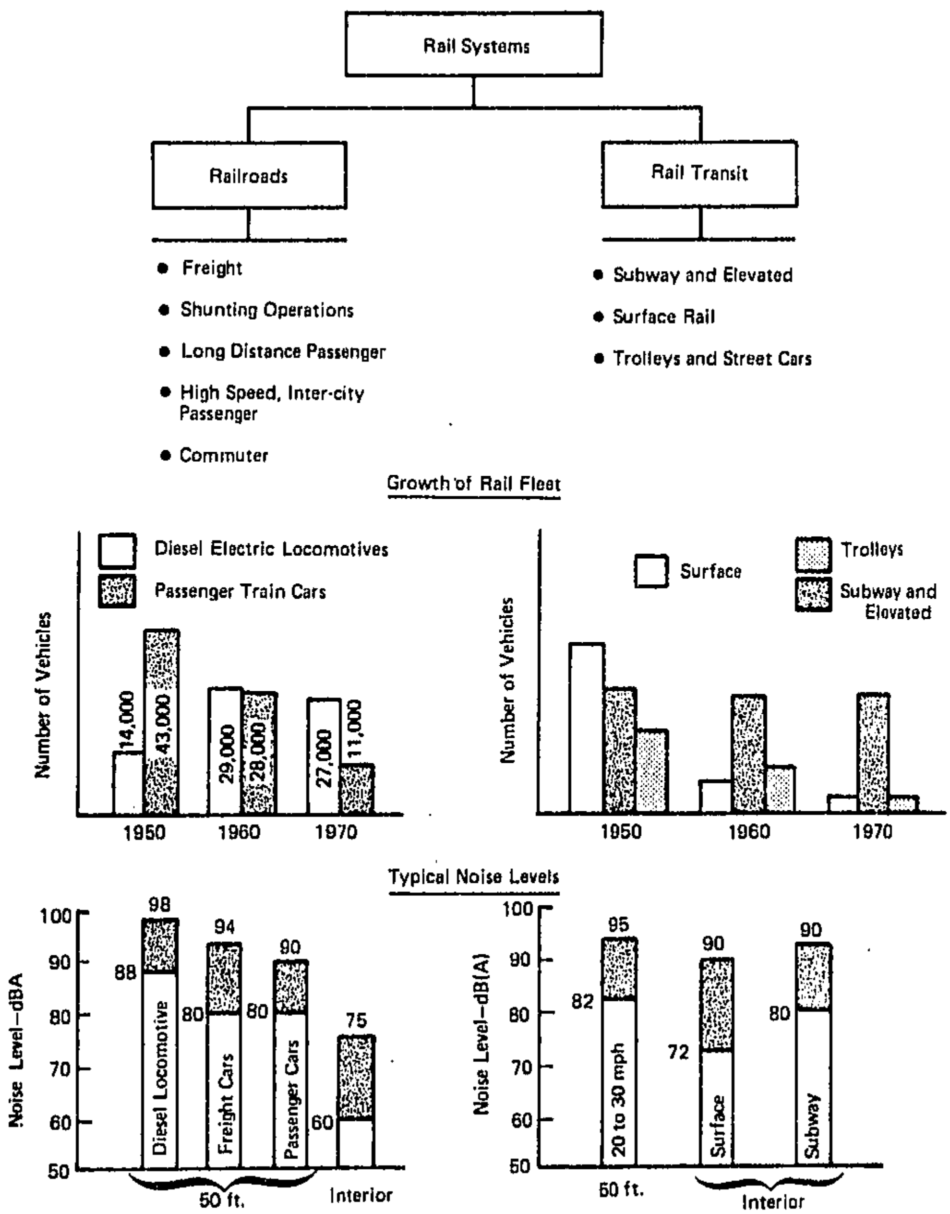


Figure 2-25. Characteristics of Rail Systems

The remainder are lower powered locomotives used for short-hauls and as switchers in railroad yards.

The sources of noise in a moving diesel-electric locomotive are, in approximate order of contribution to the overall noise level:

- Diesel exhaust muffler.
- Diesel engine and surrounding casing, including the air intake and turbocharger (if any).
- Cooling fans.
- Wheel/rail interaction.
- Electrical generator.

An additional source of noise is the siren or horn, which produces noise levels 10 to 20 dBA greater than that from the other sources. This is not a continuously operated source (30 timer per hour on a typical run), however, and is a necessary operational safety feature and is therefore excluded from the above list. The electrical locomotive draws electrical power from an overhead line and, except for noise generated during braking operations, is considerably quieter than its diesel-electric counterpart.

Train Vehicles. Since freight and passenger cars have no propulsion system of their own, the exterior noise produced is due mainly to the interaction between the wheels and the rails. The magnitude of the noise depends heavily on the condition of the wheels and track, on whether or not the track is welded, and on the type of vehicle suspension. Modern passenger vehicles with auxiliary hydraulic suspension systems in addition to the normal springs can be about 10 dBA quieter than the older vehicles and most freight cars, which have only springs. Additional noise can be produced in empty boxcars containing loose chains and vibrating sections.

The interior noise of passenger vehicles is partly due to structurally-borne noise from the wheel/rail interaction and the passing of the wheels over rail joints. Another source is airborne noise passing through the car body and windows, which becomes more important when the train is passing through cuttings and tunnels. Welded track, present on only about 10 percent of the nation's railroad track mileage, materially reduces interior noise levels, but the amount of welded track is being increased at the rate of only 3000 miles per year (or less than 1 percent per year) as the older sectional type requires replacement. In addition to the track noise, interior passenger car noise levels are produced by the air conditioning system.

In suburban areas, many commuter trains consist of multiple-unit electric cars that operate from the lead car. Many of these systems utilize modern, high-speed equipment with low track noise levels. The interior noise level, then, is dependent upon the air conditioning system.

One other major source of noise from railroads is braking operations in retarder yards, which produce a high-pitched sound at a level that can exceed 120 dBA at 50 feet.

Rapid Transit Systems

All the rapid transit/rail systems use electric multiple-unit rail cars, designed with many exit doors for rapid handling of passengers, large windows for good visibility, and lightweight structure to reduce the overall load. The result is that these vehicles have lower noise insulation than railroad passenger cars. Suspension systems universally contain steel springs, additional cushioning being provided by either rubber pads or air cushioning systems.

There is presently a wide range in the age of the operational vehicles of this type. The newer vehicles have better suspension systems than the older types, and there is also a current requirement to use air conditioned vehicles that allow all windows to be permanently sealed. Both the new suspension systems and the sealed windows serve to provide substantially lower levels inside the new transit cars.

The range of noise levels for major noise sources associated with rail transit systems is shown in Figure 2-26. The main source of noise is the interaction between the wheels and rails. This is more serious in rapid transit systems than in rail systems because the tracks are subject to a much higher rate of wear. Other sources of noise are the propulsion system and the auxiliary equipment. Rapid transit system noise is complicated by other elements not totally connected with the vehicles, including the reverberant effect of tunnels on noise in subway systems, the increased vibration-induced noise from elevated systems, and the higher reflectivity of concrete roadbeds used for some rapid transit lines.

Street and trolley cars still operate in Boston, San Francisco, Philadelphia, and other cities. In some cases they operate in conjunction with subway systems. External noise levels vary for streetcars between the old and the new types of cars, the levels ranging from approximately 68 to 80 dBA at 50 feet under varying operating conditions.

Ships

Of all the sources of noise in transportation systems, ships are the least important in terms of environmental impact. Only the noises aboard ship are significant. The only aspect of this shipboard noise of potential significance is the environment of passengers. These levels are generally lower than 65 dBA.

Environmental Impact

The preceding discussions have illustrated the nature of the noise environments for each major element of the transportation system. As with any complex situation, several views of the overall impact of transportation noise are desirable to obtain an overall perspective.

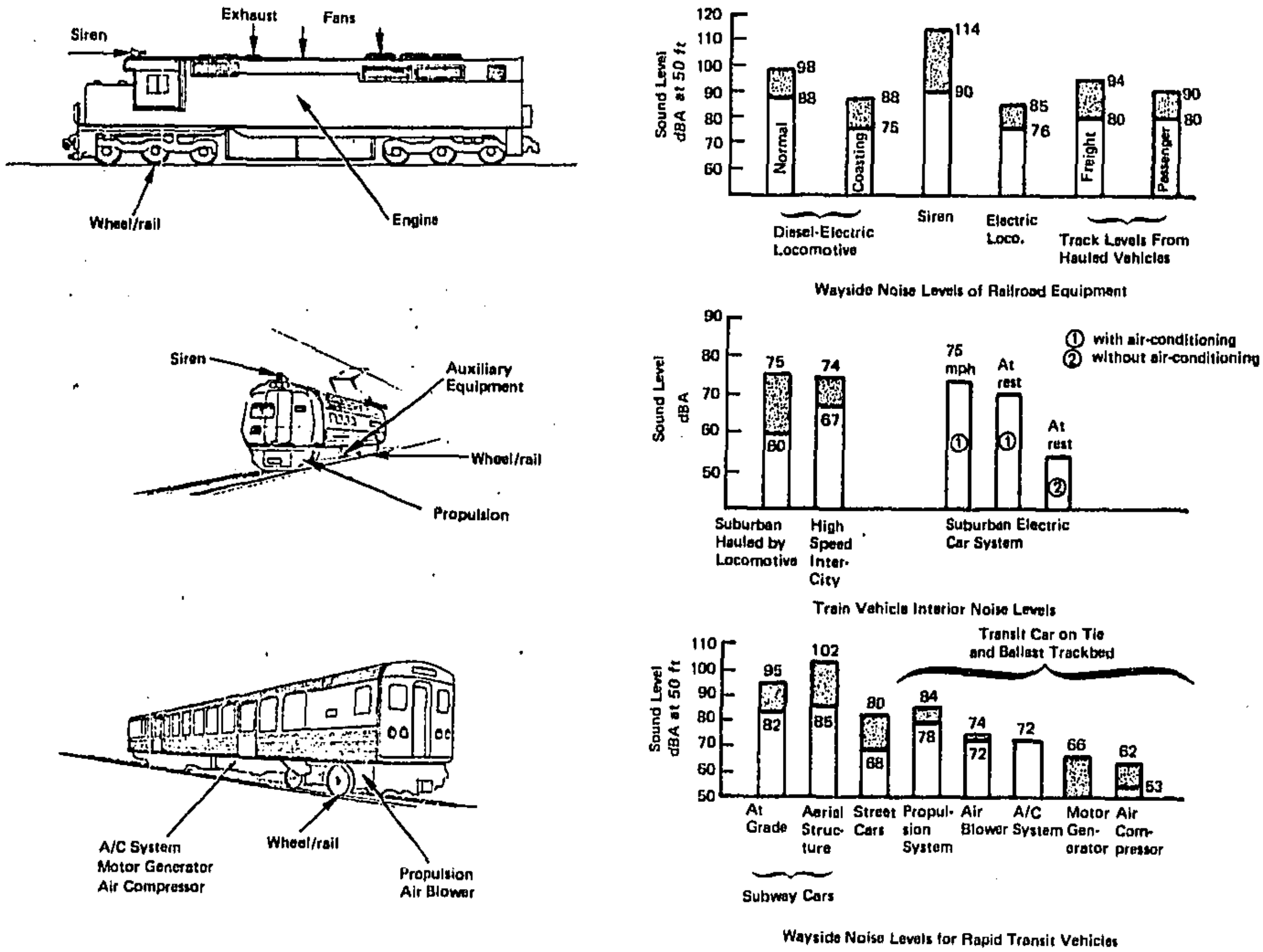


Figure 2-26. Rail Vehicle Noise Sources

First, a simplified overview of the relative contribution of each of the source categories is provided by comparing their estimated daily outputs of acoustic energy. Next, the sources are compared to estimate their relative contributions to the outdoor residual noise level in typical urban residential areas. Third, the sources are reviewed with respect to their individual single-event intrusive characteristics and their potential impact in terms of community reaction. Finally, the operator/passenger noise environment is reviewed with respect to the potential hazard for hearing damage and speech interference. Each of these views provides some insight into the relative impact of the various source categories.

Total Noise Energy Output Per Day

One useful way to order the relative impact of the various sources is to estimate the total noise energy generated in an average day. This noise energy will be higher for those elements of the transportation system that generate higher noise levels, exist in large numbers, and operate more hours per day. Table 2-9 summarizes by each category the estimates of the A-weighted noise energy generated throughout the nation during a 24-hour day.* The top 10 transportation categories, as indicated by their noise energy, produce 96 percent of the total noise energy, and, of these, heavy trucks and four-engined aircraft produce over 50 percent of the total noise energy.

Contribution of Transportation System Components to the Residual Noise Level

As discussed previously, the residual noise level in a community is the slowly changing, nonidentifiable background noise that is always there whenever one listens carefully. This noise level is normally dominated by highway vehicles moving throughout the community. Other noise sources in a community, such as aircraft, railroads,

* The passage of a sound wave is accompanied by an increase in energy. For example, when a person shouts, he produces a sound power of approximately 0.0007 watt at 1 foot from his lips. Commonly accepted mathematical formulas are available for making conversions of sound pressure to sound power. These have been used as the basis of the derivations of the noise energy values discussed herein. See EPA document NTID300.13.

Table 2-9

NOISE ENERGY FOR ELEMENTS OF THE TRANSPORTATION SYSTEM

Major Category		Noise Energy (Kilowatt-Hours/Day)
Aircraft	● 4-Engine Turbofan Aircraft	3,800
	● 2- and 3-Engine Turbofan Aircraft	730
	● General Aviation Aircraft	125
	Helicopters	25
Highway Vehicles	● Medium and Heavy Duty Trucks	5,000
	● Sports Cars, Imports and Compacts	1,000
	● Passenger Cars (Standard)	800
	● Light Trucks and Pickups	500
	● Motorcycles	500
	City and School Buses	20
	Highway Buses	12
Recreational Vehicles	● Minicycles and Off-Road Motorcycles	800
	Snowmobiles	120
	Outboard Motorboats	100
	Inboard Motorboats	40
Rail Vehicles	● Locomotives	1,200
	Freight Trains	25
	High Speed Intercity Trains	8
	Rapid Transit Trains	6.3
	Passenger Trains	0.63
	Old Trolley Cars (pre WWII)	0.50
	New Trolley Cars (post WWII)	0.08
		Total ~ 15,000

● Top 10 categories that each generate at least 125 kilowatt-hours per day.

recreational vehicles, industrial plants, or multiple air conditioning systems, are usually widely dispersed and are therefore responsible for identifiable intruding noises.

Table 2-10 summarizes the estimated daytime residual noise levels for each major type of highway vehicle operating in an average urban community. It is apparent that passenger cars and trucks are the principal noise sources. Only if all traffic were stopped would other sources be important to the residual noise level in an average urban residential community.

Table 2-10

PREDICTED CONTRIBUTIONS TO DAYTIME RESIDUAL NOISE LEVELS BY HIGHWAY VEHICLES FOR A TYPICAL URBAN COMMUNITY IN 1970

Source	Approximate Source Density, Units/Square Mile	Residual Noise Level dBA
Standard Passenger Cars	~ 50	43
Sports Cars, Compacts, and Imports	~ 20	41
Light Trucks	~ 20	42
Heavy and Medium Trucks	~ 1.5	33
Highway Motorcycles	~ 1	18
City Buses	~ 0.8	15
Total		47 dBA

The residual level was also computed with the same technique for the years 1950 and 1960. The estimated values of the daytime residual noise levels for a typical urban residential community are 45 dBA for 1950 and 46 dBA for 1960. These estimates indicate an increase over 10 years of approximately 1 dB in the residual noise level (L_{90}). This rate of increase is consistent with the available data summarized in the discussion of community noise. Again, it is emphasized that the intruding noise, not the residual, is the problem.

Relative Annoyance of Intruding Single Events

For evaluating impact of intruding single events such as resulting from a car driven past a house, each transportation subcategory can be compared according to its noise level at a fixed distance. Table 2-11 summarizes typical values for noise levels at a distance of 50 feet from surface transportation sources.

Examination of the various categories in Table 2-11 clearly shows that noise from heavy trucks, highway buses, trains, and rapid transit vehicles that normally operate along restricted traffic routes will distinctly intrude upon people living near those traffic routes. On the other hand, motorcycles and garbage trucks, which operate on all streets, are a more widely encountered source of intrusion and potentially affect more people. This noise intrusion of single events is more severe for communities in which the residual noise level is inherently low. For example, in a rural or quiet suburban community located well away from major highways, the residual noise level is 10 to 15 dB lower than in urban areas; and the passby of a noisy sportscar at night may momentarily increase the noise level by as much as 40 dB. Similarly, during the night near a major highway, noise intrusion from single trucks is readily apparent due to the lower density of automobile traffic.

Recreational vehicles operating on land are in a class by themselves. Their wide use in both residential and recreational areas and the rapid increase in their number, in addition to their high noise levels, have contributed to the current concern regarding these devices. The growth pattern is particularly significant, as indicated in Figure 2-27, which also illustrates the growth pattern of other consumer devices operated by internal combustion engines.

Table 2-11

RANK ORDERING OF SURFACE TRANSPORTATION SYSTEM ACCORDING TO A-WEIGHTED NOISE LEVEL

	Typical A-Weighted Noise Levels at 50 ft(1) dB re: $20 \mu N/m^2$	Estimated Vehicle-Miles in Urban Areas Billions
HIGHWAY		
Medium and Heavy Trucks	84 (88)	19
Motorcycles	82 (88)	NA(2)
Garbage Trucks	82 (88)	0.5
Highway Buses	82 (86)	0.1
Automobiles (Sport, etc.)	75 (86)	21
City Buses	73 (85)	2.2
Light Trucks	72 (86)	77
Automobiles (Standard)	69 (84)	335
RAIL		
Freight and Passenger Trains	94	NA(2)
Rapid Transit	86	0.33
Trolley Cars*	80	0.03
Trolley Cars**	68	0.03
RECREATIONAL VEHICLES		
Off-Road Motorcycles	85	
Snowmobiles	85	
Inboard Motorboats	80	
Outboard Motorboats	80	

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

(2) Not available.

* Pre-WWII
** Post-WWII

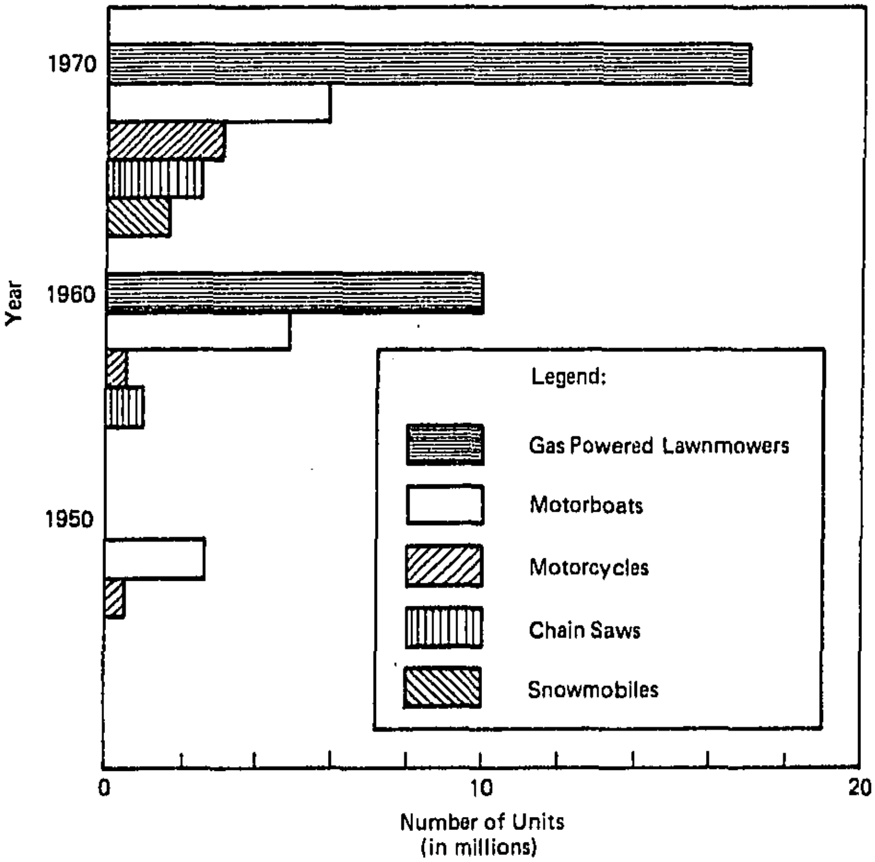


Figure 2-27. Approximate Growth of a Few Types of Noisy Recreational Vehicles and Outdoor Home Equipment

The noise intrusion of water craft is generally regarded to be fairly low. Power boats are legally required in many states to be at least 100 feet from shore when operating at high speed, thus minimizing their impact in local communities.

Overall Assessment of Noise Impact by the Transportation System on Nonparticipating Observers

The cumulative effect of the repeated occurrence of intruding noises will place a different emphasis on individual transportation system categories than is obtained by considering only a single event. This cumulative effect is expressed in terms of the land area within an NEF contour of 30, or the corresponding contour value on the CNEL scale of 65. As discussed earlier, the expected reaction of a residential urban community for CNEL-65 would be widespread complaints. Thus, the choice of the contour boundary may tend to understate the total impact, which for both airports and freeways, is certainly greater.

The estimated noise-impacted land within this NEF-30 contour for airport operations throughout the nation was approximately 1450 square miles in 1970. The area enclosed between an effective right-of-way freeway boundary and the CNEL-65 boundary is estimated to be approximately 545 square miles.

Thus, the estimated noise-impacted land within a CNEL-65 boundary for urban freeways and commercial airports as of 1970 was approximately 2000 square miles. Based on a typical population density in urban communities of 5000 people per square mile, this total noise-impacted area represents approximately 10 million people within a CNEL boundary of 65. Again, this is an underestimate, with the complete impact certain to be greater.

The noise-impacted land near rapid transit lines was not involved in this summary, since there are only 386 miles of electric railway lines, compared to about 9200 miles of freeways. However, since these lines typically serve commuters, much of the mileage is contained in densely populated city areas, and the commuting impact is far greater than would be anticipated simply by the area impacted. As with other noise sources, impact cannot be considered regarding exposure to only a single source. Individuals are routinely exposed to many such sources on a daily basis.

Because helicopter flight route patterns are essentially random, it is practically impossible to define their noise impact in terms of land area or population. A sustained public reaction has not materialized, despite the intrusive nature of the sound, probably because of the irregularity of this use pattern. However, widespread complaints have arisen regarding air taxi services in New York and police operations in Los Angeles.

Impact on Operators and Passengers in Transportation Systems

The two significant effects of noise on operators or passengers of transportation systems are potential hearing damage from excessive noise and interference with speech communication.

Potential Hearing Damage. The potential hazard with respect to hearing handicap for all categories of the transportation system is summarized in Figure 2-28 in terms of an equivalent 8-hour exposure level. This equivalent level is determined from the actual passenger noise exposure using the same rule for trading off time of exposure and level that is utilized in the noise limiting regulations adopted under the Occupational Safety and Health Act. The estimated equivalent 8-hour exposure levels of five of the transportation categories exceed the Occupational Safety and Health Act criteria for an equivalent 8-hour day. In each of these five cases, noise protection for the operator's ears is highly desirable. In occupational situations, because of longer exposure, hearing protection would become mandatory. In addition, many of the other sources, including all those exceeding an equivalent 8-hour exposure level of 80 dBA are potentially hazardous to some individuals, particularly in combination with their

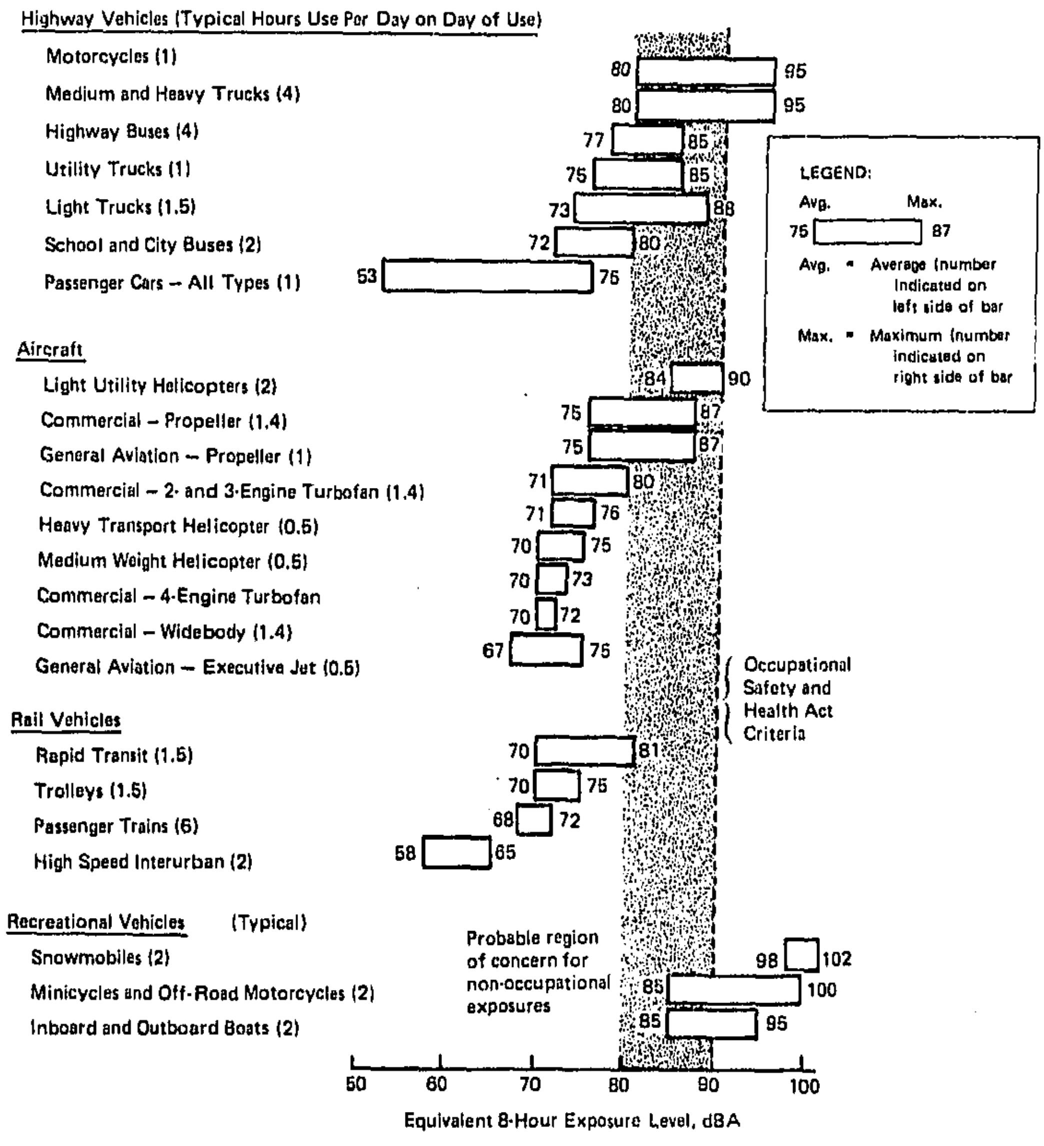


Figure 2-28. Potential Hearing Damage from Transportation System Components in Terms of Equivalent 8-Hour Exposure Levels, for Passengers or Operators

exposure to other noise environments. As indicated, a considerable exposure potential for a significant portion of the population may exist because of the combination of exposures to a variety of sources.

Speech Interference. Speech interference criteria specify maximum desirable noise levels at the listener's ear as a function of talker-listener separation for effective normal speech communication. Table 2-12 summarizes typical talker-listener separation distances in various transportation systems and corresponding desired noise limits to minimize speech interference at these distances. With the exception of V/STOL propeller or rotary-wing aircraft, the internal noise levels are not excessive in terms of speech interference, while affording a maximum of speech privacy for each passenger pair.

Table 2-12

TYPICAL PASSENGER SEPARATION DISTANCES AND SPEECH INTERFERENCE CRITERIA

	Talker-Listener Separation Feet	Speech Interference Criteria* dBA	Average Internal Noise Levels dBA
Passenger Cars	1.6 to 2.8	73 to 79	78
Buses	1	79 to 85	82
Passenger Trains	1 to 1.7	79 to 85	68 to 70
Rapid Transit Cars	1 to 1.7	79 to 85	82
Commercial Aircraft (Fixed Wing)	1.1 to 1.7	79 to 84	82 to 83
V/STOL Aircraft	1.1 to 1.7	79 to 84	90 to 93

* Maximum noise levels to allow speech communication with expected voice level at specified talker-listener separation distances.

DEVICES POWERED BY INTERNAL COMBUSTION ENGINES

The noise emanating from lawn care equipment powered by small internal combustion engines is well known to the millions of people who maintain gardens or lawns and their neighbors. The total United States production of these engines was about 10.9 million units in 1969. This total includes all engines below 11 horsepower except those used for boating, automotive, and aircraft applications. Over 95 percent of these are single cylinder, air cooled engines. The vast majority are four cycle, while the two-cycle version of the same size dominates the remaining market. More than half of the single cylinder engines power the estimated 17 million lawnmowers in use today, while the majority of the remaining engines are used in other lawn and garden equipment such as leaf blowers, mulchers, tillers, edge trimmers, garden tractors, and snowblowers. In addition, about 750,000 chain saws and 100,000 engines for equipment such as small loaders and tractors, were produced in 1970, while agricultural and industrial usage together accounted for another 1.5 million engines. The categorization of these devices by use and range of typical noise levels is summarized in Figure 2-29. The range of noise levels for the various devices in this category are shown in Figure 2-30.

Lawn Care Equipment

The characteristic noise produced by lawn care equipment has a low frequency peak corresponding to the engine firing frequency (about 50 to 60 cycles per second) and a high frequency maximum occurring anywhere from two to three octaves above the firing frequency. In the case of a lawnmower, much of the energy in the high frequency noise peak is from the exhaust, which has only a minor degree of muffling. Additional high noise levels are radiated by the rotating blade. Equipment without a rotating blade will generally have other machinery noise of the same approximate

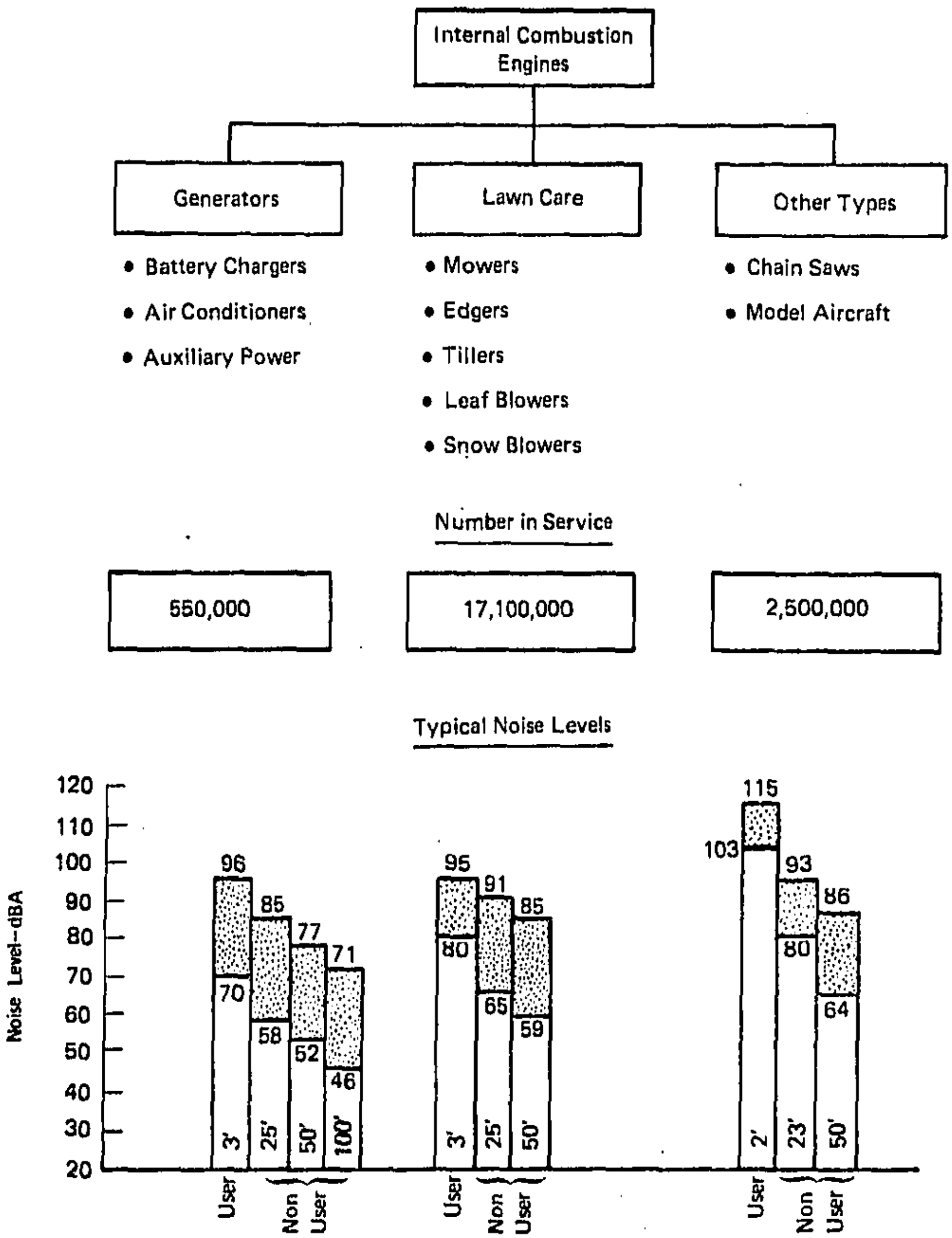


Figure 2-29. Characteristics of Devices Powered by Internal Combustion Engines

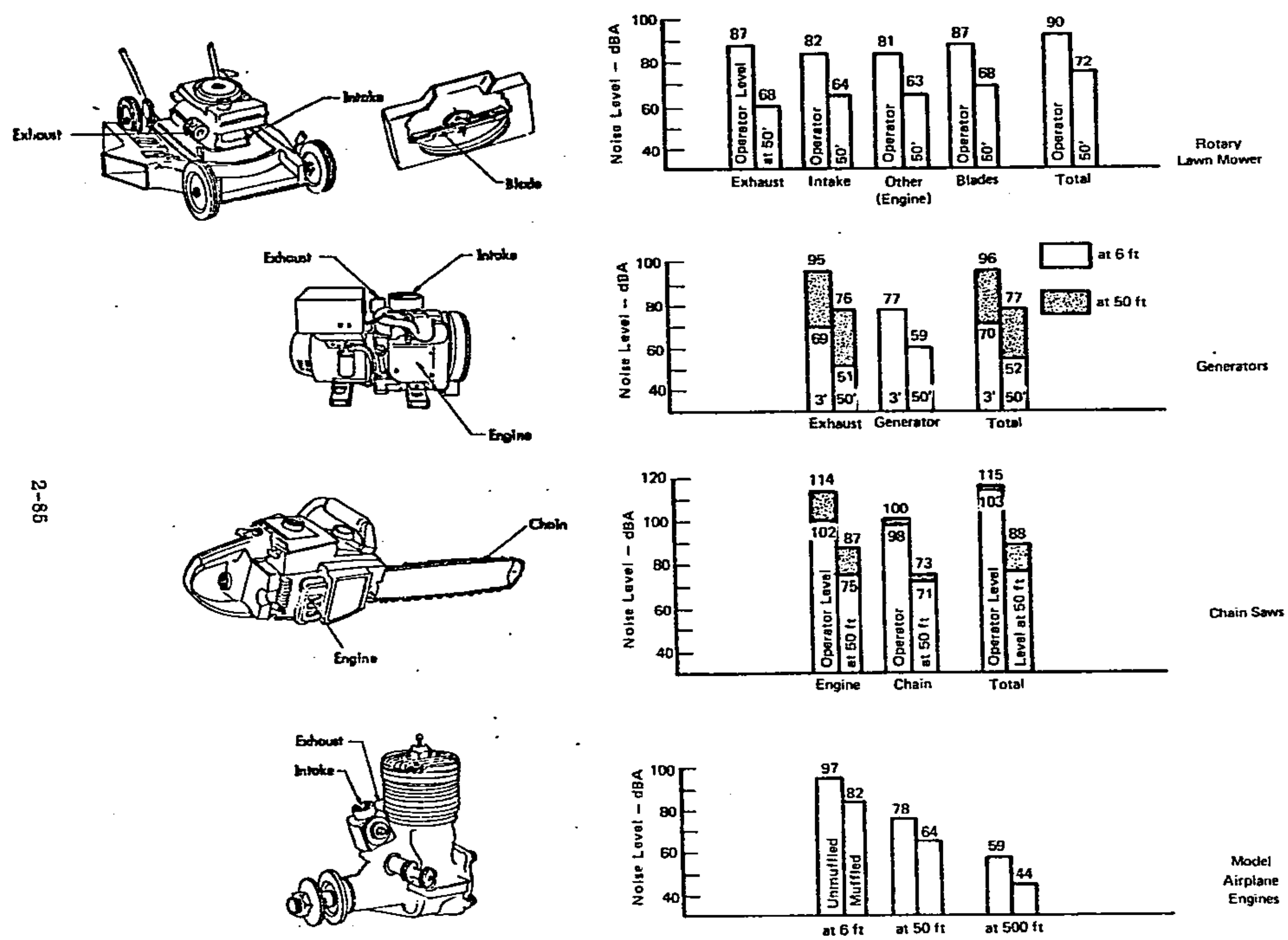


Figure 2-30. Noise Source Characteristics of Internal Combustion Engine Devices

level. The modulation of the high frequency engine noise by the engine firing frequency makes the engine noise more audible than the noise of a rotating blade or other machinery. Thus, even heavy muffling on lawn care equipment cannot totally eliminate the characteristic noise associated with this modulation.

Generators

Of the 100,000 generators sets sold each year in the United States, most are used in mobile homes, campers, and large boats, where their electrical power output is used for air conditioning, lighting, and other equipment. Their noise output is generally dominated by high frequency exhaust noise, which can be well muffled to achieve quiet operation acceptable to users and their neighbors.

Chain Saws

The typical chain saw engine is a two-cycle, high-speed device that operates with a firing frequency of about 150 times per second. A minimum muffler is usually a part of the configuration and is equipped with a spark arrestor to prevent fire. The high firing frequency and light muffler result in noise levels as high as 115 dBA at the operator position, with levels of 83 dBA common at a 50-foot distance.

Model Airplane Engines

Model airplane engines are two-cycle engines that typically operate at 12,000 to 18,000 rpm, resulting in a firing frequency above 200 Hz. Until recently, these engines had no muffling at all, and with muffling, the A-weighted noise level is reduced by about 12 decibels.

Environmental Impact

The principal characteristics of internal combustion engines as sources of potential noise impact are summarized in Table 2-13. In general, these devices are not significant contributors to the average residual noise levels in urban areas. However, the annoyance distance of most of the garden care equipment equals or exceeds about

Table 2-13

SUMMARY OF NOISE IMPACT CHARACTERISTICS OF INTERNAL COMBUSTION ENGINES

Source	A-Weighted(1) Noise Energy Kilowatt-Hrs Day	Typical A-Weighted Noise Level at 50 Feet dBA	Approx. Distance to 74 dBA Feet	8-Hr Exposure(2) Level dBA		Typical Exposure Time Hours
				Average	Maximum	
Lawn Mowers	63	74	50	77	85	2
Garden Tractors	63	78	80	N/A	N/A	
Chain Saws	40	82	130	85	95	1
Snow Blowers	40	84	160	61	75	1
Lawn Edgers	16	78	80	67	75	1/2
Model Aircraft	12	78	80	70(3)	79(3)	1/4
Leaf Blowers	3.2	76	60	67	75	1/4
Generators	0.8	71	35	-	-	-
Tillers	0.4	70	30	72	80	1

(1) Based on estimates of the total number of units in operation per day.

(2) Equivalent level for evaluation of relative hearing damage risk.

(3) During engine trimming operation.

50 feet – a typical neighbor-to-neighbor distance – indicating further noise reduction for these devices is desirable. Similarly, a distinct local increase in the noise level in rural or wilderness areas may be experienced at distances up to 1 mile from such devices as chain saws. As a result, they constitute a persistent source of annoyance for persons seeking the solitude of wilderness areas. Use of chain saws can result in equivalent 8-hour exposure levels of 83 to 90 dBA for the operator, indicating the desirability of hearing protection for operators.

NOISE FROM INDUSTRIAL PLANTS

Industrial plant activity in the United States ranges from the small single machine garage operation to the large multimillion dollar, multiproduct operation. U.S. Department of Commerce Statistical Abstracts for the year 1967 reported that there were 311,000 industrial establishments in the United States employing approximately 14.36 million production workers. Although the types of industrial activities vary greatly, for the purpose of this report they have been categorized into four basic types:

1. Product fabrication
2. Product assembly
3. Power generation
4. Process plants.

Due to the broad nature of the product fabrication industry, it was further subdivided into metal fabrication and molding.

To investigate the industrial plant as a total noise source and to evaluate the effect of this noise source on the community, a case study was performed that included examples of each industrial category. Specific industrial activities typical of possible sources of community noise were studied and are as follows.

- Metal fabrication — can manufacturing
- Molding — glass bottle manufacturing
- Product assembly — automobile assembly
- Power generation — public utility electric
- Process — oil refinery

Based on Bureau of the Census and the Automobile Manufacturers Association data (as of 1967) there were 305 glass and glassware manufacturing plants, 438 petroleum refineries, 3429 electric power generating plants, 98 automobile assembly plants, and 300 can manufacturing plants in the U.S. The number of plants being represented by the specific plants of the case study account for approximately 1.5 percent of the total number of industrial establishments in the United States.

Plant Noise Sources

A study of industrial plants as sources of community noise must begin with the individual noise sources within the plant. Industrial plant noise sources can be generally classified into five major categories.

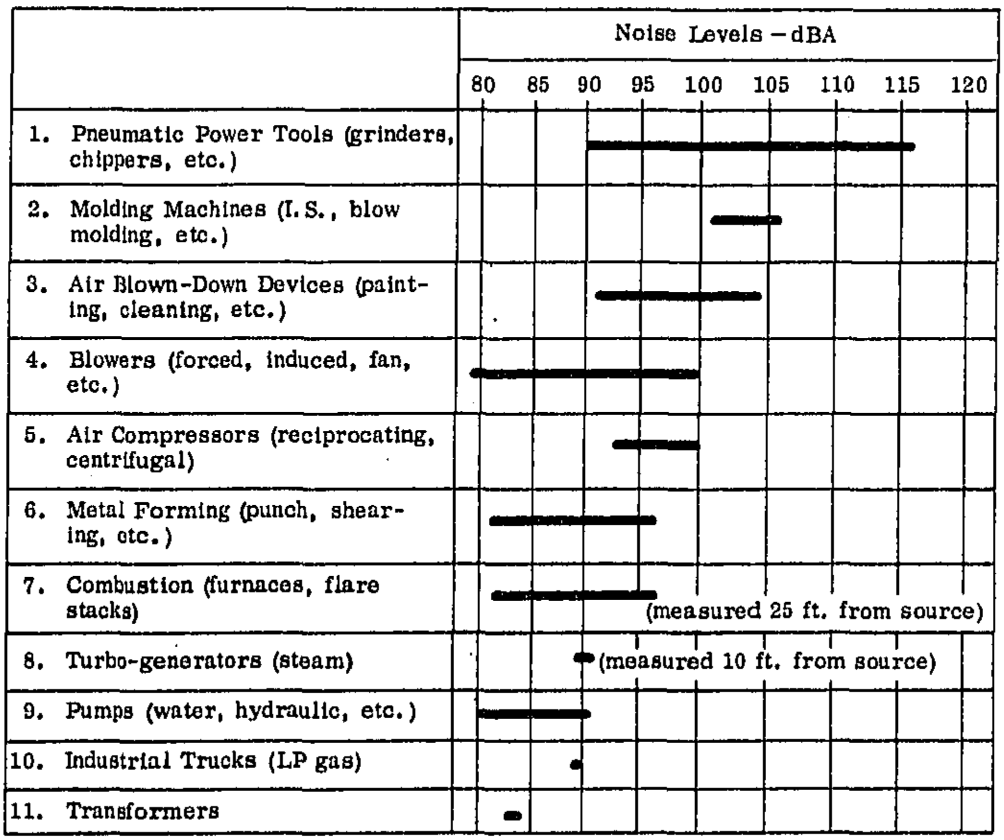
- Impact — punch, presses, stamping, hammers
- Mechanical — machinery unbalance, gears, bearings
- Fluid Flow — fans, blowers, compressors, valves
- Combustion — furnaces, flare sticks
- Electromechanical — motors, generators, transformers

A brief description of the types of individual noise sources observed in the typical plants of the case study conducted for this report are given in the following subsections.

The range of industrial machinery and equipment noise levels (A-weighted) observed within the five typical plants surveyed are presented in Table 2-14.

Table 2-14

RANGE OF INDUSTRIAL MACHINERY, EQUIPMENT, AND PROCESS NOISE LEVELS*



*Measured at operator positions, except for 7 and 8.

Glass Manufacturing Plants

Glass bottles are manufactured by "blowmolding" the molten glass to the desired size and shape. High pressure air is used for cooling, pneumatic control, and operation of the glass molding machines and is normally vented into the atmosphere. The turbulent mixing of the high pressure air with the atmosphere is the major noise source. Such noise sources are typically located within masonry-type buildings that may contain acoustic louvers at air inlets and exhausts.

Oil Refineries

The noise sources within a typical oil refinery are furnaces, compressors, heat exchangers, cooling fans, pumps, control valves, and air and steam piping leaks, all of which are located outdoors. Furnace noise is unique in that it is a combination of high frequency noise produced by the gassified fuel, low frequency noise produced by the air intake, and, finally, the noise produced by the combustion process itself.

Public Utility Electric Power Plants

A power plant is a complex system of furnaces, turbine generators (gas and steam), air compressors, transformers, and associated equipment such as forced draft blowers, induced draft fans, and control valves. Turbine-generators and air compressors are usually located inside masonry-type buildings, while the other noise sources are outdoors.

Automobile Assembly Plants

The mass production of automobiles requires the use of electrically and pneumatically powered labor assist devices such as grinders, impact wrenches, and air blowdown devices. The combination of tool and operation noise is of a broadband type, with the levels greatest at high frequencies.

Can Manufacturing Plants

The process of metal stamping requires metal forming, cutting, punching, shearing, and pressing, all of which are noisy impact operations.

Community Noise Climate

Industrial plants in the past were normally located in heavily populated urban areas due to requirements for skilled and semiskilled labor and transportation. By locating in or near a large city, the industries were able to draw employees from a large labor pool and had a ready means, through railroads, highways, and port facilities, to receive raw material and to ship their finished products.

Groups of industrial plants, in general, raise the residual noise level in the surrounding community to such a level that intrusive noise due to individual plants is masked or minimized. The rise in the residual level is caused by the exceedingly high noise levels within a plant due to industrial machinery and processes and the increase in truck traffic due to the existence of the plant.

During the past several decades skilled and semiskilled labor has migrated from the cities, a trend followed by commercial and industrial activity. The attraction of local industrial plants to the suburbs has been partly attributed to more favorable municipal tax structures, the relocated labor pool, and the clogging of city arteries by increased traffic. Plant noise has become more evident in suburban and urban areas, due to the lower existing residual levels, and may generate complaints.

Noise measurements in and around the communities adjacent to the industrial plants selected for the case study were made during weekend periods when the plants were either shut down or their mode of operation differed significantly from normal weekday operation, and during daytime and nighttime periods during the week. Results of the noise surveys conducted for the case study are discussed in the following subsections. The residual noise levels (L_{90}) measured (A-weighted) are presented on area maps, Figure 2-31 through Figure 2-35.

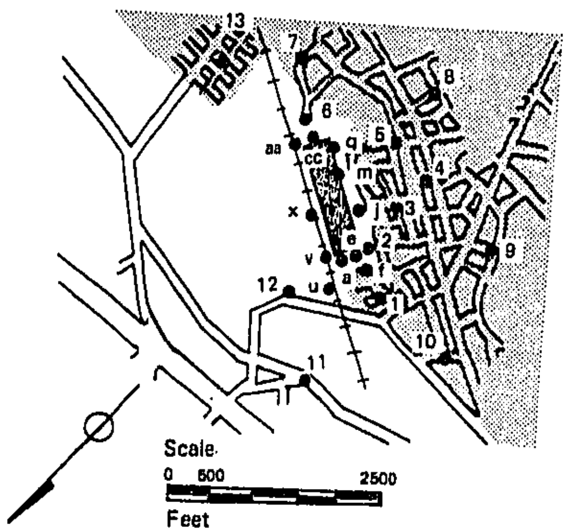
Glass Manufacturing Plant Example

The glass manufacturing plant, Figure 2-31, is located in a community with a population of 5535. To the south and southwest of the plant, the land use is mainly residential, with a predominance of multifamily homes. Homes on the east side of the plant are single family, detached housing units.

The plant operates on a three-shift basis but is closed, except for maintenance on weekends. Since there are no nearby major highways, airports, or construction activity, the glass manufacturing plant is the predominate noise source in the community. Even though the noise levels in the community are relatively low, residents have filed complaints with their local board of health and have even threatened legal action. The basis of the complaints is the intrusive sounds produced by large air intake vents located on the roof at one end of the factory building (near measurement position #2).

Oil Refinery Example

The oil refinery, Figure 2-32, is located within an industrial area of a city of 41,409 persons. It is bordered by major highways to the north and east, and a turnpike passes through the southern portion of the property. The refinery operates three shifts per day, 7 days per week. The refinery is not the predominate source of noise in the nearby residential community of multifamily dwellings. The noise level observed at measurement position "1" is not due to the refinery noise sources but is due to the combined noise of the turnpike and a nearby chemical plant. The fenceline noise measurement at position "b" is high due to temporary construction activity, while the measurement at positions "g", "h", and "i", though high at night, cannot be attributed to the refinery, since only storage tanks are located nearby. Plant personnel and local community officials know of no complaints attributable to the long term operations of the refinery.



Community Residual Noise Levels in dBA

	1	2	3	4	5	6	7	8	9	10	11	12	13
Weekend	46	54	45	39	41	43	–	–	48	41	41	51	43
Weekday	50	59	44	42	42	40	44	40	41	44	39	53	43
Weeknight	52	61	46	40	43	45	43	40	41	41	42	49	42

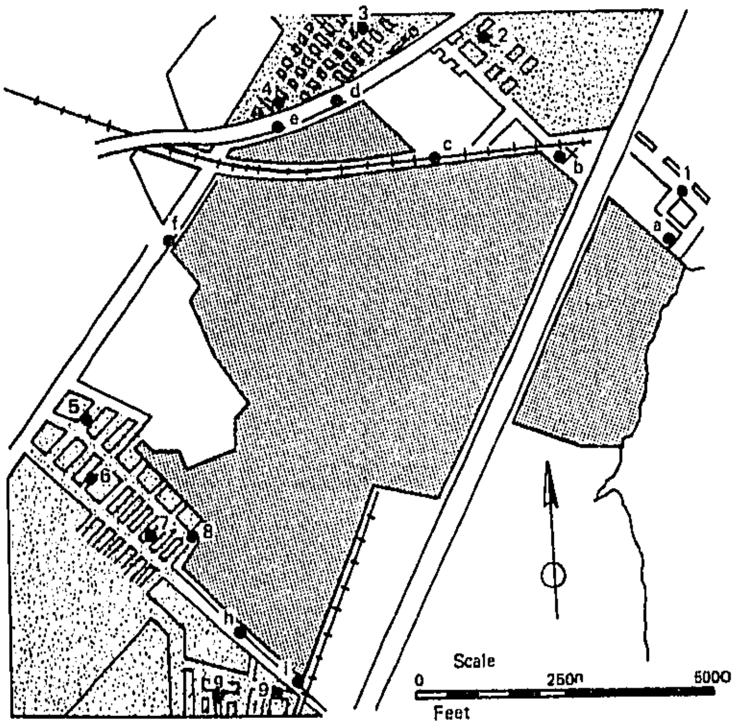
Plant Property Line Residual Noise Levels in dBA

	a	e	f	j	m	q	cc	aa	x	v	u
Weekend	50	62	59	68	55	41	44	40	60	65	52
Weekday	49	64	61	68	59	49	50	49	66	68	55
Weeknight	51	64	63	69	58	48	41	46	61	65	54

Key

- Industrial Noise Source
- Residential Area
- Railroad Track
- Highway
- Measurement Location

Figure 2-31. Glass Manufacturing Plant Community



Community Residual Noise Levels in dBA

	1	2	3	4	5	6	7	8	9
Weekend	59	49	62	55	50	50	50	48	51
Weekday	63	52	50	56	48	51	54	47	50
Weeknight	60	51	51	50	47	49	59	47	49

Plant Property Line Residual Noise Levels in dBA

	a	b	c	d	e	f	g	h	i
Weekend	55	71	60	60	60	55	54	52	56
Weekday	63	68	60	62	64	63	51	52	53
Weeknight	58	67	59	59	62	61	49	50	54

Key

- Industrial Noise Source
- Residential Area
- Railroad Track
- Highway
- Measurement Location

Figure 2-32. Oil Refinery Community

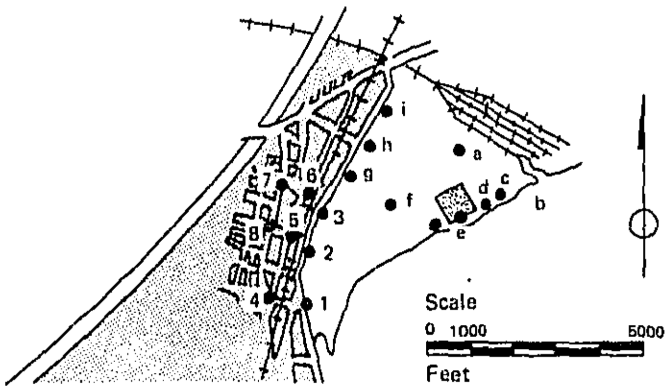
Power Plant Example

This power plant, Figure 2-33, is located near a community of single-family detached housing that is part of a larger urban municipality of 98,944 persons. The power plant operates 7 days per week, with its power generating units being activated upon demand. The main power sources are five steam turbogenerators, with a gas turbine generator reserved for peak loads.

In general, the community noise level is established by the turnpike to the north and the power plant and oil refinery (not shown) to the south. Note that the community noise levels are constant throughout the workweek and weekend. The power plant noise is directed toward the waterfront area. The high noise level at the property line, position "a," during the weekend was due to flow noise in a pipe nearby, while the noise at "e" was due to a pumping station. Sporadic complaints have been received by the power plant concerning operation of the gas turbine generator.

Automobile Assembly Plant Example

The automobile assembly plant, Figure 2-34, is situated in an industrial area. The area south of the plant is mainly residential, while the land to the north and west is residential but mixed with business activity. The population of the town surrounding this plant is 10,534. The plant operates on a two-shift per day basis, with a third shift (11 p.m. to 7 a.m.) reserved for maintenance and restocking operations; and no work is normally conducted at the plant on weekends. Since this plant is not located near major highways, airports, or construction activity, the property line and community data indicated that the assembly plant is the principal source of noise in the community. The weeknight noise levels approach weekday levels because of the unloading of railroad cars during restocking. Neither plant personnel nor community officials expressed a knowledge of any noise complaints concerning the plant.



Community Residual Noise Levels in dBA

	1	2	3	4	5	6	7	8
Weekend	48	50	50	50	52	58	57	54
Weekday	48	51	49	53	55	56	55	54
Weeknight	51	52	52	52	53	56	57	54

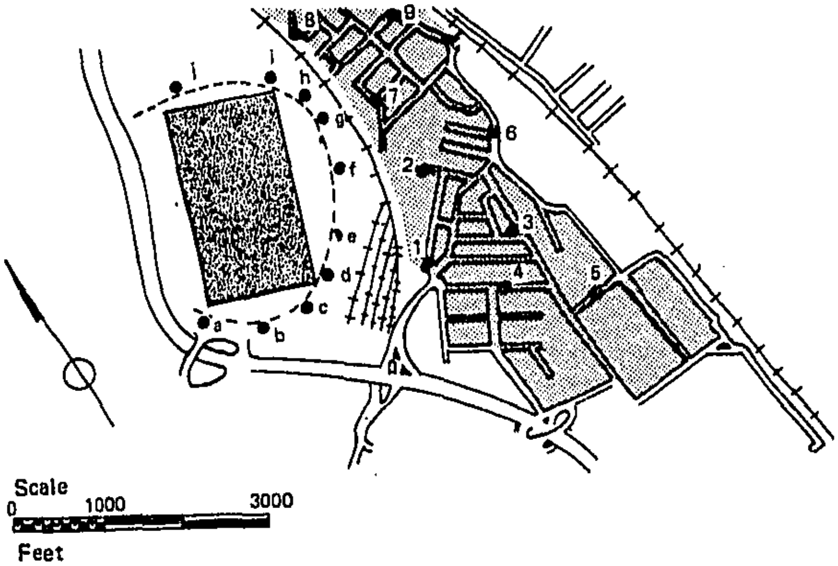
Plant Property Line Residual Noise Levels in dBA

	a	b	c	d	e	f	g	h	i
Weekend	81	58	63	69	64	53	54	59	68
Weekday	64	59	61	72	80	61	59	57	63
Weeknight	68	63	67	70	80	61	60	61	65

Key

- Industrial Noise Source
- Residential Area
- Railroad Track
- Highway
- ● Measurement Location

Figure 2-33. Power Plant Community



Community Residual Noise Levels in dBA

	1	2	3	4	5	6	7	8	9
Weekend	47	43	49	45	43	47	45	48	47
Weekday	50	48	50	49	47	54	50	53	50
Weeknight	51	50	50	50	47	52	48	54	48

Plant Property Line Residual Noise Levels in dBA

	a	b	c	d	e	f	g	h	i	j
Weekend	54	47	46	46	47	54	54	49	54	46
Weekday	58	57	55	53	54	62	57	54	55	54
Weeknight	57	57	56	51	53	58	55	53	54	54

Key

- Industrial Noise Source
- Plant Property Line
- Residential Area
- Railroad Track
- Highway
- Measurement Location

Figure 2-34. Automobile Assembly Plant Community

Can Manufacturing Plant Example

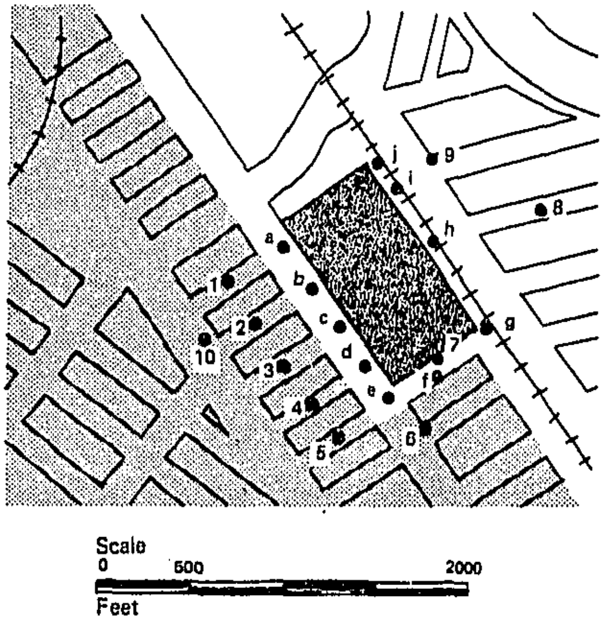
This plant, Figure 2-35, is located in a moderately sized city with a population of 144,824. It is located within an industrial-residential area and is bounded by streets having dense automobile and truck traffic. The homes in the nearby community are multifamily dwellings. The can manufacturing plant operates on a three-shift basis during the work week but is essentially shut down during the weekend.

It appears that the community noise is due to both surface transportation and the plant. Noise levels in the community are similar for the weekend, weekday, and week-night periods, although the noise levels are generally higher during the weekday along portions of the property line. No information regarding community complaints attributable to the plant is available from plant personnel or city officials.

Community Impact

A review of the data obtained from the case studies shows that although interior plant noise levels due to individual machines, equipment, or processes are exceedingly high, the impact of plants on the community as indicated by complaint history was not significant, with the single exception of the glass manufacturing plant. The noise that actually reaches the community is reduced by plant building construction and the distance between the plant and the community. Often, the plant combines with other noise sources to create the community noise climate. The five plants in this study are located in areas in which the residual noise levels compare favorably with levels shown in Table 2-2. The community adjacent to each plant may be categorized as follows:

- Glass Manufacturing Plant — Quiet Suburban Residential to Normal Suburban Residential.
- Oil Refinery — Urban Residential to Noisy Urban Residential.
- Power Plant — Urban Residential to Noisy Urban Residential.



Community Residual Noise Levels in dBA

	1	2	3	4	5	6	7	8	9	10
Weekend	55	49	53	51	50	50	57	56	51	58
Weekday	53	49	55	49	51	54	59	56	56	56
Weeknight	48	49	53	51	47	49	58	50	56	47

Plant Property Line Residual Noise Levels in dBA

	a	b	c	d	e	f	g	h	i	j
Weekend	58	59	59	61	58	58	52	50	49	53
Weekday	60	65	64	65	60	60	56	52	57	63
Weeknight	53	63	63	61	58	62	53	43	53	66

Key

- Industrial Noise Source
- Residential Area
- Railroad Track
- Highway
- ● Measurement Location

Figure 2-35. Can Manufacturing Plant Community

- Automobile Assembly Plant – Urban Residential.
- Can Manufacturing Plant – Noisy Urban Residential to Very Noisy Urban Residential.

The noise data collected for this case study was included in Figure 2-9. As would be expected, the glass manufacturing plant noise levels, which exceeded the community levels by up to 29 dBA, caused widespread complaints and threats of legal action as predicted by Table 2-7. Complaints were received at only one of the other four plants, even though the noise levels they produced in their communities would lead one to expect sporadic complaints (Table 2-7). Complaints, as an indicator of community impact, must be viewed with caution. Many people can be annoyed but will not complain to authorities because they believe it futile. Further, it is also known that residents may not object to plant noise even at fairly high levels, if

- It is continuous.
- It does not interfere with speech communication.
- It does not include pure tones or impacts.
- It does not vary rapidly.
- It does not interfere with sleep.
- It does not contain fear-producing elements.

Counter-balancing the above effects, individuals or families may be annoyed by an industrial noise that does not annoy other plant neighbors. This often may be traced to unusual exposure conditions or to interpersonal situations involving plant management.

CONSTRUCTION EQUIPMENT AND OPERATIONS

Construction Site Noise

In recent years, noise associated with construction projects has become increasingly responsible for the degradation of the human environment. Many construction projects of various types and sizes are active at any given time in the urban, suburban, and rural areas of the United States. Many people residing or working near or passing by construction sites are thus exposed to extreme noise levels often for periods of several years.

Types of Construction Sites and Activities

For purposes of this report the fifteen site categories used by the U.S. Bureau of Census and by various state and municipal bodies can be reduced to the following four major types:

1. Domestic housing — including residences for one to several families.
2. Nonresidential buildings — including offices, public buildings, hotels, hospitals, schools.
3. Industrial — including industrial buildings, religious and recreational centers, stores, service and repair facilities.
4. Public works — including roads, streets, water mains, sewers.

Noise from construction of such major civil works as dams and bridges affects relatively few people (other than those employed at or near such construction sites) and therefore has not been studied in detail for this report. Also, exposure of construction workers to noise is a serious problem but was omitted from this study since occupational hazards are considered to be beyond the purview of this section of this report and was covered in the various EPA hearings on noise.

The type of activity at any given site varies considerably as construction progresses. Further, since the noise produced on the site depends on the equipment being used, it exhibits a great deal of variability. For purposes of characterizing this noise, one may consider construction at a given site in terms of the following five consecutive phases:

1. Ground clearing — including demolition and removal of prior structures, trees, rocks.
2. Excavation.
3. Placing foundations — including reconditioning old roadbeds, compacting trench floors.
4. Erection — including framing, placing of walls, floors, windows, pipe installation.
5. Finishing — including filling, paving, cleanup.

Characterization of Site Noise

To totally describe construction site noise, the five described phases for each of four different types of sites must be considered. However, there is an additional complication. Since the intrusion produced by any noise depends on the residual noise, the residual noise levels that exist at a site location in the absence of any construction activity must be taken into account. For comparison purposes, it is enough to consider only the two cases of urban (relatively noisy) and surburban (relatively quiet) environments.

For purposes of these site noise characterizations, a model was developed in which the equipment producing the highest A-weighted noise levels was taken to be located 50 feet from an observer (at the boundary of the site), and all other equipment was considered as being located at 2000 feet from the observer. The noise contributions of the various equipment items were calculated for representative duty cycles. Although this construction site noise model may not be entirely realistic, it still may be expected to yield at least a relative measure of the noise annoyance potential of each type of site and construction phase.

The energy equivalent noise levels (L_{eq}) for each construction phase at each site are shown in Table 2-15. For each phase/construction type element, a range of levels is given, reflecting different mixes of construction equipment that might be used for the same kind of process. The range encompasses maximum (I) and minimum (II) concentrations of equipment.

Table 2-15

TYPICAL RANGES OF ENERGY EQUIVALENT NOISE LEVELS, L_{eq} IN dBA, AT CONSTRUCTION SITES

	Domestic Housing		Office Building, Hotel, Hospital, School, Public Works		Industrial Parking Garage, Religious Amusement & Recreations, Store, Service Station		Public Works Roads & Highways, Sewers, and Trenches	
	I	II	I	II	I	II	I	II
Ground Clearing	83	83	84	84	84	83	84	84
Excavation	88	75	89	79	89	71	88	78
Foundations	81	81	78	78	77	77	88	88
Erection	81	65	87	75	84	72	79	78
Finishing	88	72	89	75	89	74	84	84

I – All pertinent equipment present at site.

II – Minimum required equipment present at site.

The maximum levels range from 77 to 89 dBA for all categories and have an average value of approximately 85 dBA. The minimum values for all categories have a wider range, extending from 65 to 88 dBA, and have an average value of 78 dBA. The table also shows that the initial ground clearing and excavation phases generally are the noisiest, that the intermediate foundation placement and erection phases are somewhat quieter, and that the final finishing phase tends to produce considerable noise annoyance.

The expected community reaction to construction noise may range from none to vigorous community action to stop the project, depending on the total circumstances. Calculations for three construction situations are presented in Table 2-16. Depending on the season, attitude toward the project, and existence of equipment having an impulsive noise character, the normalized community noise equivalent levels given in the table could be as much as 15 dB lower or 5 dB higher than the values appropriate to a specific situation. The biggest factor in this possible range results from the application of the attitude correction of -10 dB, which is appropriate for a project of known duration when the community recognizes that the project is necessary. The magnitude of this correction implies a significant acquiessance by the community to the noise of construction activity.

Construction Equipment Noise*

Although there is a great variety in the types and sizes of available construction equipment, similarities in the dominant noise sources and operational characteristics of commonly used equipment items permit noise characterization of all equipment in terms of only a few categories, as discussed subsequently.

* See also the extensive data provided on construction equipment noise at the EPA Hearing at Atlanta and Washington, D. C.

Table 2-16

EXPECTED COMMUNITY REACTION TO THREE TYPICAL EXAMPLES OF CONSTRUCTION NOISE

Factor	Single House Built in Normal Suburban Community	Major Excavation & Construction in Normal Suburban Community	Major Public Works Project in Very Noisy Urban Residential Area
Energy Equivalent Noise Level (L_{eq}) in dBA for 8-Hour Work Day	70*	85	85
Duration & Time of Day Correction Factor	-5	-5	-5
Community Noise Equivalent Level	65	80	80
Additional Correction Factors from Table 2-4:			
Seasonal	0	0	0
Residual Noise Level	+5	+5	-5
Experience & Attitude	-10	-10	-10
Pure Tone or Impulse	0	0	0
Normalized CNEL	60	75	65
Expected Reaction from Figure 2-9	Sporadic complaints	Threats of legal action or strong appeals to local officials to stop noise	Widespread complaints

*Considering only erection and finishing phases for minimal equipment.

Equipment Powered by Internal Combustion Engines

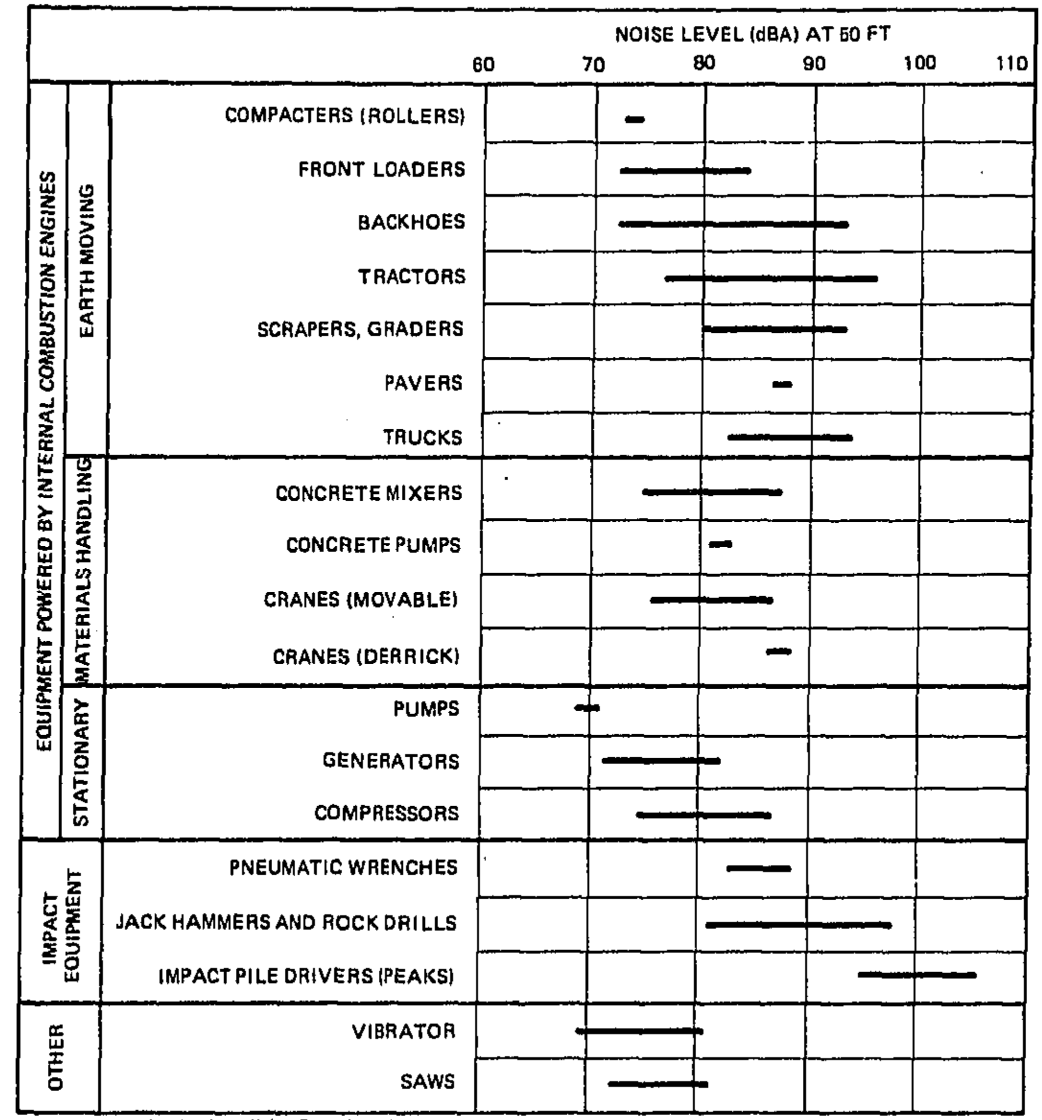
Engine-powered equipment may be characterized according to its mobility and operating characteristics as:

1. Earthmoving equipment, including excavating machinery (such as bulldozers, shovels, backhoes, front loaders) and highway building equipment (such as scrapers, graders, compactors).
2. Materials handling equipment, such as cranes, derricks, concrete mixers, and concrete pumps.
3. Stationary equipment, such as pumps, electric power generators, and air compressors.

Earthmoving equipment employs internal combustion engines (primarily of the diesel type) rated from about 50 hp to above 600 hp, both for propulsion and power for working mechanisms. Materials handling equipment, for which locomotion does not constitute a part of the major work cycle, employs internal combustion engines for powering working parts. In stationary equipment, of course, engines are used for the desired power generation.

Noise levels observed 50 feet from construction equipment are shown in Figure 2-36. These levels range from 72 to 96 dBA for earthmoving equipment, from 75 to 88 dBA for materials handling equipment, and from 70 to 87 dBA for stationary equipment.

In virtually all engine-powered equipment, the engine constitutes the primary noise source. Usually, exhaust noise predominates, but intake noise also tends to be significant. Noise from fans used for cooling the engine and hydraulic system often constitutes an important component, with noise from mechanical or hydraulic power transmission or actuation systems generally of secondary importance. In earthmoving equipment, the tracks often contribute noticeable noise, and in both



Note: Based on Limited Available Data Samples

Figure 2-36. Construction Equipment Noise Ranges earthmoving and materials handling equipment, the working process – interaction of the machine and the material on which it acts – often contributes much noise.

For all engine-powered equipment, the greatest noise reductions may be obtained by quieting the engines. Significant amounts of noise reduction may often be readily achieved by the use of better exhaust mufflers, intake silencers, and redesigned cooling fans. Use of acoustic enclosures for stationary equipment also appears to be a readily implemented and generally useful noise reduction approach (which has already been employed by some air compressor manufacturers). Practical, long term abatement on the order of 15 to 20 dBA can probably be achieved by basic engine design changes. Of course, replacement of the internal combustion engine by a quieter prime mover, such as a gas turbine or electric motor, would eliminate the reciprocating engine noise altogether.

Impact Equipment and Tools

Pile drivers and pneumatic tools accomplish their functions by causing a "hammer" to strike against a work piece. The resulting impact constitutes one of the major noise sources associated with such equipment, and because this impact is essential to operation of the equipment, its control generally cannot be accomplished practically. Representative noise levels are indicated in Figure 2-36.

In steam-driven pile drivers, noise is also produced by the boiler and by release of steam at the head; in diesel drivers, noise is also produced by the combustion explosion that actuates the hammer. Impact noise is absent in the so-called sonic pile drivers, which have no drop hammer since they use engine-driven eccentric weights to vibrate the driven pile at resonance. For such drivers, the engines are the primary noise sources. Unfortunately, the use of these pile drivers is not widespread, owing in part to codes for pile load-bearing assessment based on impact response.

Most impact tools, such as pavement breakers and rock drills, are pneumatically powered. The same is true of such hand-held tools as impact wrenches. In such tools, noise is produced primarily by the high pressure exhaust and by the working impact. This pneumatic exhaust noise does not occur in hydraulically or electrically powered tools.

The use of tools that do not involve impacts appears to be the best means for coping with impact noise. Where such replacement is not possible, use of enclosures may be required, although these tend to be cumbersome, costly, and of limited benefit. Exhaust noise from pneumatic tools (or from steam or diesel pile drivers) can be reduced effectively by mufflers, but the size and weight limitations on workman-handled tools limit the size and effectiveness of mufflers for such tools.

Other Equipment and Tools

The two foregoing categories clearly do not exhaust the list of tools and equipment used in construction work. They do, however, encompass a significant portion of the noisier ones.

Although concrete vibrators are not noisy in and of themselves, their action usually shakes the wooden concrete forms, and these vibrations produce a significant amount of noise (Figure 2-36). Reinforcing the forms would provide some reduction.

The intense high-pitched whine of power saws (Figure 2-36) is a significant factor in several construction phases; e.g., wood cutting occurs in the construction of concrete forms, in assembly of frames, and in finishing operations. Noise control in this instance would involve use of specially designed laminated (damped) blade disks and enclosure of the working areas.

Environmental Impact

Table 2-17 summarizes the exposure of people other than construction workers, to construction noise*, in terms of a statistic – the person-hour – which reflects both the number of people exposed and the duration of their exposure. This information is based on an analytical model of site noise, propagation conditions, and population densities. Accordingly, care must be taken in interpreting exposure figures expressed in person-hours. First, exposures so expressed are obviously intended as order-of-magnitude rather than exact estimates. Second, direct comparisons among exposures expressed in person-hours to noise sources of greatly different character may not be freely made.

It is apparent from Table 2-17 that the most widespread effect of exposure to construction noise is speech interference. Construction noise significantly degrades speech communication for about 300 million person-hours per week in the U.S. and can also be responsible for as much as 10 million additional hours of severe speech interference. Not only are those living and working in the vicinity of construction sites (approximately 30 million people) affected, so also are passersby (approximately 24 billion encounters per year). People experiencing speech interference from construction noise in home or work environments can be exposed nearly continuously during the working day, for weeks or even months at a time. On the average, the transmission loss characteristics of buildings are high enough to moderate the speech interference effects of intrusive construction noise. Transient exposure to construction noise is likely to interfere with speech to a greater degree than constant exposure, since there is little or no attenuation of the noise.

* For construction workers, there are serious risks of hearing impairment because of job-related noise.

Table 2-17

ORDER-OF-MAGNITUDE ESTIMATES OF EXPOSURE TO CONSTRUCTION NOISE EXPRESSED IN MILLIONS OF PERSON-HOURS PER WEEK[+]

Noise Source	Speech Interference* Moderate (45-60dBA)	Speech Interference* Severe (>60dBA)	Sleep Interference* Slight (35-50dBA)	Sleep Interference* Moderate (50-70dBA)	Hearing Damage Risk Slight (70-80dBA)	Hearing Damage Risk Moderate (80-90dBA)
Primary (Stationary) Exposure to Domestic Construction Noise	44			2	0	
Primary (Stationary) Exposure to All Other Building Construction	38			2	0	
Primary (Stationary) Exposure to All Other Construction in SMSA[x] Areas	14			1	0	
Secondary (Passerby) Exposure of Pedestrians to Construction in All SMSA[x] Areas		10	0			10
Secondary (Passerby) Exposure of Drivers and Passengers to All Construction in SMSA[x] Areas		0.3	0			0.3

*Entries in these columns may not be interpreted directly as person-hours of direct speech or sleep interference (see text).

[+]These figures apply to the U.S. population other than construction workers.

[x]Standard Metropolitan Statistical Area.

Use of available noise reduction techniques could significantly reduce the speech interference caused by construction noise. The total number of person-hours of speech interference attributable to construction noise might be diminished by about a third if noise levels were reduced by 10 dBA.

To the extent that construction activity and sleep do not commonly occur during the same hours, construction noise does not interfere with sleep. Of course, occasional nighttime construction occurs and seriously disturbs the sleep of people living nearby. Approximately 15 percent of those who may encounter noise intrusions from construction sites do so while attempting to sleep during daytime construction hours. These people spend about 20 million person-hours per week sleeping in noise levels that may interfere with sleep. About 40 percent of the people exposed to construction noise sufficiently intense to interfere with sleep would be awakened. A somewhat smaller percentage might encounter difficulty in falling asleep due to noise intrusions. Reducing construction noise levels by 10 dBA would not greatly reduce sleep interference caused by such intrusions. To relieve the situation, more significant levels of noise reduction are required.

On the average, the risk of hearing damage from construction noise for those not directly concerned with construction activity does not seem to be great. In most cases, the distance between the construction site and people exposed to its noise and the transmission loss of buildings or vehicles are sufficient to minimize the probability of hearing damage. However, it is likely that peak noise levels from construction sites present some risk to people who are in frequent proximity to the site. The greater number of such people (presumably pedestrians or onlookers), however, are subject only to exposure of short durations.

Without doubt, a major consequence of exposure to construction noise is annoyance. Both those people exposed to construction noise on a regular, long-term basis and those exposed on a transient basis are annoyed by their exposure. Annoyance may be particularly great if the noise intrusion from the construction site is perceived as unnecessary or inappropriate. People who must endure weeks or months of construction noise exposure may exhibit some form of habituation to the noise, but despite the commonly expressed attitude toward noise of "you get used to it," it is doubtful that construction noise ever loses much of its annoyance capability.

Although it is extremely difficult to absolutely quantify the annoyance produced by construction noise, it is clear that such noise is a serious environmental pollutant. The speech and sleep of millions of people are disturbed; many people working or living near or passing by construction sites are exposed to levels that could contribute to hearing damage. As indicated by community and individual complaint behavior, construction is certainly a source of community annoyance.

HOUSEHOLD AND BUILDING NOISE

Characteristics of Noise Sources

Home Appliances

In general, motors, fans, knives (or other cutting blades), and air flow are the most frequent sources of noise from home appliances. Noise radiated from the casing or panels of the appliances and noise radiated from walls, floors, cabinets, sinks (set into vibration by solid structural connections) are also of major importance. The noise generating mechanisms of several appliances that have high enough noise levels and exposure time to be considered annoying are reviewed below.

Room Air Conditioners. The major sources of noise in the air conditioning process are the motor, the blower (evaporator fan), the propeller fan (condenser fan), the compressor, and the air flow across the evaporator coils. In addition, panels of the housing radiate noise, as does the structure to which the air conditioning unit is mounted.

Food Waste Disposers. The primary noise sources include the motor, the grind wheel, the sloshing of water and waste against the housing of the chamber, and resonances in the sink.

Dishwashers. The noise generating mechanisms in a dishwasher, in addition to the impingement of water against the sides and top of the tub, are the motor, the pump, the excitation of panel casings, the structural connections to water supply, water drain and cabinet, and the blower.

Vacuum Cleaners. The primary noise sources in vacuum cleaners are the motor, blower, resonances of the unit structure, and, in upright vacuum cleaners, a mechanism (either vibrating agitators or rolling brushes) that beats the carpet to bring dirt to the surface.

Toilets. The important parameters in toilet noise are the type (tank vs valve) and the mounting (floor vs wall). In each type of toilet, noise is attributed to valves and water flow.

Building Equipment

The majority of electrical and mechanical equipment in buildings is used to supply the building occupants with a suitable quantity of air at a comfortable temperature and moisture content. In addition, fluid pumping and piping systems and elevators, escalators and other conveyences are used for moving people and materials. Much of this equipment is hidden in mechanical equipment rooms, above ceilings, in walls, or behind cabinet-type exterior enclosures, as illustrated in Figure 2-37.

Characteristics of Environment and Noise Levels

Home Appliances

Because of the scarcity of reliable data, for the purposes of this report, measurements were recently made on 30 types of home appliances and 11 types of home shop tools. Sound levels were measured in dBA at a distance of 3 feet from the appliance installation and at a height of 5 feet; this measurement position approximates the location of the operator's ear for those appliances requiring an operator. For those appliances not requiring an operator, this position represents noise levels in the vicinity of the appliance. Noise levels in the reverberant field of the room in which the appliance is being operated may be on the order of 2 to 3 dBA less than the values measured at 3 feet.

Noise levels in adjacent rooms, with the interconnecting door open, may range from 10 dBA less than the levels at 3 feet to as much as several dBA greater than the levels at 3 feet, depending upon the details of the installation. For the appliances used near the ear (e.g., an electric shaver), the noise level at the ear may be as much as 10 dBA greater than the levels at 3 feet. Figure 2-38 summarizes the

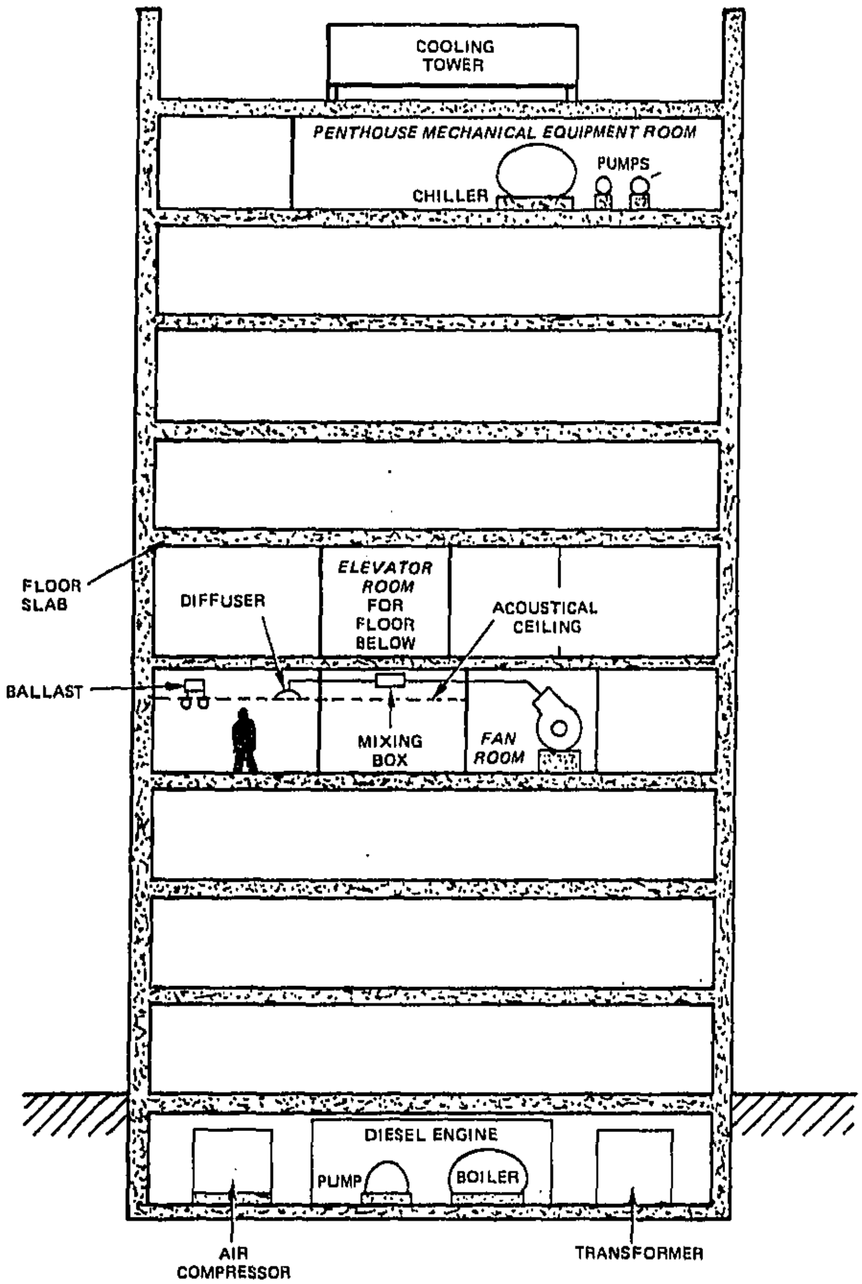


Figure 2-37. Cross-Section of a Typical Multistory Building Showing Building Equipment

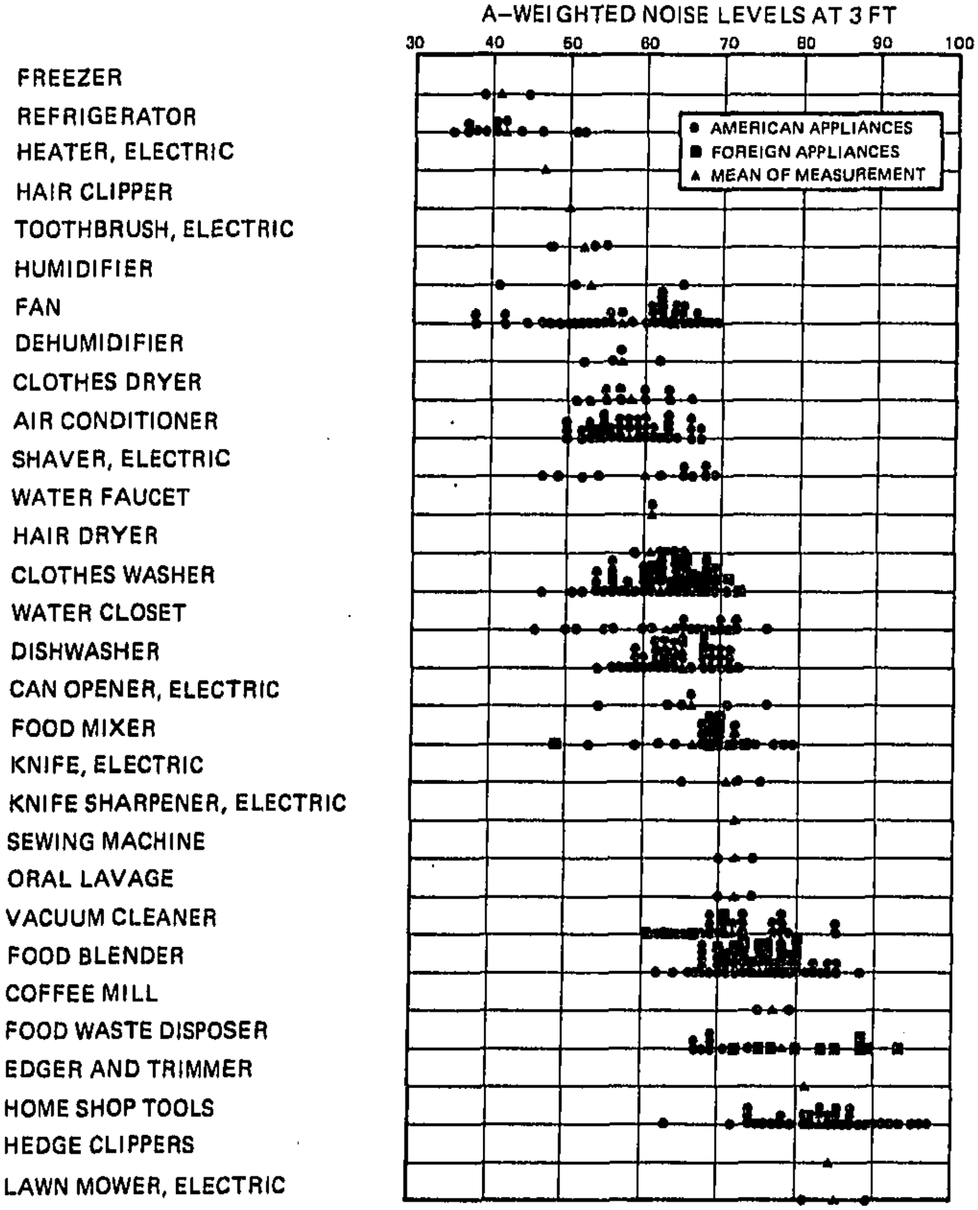


Figure 2-38. A Summary of Noise Levels for Appliances Measured at a Distance of 3 Feet

noise measurements made for this study and some of those reported in the literature. Each point represents a single measurement. Several measurements are given for a single appliance that operates in different modes. The solid circles represent noise levels generated by domestic appliances; foreign brands are represented by the solid squares.

Building Equipment

The exposure of occupants to the noise generated by building equipment, summarized in Table 2-18 and Figure 2-39 shows that occupants are directly exposed to the noise of only about eight different types of equipment. The noise generated by these units is, thus, of special interest since there are no intervening walls to provide noise reduction.

Although details of the frequency spectrum are important in selecting noise control treatments, the model presented here is keyed, for simplification, to dBA. Figure 2-40 summarizes the noise exposure, in dBA, of an occupant to individual sources. The upper level in each case is representative of the sound level near the source – i.e., at 3 feet. The lower level is representative of the level to which the noise from a particular source is reduced as it is transmitted through enclosures, partitions, etc., as illustrated in Figure 2-37.

In summary, the noise environment of a building is a feature that architects and landlords can control through the proper selection of equipment and the utilization of noise control techniques, if there is a willingness to bear the cost and allocate the necessary space.

Impact of Household Appliances and Building Equipment

For purposes of this report, home appliances and building equipment were divided into four broad categories on the basis of their noise levels.

Table 2-18

EXPOSURE OF BUILDING OCCUPANTS TO THE NOISE OF BUILDING EQUIPMENT

Building Equipment	Location	Type of Exposure		
			Indirect	
		Direct	Through Mechanical Distribution System	Through Walls, Floors, etc.
Air Conditioning	MER*		x	x
	Roof Unit		x	x
	Wind.Unit	x		
Absorption Machines	MER			x
Air Compressor	MER			x
Ballasts	Room	x		
Boilers	MER			x
Boiler Feed System	MER			x
Chillers	MER			x
Condensers	Rooftop			x
Cooling Towers	Rooftop			x
Dehumidifiers	MER		x	x
Diesel Eng.	MER			x
Diffusers	Room	x		
Electric Motors	MER			x
Elevators	Varies	x	x	x
Escalators	Varies	x	x	x
Fans	MER		x	x
	Room	x		
Furnaces	MER			x
Gas Turbines	MER			x
Heat Pumps	MER			x
Humidifiers	MER		x	x
Mixing Boxes and Air Control Units	Varies	x	x	
Pneumatic Transporter System	Varies		x	x
Pumps	MER			x
Steam Valves	MER			x
Transformers	MER			x
Unit Vent and Unit Heat	Room	x		

* Mechanical Equipment Room

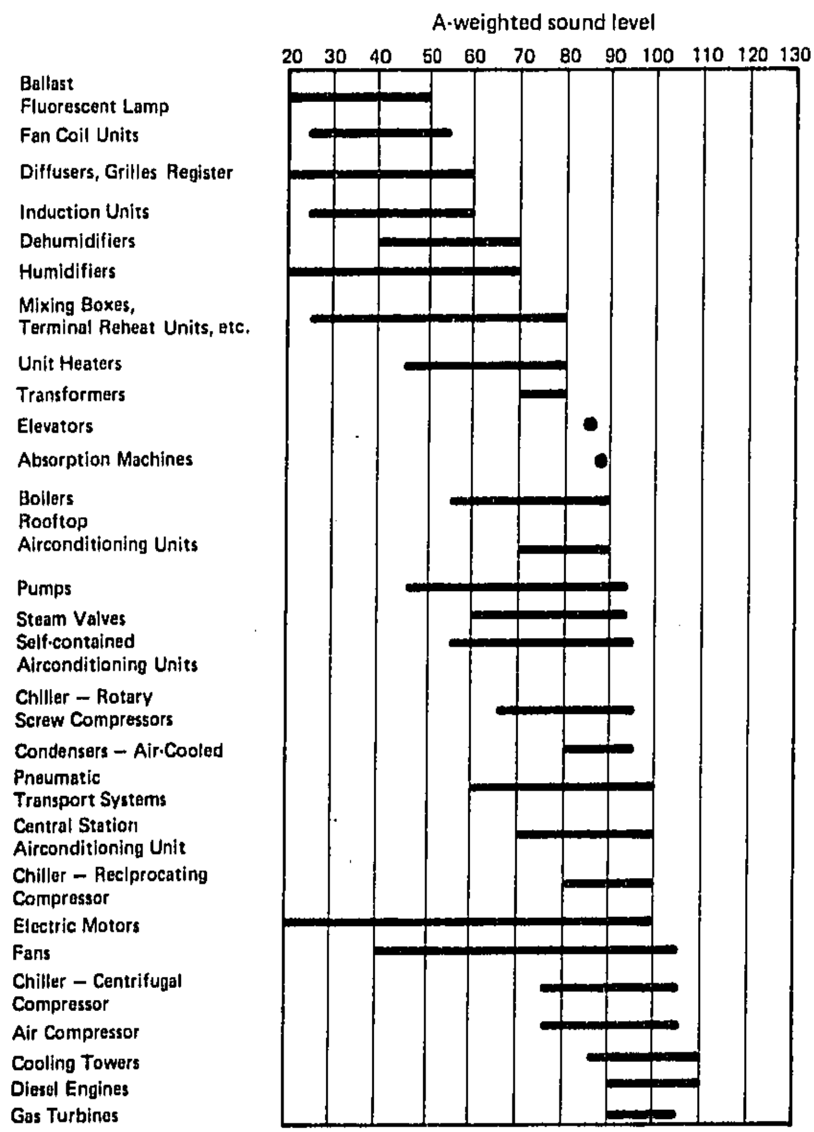


Figure 2-39. Range of Noise in dBA Typical for Building Equipment at 3 Feet

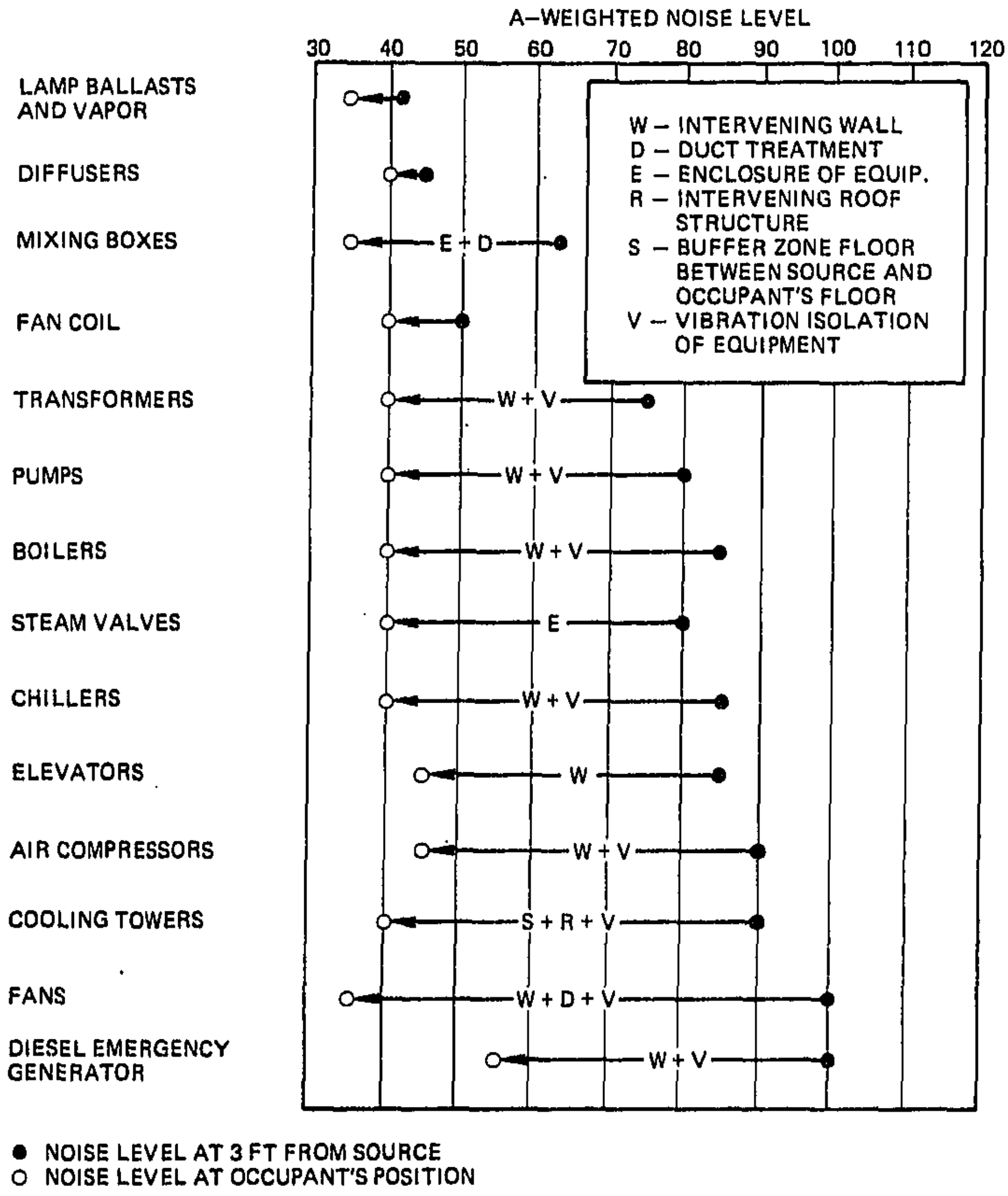


Figure 2-40. Range of Building Equipment Noise Levels to Which People Are Exposed

1. Quiet major equipment appliances, characterized by operating levels lower than 60 dBA.
2. Quiet equipment and small appliances, characterized by noise levels between 60 and 70 dBA.
3. Noisy small appliances, characterized by noise levels between 70 and 80 dBA.
4. Noisy electric tools, characterized by noise levels in excess of 80 dBA.

Table 2-19 lists the mean noise levels, in dBA, for such appliances in their normal operating environments.

Group I: Quiet Major Equipment and Appliances

Group I contains the noise sources to which people are exposed for the greatest lengths of time, such as most building climate-control equipment, food-refrigeration appliances, and clothes dryers. In general, due to the low levels of noise produced by equipment and appliances in Group I, effects of exposure are either negligible or mild, with no appreciable risk of hearing damage. Under certain conditions such equipment may be capable of delaying the onset of sleep of those suffering secondary exposure. The major effect of exposure to noise from Group I equipment and appliances is speech interference. It would be necessary to conduct conversations in the immediate vicinity of the noisier sources in Group I at somewhat higher than normal voice levels or by reducing the distance between speakers.

Group II: Quiet Major Equipment and Small Appliances

Most of the noise sources in Group II are found in many American homes, although not all of the sources are as common as those in Group I. Because Group II sources typically require operators, the most common pattern of exposure to their noise is one of infrequent and brief encounters.

Of the three major effects by which noise impact is gauged in this report, noise sources in Group II significantly contribute to only speech interference.

Table 2-19

NOISE LEVELS OF HOME APPLIANCES AND BUILDING EQUIPMENT ADJUSTED FOR LOCATION OF EXPOSURE (IN dBA)

Noise Source	Level of Operator Exposure*	Level of Exposure** of People in Other Rooms
Group I: Quiet Major Equipment and Appliances		
Refrigerator	40	32
Freezer	41	33
Electric Heater	44	37
Humidifier	50	43
Floor Fan	51	44
Dehumidifier	52	45
Window Fan	54	47
Clothes Dryer	55	48
Air Conditioner	55	48
Group II: Quiet Equipment and Small Appliances		
Hair Clipper	60	40
Clothes Washer	60	52
Stove Hood Exhaust Fan	61	53
Electric Toothbrush	62	42
Water Closet	62	54
Dishwasher	64	56
Electric Can Opener	64	56
Food Mixer	65	57
Hair Dryer	66	51
Faucet	66	51
Vacuum Cleaner	67	60
Electric Knife	68	60
Group III: Noisy Small Appliances		
Electric Knife Sharpener	70	62
Sewing Machine	70	62
Oral Lavage	72	62
Food Blender	73	65
Electric Shaver	75	52
Electric Lawn Mower	75	55
Food Disposal (Grinder)	76	68
Group IV: Noisy Electric Tools		
Electric Edger and Trimmer	81	61
Hedge Clippers	84	64
Home Shop Tools	85	75

*Termed "primary exposure"
**Termed "secondary exposure"

Hearing-damage risk is negligible for operators and for those who may experience secondary exposure, and sleep interference is a problem only for the few people who experience high level secondary exposure while attempting to sleep.

Users of the appliances in Group II find speech communication during operation difficult. Conversations generally must be conducted with significantly greater than normal vocal effort or at short ranges. For many people, temporary interruptions of conversation during applicable use of such equipment and appliances are probably found to be preferable to conducting conversations under strained conditions.

Annoyance is the most significant of the indirect consequences of exposure to noise from Group II appliances. While the operator may be annoyed by brief speech interference, people experiencing secondary exposure may be equally, if not more, annoyed. The annoyance of such people (including neighbors in multifamily residences and family members in other rooms) is conditioned in part by the intrusive nature of the exposure and in part by feelings created by the inability to control the noise source.

Group III: Noisy Small Appliances

The distribution and exposure patterns of noise sources in Group III continue the trend observed in Groups I and II. Based on ownership data, it was found that Group III appliances are found in <u>fewer homes</u> than are the appliances of preceding groups. Exposure to noise from this group of appliances is brief and is separated by long intervals. Both of these factors moderate the impact of the relatively high level noise produced by these appliances.

Hearing-damage risk cannot be dismissed as of minor importance for this group of noise sources. While it is true that the average exposure to noise sources of Group III is measured in fractions of hours per week, it is likely that certain elements of the public are exposed to some Group III source for prolonged periods of time. Home seamstresses, for example, could easily be exposed to several hours of sewing machine noise daily. Although even this sort of exposure would not constitute an imminent hazard to hearing, it could nevertheless hasten eventual hearing damage in the context of cumulative exposure from many sources.

Operators of the appliances of Group III must contend with severe speech interference. Although communication by shouting may be possible during appliance use, operators would probably tend to avoid conversation at these times. Even secondary exposure to the noise of Group III appliances interferes somewhat with speech intelligibility.

Sleep interference caused by noise of Group III appliances is minimal for the same reasons that they are negligible for Group II appliances. Also, annoyance is the major indirect effect of noise exposure for Group III, as is true for Group II. The operator may find the noise signature of the appliance unpleasant, particularly if it contains pure tone components or a highly variable temporal distribution of sound levels.

Group IV: Noisy Electric Tools

Group IV contains the appliances that produce the highest levels of noise in the home environment. In this category are about 4 million electric yard care tools and 12 million electric shop tools.

Hearing-damage risk can be great if exposure to the noise levels produced by Group IV sources is habitual or prolonged. Hobbyists engaging in regular use of power tools are likely to experience prolonged exposure at working distances of a few feet. Such use of tools can produce the risk of hearing impairment.

Speech interference produced by Group IV sources can be of sufficient magnitude to preclude verbal communication in any form other than shouting directly into the ear. Even the speech interference due to secondary exposure can be great enough so that conversations must be conducted at high voice levels.

Sleep interference from secondary exposure to home shop tools or electric yard care tools is a distinct possibility, and people attempting to sleep while experiencing such noise exposure would have considerable difficulty. Both annoyance and stress are probable byproducts of the noise from Group IV equipment. A neighbor's noise, particularly at levels as high as those of Group IV sources, is rarely welcome.

Summary of Effects of Appliance Noise on People

Table 2-20 summarizes the impact of appliance noise on people in concise terms for the interpretation of figures expressed in person-hours. The table relates person-hours of exposure directly to the major criteria. It should be emphasized that these values of exposure represent potential effects. For example, fans will create conditions that would moderately interfere with speech intelligibility for 1.2 billion person-hours per week. The actual speech interference depends on the fraction of that time people attempt to speak while a fan is running.

Table 2-20

ORDER-OF-MAGNITUDE ESTIMATES OF EXPOSURE TO HOME APPLIANCE AND BUILDING EQUIPMENT NOISE EXPRESSED IN MILLIONS OF PERSON-HOURS PER WEEK

Noise Source	Speech Interference*		Sleep Interference*		Hearing Damage Risk	
	Moderate	Severe	Slight	Moderate	Slight	Moderate
Group I: Quiet Major Equipment and Appliances						
Fans	1200		0		0	
Air Conditioner	242		121		0	
Clothes Dryer	94		10		0	
Humidifier	10		15		0	
Freezer	0		0		0	
Refrigerator	0		0		0	
Group II: Quiet Equipment and and Small Appliances						
Plumbing (Faucets, Toilets)		535	267		0	
Dishwasher		461	4		0	
Vacuum Cleaner		280	0.5		0	
Electric Food Mixer		222	1		0	
Clothes Washer		215	0.5		0	
Electric Can Opener		117	0.2		0	
Electric Knife		1	0.1		0	
Group III: Noisy Small Appliances						
Sewing Machine		19		0.5	9	
Electric Shaver		6		1	5	
Food Blender		2		0.2	0.5	
Electric Lawn Mower		1		1	0.3	
Food Disposer		0.5		0.5	0.5	
Group IV: Noisy Electric Tools						
Home Shop Tools		5		2		1
Electric Yard Care Tools		1.5		.1		0.4

*These figures are not directly interpretable in terms of person-hours of lost sleep or speech interference (see text).

OVERALL ASSESSMENT OF ENVIRONMENTAL IMPACT OF MAJOR NOISE SOURCES

The impact of noise has been discussed for each of the major non-occupational noise source categories. These impact assessments have been developed from various points of view, which are pertinent to the noise and use characteristics of each source category. Together with the presentation of the detailed noise characteristics of the sources and the community, they provide the basic data for an assessment of the total environmental impact of noise. This assessment is made relative to interference with speech, community reaction, and noise that may produce potential hearing damage. The impact assessments are based upon criteria specified elsewhere in this report and the data presented earlier in this chapter.

It should be kept in mind that the noise environment is primarily a product of man and his machines and consists of an all-pervasive and nonspecific residual noise, to which is added both constant and intermittent intrusive noises. The residual noise level in urban residential communities is generally the integrated result of the noise from traffic on streets and highways but does vary widely with the type of community.

Interference with Speech

Residual noise levels in suburban and rural areas do not appear to interfere with speech communication at distances compatible with normal use of patios and backyards. However, some interference with outdoor speech is found in urban residential communities, and considerable continuous interference is found in the very noisy urban and downtown city areas. Thus, the use of outdoor spaces for relaxed conversation is effectively denied to an estimated 5 to 10 million people who reside in very noisy urban areas.

The backyards, patios, and balconies facing an urban freeway are similarly rendered useless on a continuous basis, except when traffic is light in the early morning hours. Although windows are kept closed in many dwelling units adjacent to freeways to keep out the noise, the noise level inside the dwelling may still be too high for relaxed conversation. An estimated 2.5 to 5 million people living near freeways are significantly affected by such intrusive noise. Probably, another 7 to 14 million people are affected to a lesser degree by the noise from traffic on the 96,000 miles of major arterial roads in urban communities.

Construction in urban areas is characterized by a relatively high continuous intrusive noise level, plus intermittent higher level noise events. It is estimated that, during daylight and early evening hours, the ability of 21 million people to enjoy outdoor conversation is severely impaired; particularly during the higher level noise events. In many of these cases, the ability to converse indoors is also impaired. The tolerance of people to construction noise appears to be higher than to other intruding noises because of the expectation that the construction activity will soon cease. However, in many larger cities where there appears to be almost continuous construction activity near apartment dwellings, intolerance of construction noise may be expected to be similar to that of other forms of noise intrusion.

Thus, the combination of continuous daytime noise caused by traffic on city streets, major arterial streets, and freeways impairs the utility of the patios, porches, and yards of approximately 7 to 15 percent of the total population, while at any one time the noise from construction similarly affects another 10 percent.

The noise from many home appliances and other equipment makes it difficult for the operator and others in the home environment to converse or hear a child's cry. The noisier items in this category include power lawnmowers, home shop tools, food disposers and blenders, sewing machines, electric shavers, and vacuum cleaners, and it is estimated that at least 66 million people operate one or more of these devices. Together with an estimated 115 million dwelling occupants, they experience a severe reduction in speech intelligibility whenever such devices are used.

Community Reaction

Community reaction may be expected to begin when the energy equivalent level of an intruding noise exceeds the residual noise level. The degree of reaction depends, as discussed elsewhere in this report, primarily on the amount of the intrusion and, secondarily, on other characteristics of the noise and on additional factors such as season of the year and attitude of those exposed. The impact of several forms of noise, events such as noise from aircraft overflights, noise from diesel trucks on the highway, and industrial noise, is best evaluated in terms of community reaction.

The most significant national problem that can be defined in such terms is aircraft noise. There are, by conservative estimate, 7.5 million people living in areas where aircraft noise exceeds the level required to generate widespread complaints. This estimate assumes that all of the people affected live in residential urban communities. A more realistic estimate, including people who live in quiet and normal suburban communities and are affected by aircraft noise, is 15 million. Not only does aircraft noise interfere with TV viewing and speech communication for most of the people exposed, it also disturbs the sleep of many.

Community reaction can also be expected from the uncounted millions annoyed by devices such as motorcycles, minicycles, and sportscars operated in a noisy manner on residential streets; dunebuggies, off-road motorcycles, chainsaws and snowmobiles operating in the wilderness; power lawnmowers, hedge clippers, and shop tools operated by a neighbor on weekend mornings. The number of such noise sources is rapidly growing, and their impact is spreading.

Industrial noise also results in complaints of varying degree in communities throughout the United States. However, it is difficult to quantify the number of people disturbed because the majority of industrial noise problems are resolved at a local level. The process of accommodation continually occurs in various communities when new plants are constructed or new machines or operations are added to existing plants. These local accommodations are accomplished in many ways, including direct interaction between the plant management and the community, lawsuits, enforcement of local noise or zoning ordinances, and other actions by local officials.

Hearing Damage Risk

There is a long history of occupational noise causing various degrees of hearing impairment in some of the working population. The legal structure for the protection of workers now exists through the provisions of the Occupational Health and Safety Act, and also the Coal Mine Safety and Health Act.

However, there are also many occasions when people may be exposed to potentially hazardous noise in non-occupational environments. The more significant of these potential hazardous noise exposures are summarized in Table 2-21. These data include only those people directly affected by the noise sources, that is, operators and passengers rather than bystanders. Although those who are only occasionally exposed to such noises will not necessarily suffer permanent hearing impairment, frequent exposure to the noise from any one or several of such sources, or occasional exposure in combination with industrial noise, will increase the risk of incurring such damage. In addition, the proliferation and use of such noise sources further increase the risk of hearing impairment for a substantial percentage of the general population.

Summary of Assessment

This data shows that approximately 22 to 44 million people have lost part of the utility of their dwellings and yards to noise from traffic and aircraft on a continuous basis, and another 21 million at any one time are similarly affected by noise from construction activity. Further, many people are exposed to potentially

Table 2-21

APPROXIMATE NUMBER OF OPERATORS OR PASSENGERS IN NON-OCCUPATIONAL SITUATIONS EXPOSED TO POTENTIALLY* HAZARDOUS NOISE FROM VARIOUS SIGNIFICANT SOURCES

Source	Noise Level in dBA		Approximate Number of People Exposed (In Millions)***
	Average**	Maximum	
Snowmobiles	108	112	1.60
Chain Saws	100	110	2.50
Motorcycles	95	110	3.00
Motorboats (over 45 HP)	95	105	8.80
Light Utility Helicopters	94	100	0.05
General Aviation Aircraft	90	103	0.30
Commercial Propeller Aircraft	88	100	5.00
Internal Combustion Lawnmowers and other Noisy Lawn Care Equipment	87	95	23.00
Trucks (Personal Use)	85	100	5.00
Home Shop Tools	85	98	13.00
Highway Buses	82	90	2.00
Subways	80	93	2.15

*Although average use of any one of these devices by itself may not produce permanent hearing impairment, exposure to this noise in combination, or together with occupational noise will increase the risk of incurring permanent hearing impairment.

**Average refers to the average noise level for devices of various manufacture and model type.

***Single-event exposures. Many individuals may receive multiple exposures. For example an individual may be exposed during the week to noise from any or all of the above sources.

hazardous noise when operating noisy devices. Although the number exposed to potentially hazardous noise cannot be accurately assessed (since the people referred to in Table 2-21 are not additive), a total of 40 million people might be reasonable.

Thus, not including the contribution of appliances, noise appears to affect at least 80 million people, or 40 percent of the population. Roughly one-half of the total impact of noise represents a potential health hazard (in terms of hearing impairment potential alone), and the remaining half represents an infringement on the ability to converse in the home. Such impact estimates clearly show the need to reduce the number of devices that emit potentially hazardous noise levels and to reduce the outdoor noises that interfere with the quality of life.

CHAPTER 3

CONTROL TECHNOLOGY AND ESTIMATES FOR THE FUTURE *

This chapter summarizes the noise reduction efforts of industry and the noise reduction potential for the various sources discussed in Chapter 2. The past, current, and planned efforts of industry have been determined for the purpose of this report by communication with representative companies and industrial associations. This chapter is intended to give insight into the industry situation with respect to noise control and should not be considered to represent carefully drawn industry positions.** The noise reduction potential has been estimated for most of the sources based on existing experimental data, when available, and upon application of known technology to sources for which no noise control experimental data exists.

The noise of many of the sources has been extrapolated to the year 2000, both with and without additional noise control. Although such extrapolations are conjectural, they do provide a useful framework for establishing today's noise control priorities.

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* This chapter is based upon material prepared by the Staff EPA Office of Noise Abatement and Control as a result of testimony received during public hearings and on data contained in EPA Technical Information Documents NTID300.1, "Noise from Construction Equipment and Operations, Building Equipment, and Home Appliances" (EPA contract 68-04-0047, Bolt, Beranek and Newman); NTID300.2 "Noise from Industrial Plants" (EPA contract 68-04-0044, L.S, Goodfriend Associates); NTID300.13, "Transportation Noise and Noise from Equipment Powered by Internal Combustion Engines" (EPA contract 68-04-0046, Wyle Laboratories); and NTID 300.14, "The Economic Impact of Noise," prepared under interagency agreement between EPA and the National Bureau of Standards.

** Such statements, containing detailed technical data, are contained in the transcripts of the various EPA hearings on noise.

TRANSPORTATION INDUSTRY PROGRAMS

The significance of noise from the transportation system is recognized in varying degrees by many segments of the transportation industry. This awareness is reflected in the degree of effort expended by the industry toward noise reduction. This discussion considers the general nature of each industry as it relates to effecting noise reduction programs, reviews the results of such programs, and presents estimates of the noise reduction that could be achieved through additional effort—both by industry and the cognizant government agencies.

Commercial Aircraft

The excessive noise resulting from jet aircraft operations is perhaps the most widely recognized and acted upon noise problem.

The airport noise problem originated in the late 1950's with the introduction of jet aircraft, which were much noisier than the propeller aircraft they replaced, and was compounded by the post-war construction of homes on vacant land around airports. The problem grew to major proportions with the rapid growth of the commercial fleet and spread to more airports with the introduction of commercial air operations to smaller cities and towns. Despite concerted efforts in research and development of quieter engines by the industry, significant progress was slow until spurred by federal regulation.

The negative public reaction to commercial aircraft noise led to the adoption of a federal regulation limiting the noise emission of new airplanes. This noise regulation, Federal Aviation Regulation Part (FAR) 36—Noise Standards: Aircraft Type Certification—became effective in December of 1969. The limits in this regulation apply primarily to subsonic aircraft of new design having gross takeoff weights exceeding 75,000 pounds.

The majority of aircraft in the present fleet exceed the FAR-36 noise limits by 5 to 15 EPNdB. Thus, new aircraft certified under FAR-36, such as the three-engined widebody and later model four-engined widebody aircraft, will be substantially quieter than aircraft in the present fleet. The reduction of noise to the FAR-36 limits could significantly aid in the solution of today's airport noise problem.

However, further noise reduction is required to accomplish an economically balanced and publicly satisfying solution at the majority of affected airports and to accommodate the anticipated future growth of the fleet. To develop the technology for noise reduction, the federal government has supported various research and development programs. The current funding level by both government and industry on jet engine noise alone now exceeds $37 million annually. One result of federal and industry sponsored research and development during the 1960's is demonstrated in the noise characteristics of the new DC-10 aircraft, which is quieter than the limits imposed by FAR-36 and much quieter than the other aircraft in the current fleet.

Noise Reduction Programs for Jet Aircraft *

The design features responsible for the noise reduction in new aircraft are associated with improvements in engine bypass ratio and fan design with new designs for inlet and discharging ducts of the new engines. Noise reduction technology has also been accelerated through several research and development programs aimed at utilizing existing turbofan engines that are modified with a noise reduction retrofit package. An example of such an effort is the NASA Acoustically Lined Nacelle Program, which has demonstrated the feasibility of significantly reducing engine noise on approach and of moderately reducing takeoff and sideline noise. A current

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* For details on economics and technological problems associated with jet engine noise, see the transcript of the EPA hearings held in Washington, D. C.

FAA sponsored program is expected to produce hardware that can be certificated by the end of 1972. The existence of such hardware may establish retrofit as a viable method for reducing airport noise, to be considered as an alternative to aircraft replacement.

Another NASA program, due to be completed in 1973, is the Quiet Engine Program aimed at demonstrating the feasibility of designing a new turbofan engine with takeoff and approach levels significantly lower than any achieved to date. This program, together with the new FAA Core Engine Noise Reduction Program and others are the forerunners of the total research and development effort required to reduce noise of future aircraft to acceptable levels.

A parallel and supplemental approach to engine noise reduction in airport communities is the alteration of flight procedures during takeoff and landing. Significant noise reductions have been demonstrated with most commercial aircraft currently in operation by using power cutback procedures (i.e., reducing engine thrust after the initial takeoff climb). To reduce noise impact during approach, a two-segment landing procedure has been proposed. This procedure consists of an initial glide slope terminated prior to landing in the standard 3-degree glide slope. Noise reductions comparable to those achieved by the power cutback have been achieved with this procedure. Although the feasibility of the steep approach method, in terms of operational safety, has not been verified for all types of aircraft, it is already being used by at least one major airline, when operating under visual flight conditions.

Noise Reduction Potential for Jet Aircraft

The noise reduction achievable by means of current and potentially available technology, starting with the technology demonstrated in the DC-10 engines and those of the federally funded research programs, is summarized in Table 3-1. The noise levels are specified in terms of the FAR-36 takeoff measurement locations. The table indicates, for example, that a noise reduction of 10 to 15 EPNdB below the levels generated by the DC-10 aircraft should eventually be possible for that size aircraft.

Table 3-1

ESTIMATED AIRCRAFT NOISE REDUCTION POTENTIAL

	Noise Reduction EPNdB re DC-10	EPNdB
DC-10 Technology	0	100
Quiet Engine Design Goal*	5	95
Future Quiet Engine	10 to 15	85 to 90

*Recent test results indicate the engine is quieter than the design goal.

To place this noise reduction potential in proper perspective, it is constructive to consider the growth of noise impact during the last decade due to commercial aircraft operations and to project future trends on the basis of current and potential noise reduction technology. Figure 3-1 shows the range of projected impact area depending on the application of noise reduction technology to the current commercial aircraft fleet. The following significant factors are illustrated by this figure:

- Maintaining the current aircraft noise levels would result in an increase in impacted area to 187 percent of the 1970 figure by the year 2000, due to increases in air traffic.
- Retrofit of existing aircraft necessary to ensure compliance with FAR-36 would result in a significant decrease in impact area in the 1976-1987 time period. This assumes availability of an effective and economical retrofit package.

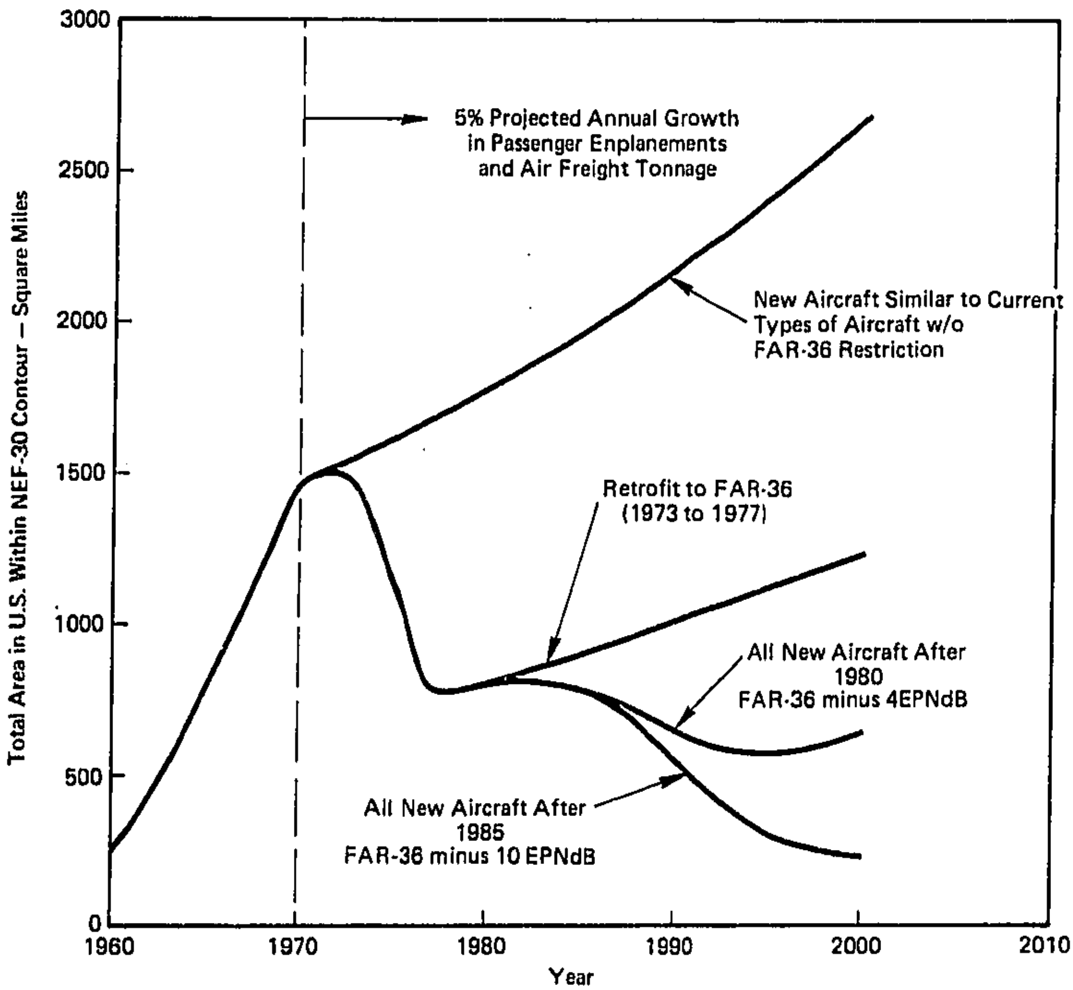


Figure 3-1. Noise-Impacted Areas (NEF-30 or Higher) as Function of Jet Engine Noise Reduction Goals

- A reduction in aircraft noise levels corresponding to FAR-36 and assuming a further 10-EPNdB noise reduction due to advances in technology would result, by the year 2000, in an 83-percent reduction in impact area below the 1970 value.

In summary, significant reductions in the noise impact of commercial aircraft are technically achievable in spite of projected increases in air traffic. However, the ultimate reduction goals can be effected only by a continuing commitment of resources by industry and the federal government to achieve the required advance in technology. This may well include changes in operational procedures that would cost little or nothing, provided safety is not compromised. It may also involve changes in land use requirements, zoning regulations, and similar restrictions.

V/STOL Aviation

STOL Aircraft

The anticipated development of large STOL commercial aircraft during the next decade will create new demands for noise abatement technology. In addition to operating out of large commercial airports, these aircraft will operate out of short field general aviation airports that had not previously created an adverse noise impact on the surrounding communities.

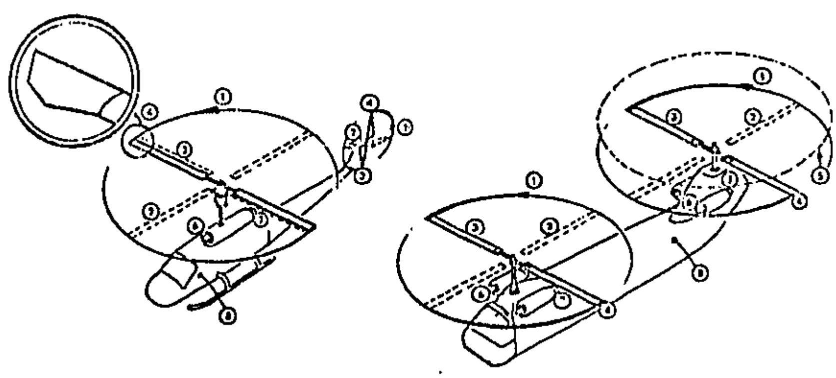
New STOL aircraft are expected to be subject to new noise certification regulations developed specifically for this type of aircraft. A design objective of 95 EPNdB at 500 feet for STOL aircraft has been tentatively selected. However, no regulatory limits have been established to date.

Design of vehicles and propulsion systems meeting this goal is being approached by intensive research and development of suitable propulsion and lift concepts that may be examined with respect to potential jet noise technology. Although the STOL industry can take advantage of noise reduction technology previously discussed in terms of commercial jet aviation, it must overcome new problems associated with its unique propulsion requirements.

VTOL Aircraft (Helicopter)

The VTOL industry is primarily geared to military helicopter requirements, which account for approximately 80 percent of the more than 20,000 vehicles produced prior to January 1970. The vulnerability to enemy action of military helicopters has been closely correlated to their excessive noise signature, which allows early detection and consequent retaliatory enemy reaction. The industry has therefore been engaged in research and development programs specifically aimed at reducing helicopter noise. However, there are no regulations limiting the noise of helicopters for civil use; thus, there is little motivation for transferring this helicopter noise abatement technology into the civil sector. The major sources of helicopter noise that have been, or can be, reduced are summarized in Figure 3-2.

With the increasing use of helicopters within the urban service system, community reaction to the noise intrusion will continue to increase. It has been demonstrated that substantial noise suppression can be provided for current helicopter designs and, therefore, it is practical to consider that the helicopter can eventually become compatible with community usage. In the long run, this result can be achieved only by incorporating adequate noise reduction methodology into vehicles produced for the urban user. However, application of available noise control technology to currently marketed light piston-powered helicopters can be fostered by regulatory action. In addition, consumer groups (such as large city governments and leagues of cities) might precipitate the availability of quieter civil helicopters by exercising their purchasing power. The potential for future helicopter noise reduction is summarized in Table 3-2.



① Lower revolutions per second

② More blades

③ Large blade area

④ Modified blade tip shapes

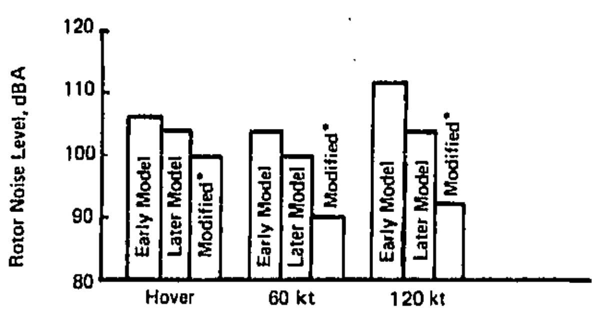
⑤ Reduced blade interaction

⑥ Engine inlet suppression

⑦ Engine exhaust muffling

⑧ Cabin insulation improvements

Current Design Approaches to Helicopter Noise Reduction



*Rotor Blade Modifications

Demonstrated Noise Reduction of a Heavy-Helicopter Twin-Rotor System

Figure 3-2. Noise Reduction for Helicopters

Table 3-2

ESTIMATED NOISE REDUCTION POTENTIAL FOR HELICOPTERS

Time Period	Noise Reduction, dB*		
	Heavy Transport Helicopters	Light and Medium Turbine-Powered Helicopters	Light Piston-Powered Helicopters
Potential by 1975 Utilizing Available Production Methods	0	5	10
Potential by 1985 Utilizing Current Industry Trends	10	15	10
Potential by 1980 to 1985 Utilizing Demonstrated or Advanced Technology	10	17	20

*Noise reduction relative to typical current noise levels in dBA at 1000 feet.

General Aviation Aircraft

The majority of general aviation aircraft are owned by private individuals and are used for personal and recreational flying. Therefore, the general aviation aircraft industry deals predominantly with a consumer market similar to that for automobiles or motorcycles. Consequently, the exploitation of technologies that bear only indirectly on product desirability, such as exterior noise reduction, is relegated to a secondary level of importance. However, the attitude of a vast majority of those affected by general aviation noise is such that this approach is not considered acceptable.

At present, general aviation aircraft are not a major source of community noise, although internal noise in many types is of importance with respect to hearing damage.

Approximately one-half of the aircraft operate near hub airports, where their noise characteristics, except for the executive jets, are masked by the much noisier commercial aircraft. The remainder of the aircraft are distributed over more than 11,000 airports within the U.S. Thus, the general aviation industry has not, until recently, considered aircraft noise in terms of the nonparticipant environment. Furthermore, there are no noise regulations for the majority of these aircraft, which are below the 75,000-pound minimum gross weight considered by FAR-36.

The general aviation fleet has grown rapidly during the last 15 years and will continue to grow at an accelerated rate until at least 1985. More important, from a noise standpoint, is the growing proportion of larger and more powerful multiengined piston, turboprop, and turbojet aircraft in the projected fleet. Because of this changing mix, the typical general aviation aircraft could become noisier in the future. This factor, in addition to the increase in the number of aircraft operations, will lead to an increasing potential for the production of community noise intrusions.

Noise Reduction Programs

Reduction of interior cabin noise levels is presently a much higher priority item for the general aviation industry than is reducing exterior levels. Some improvement has been achieved by reducing noise from the engine and propeller and by increasing transmission loss through the cabin walls. The general aviation industry's plans for further reduction indicate that interior noise levels of about 75 dBA are possible within the next 10 years. Such an accomplishment would essentially eliminate any potential hazard of hearing loss and would result in cabin noise levels comparable to the interior noise levels of an average automobile at highway speeds. The general aviation industry has recently begun to use quieter turbofan engines for business jet aircraft instead of the noisier pure turbojets. This quieter engine can provide a substantial reduction in external noise, with equal or improved aircraft performance. However, an equivalent noise reduction throughout the business jet fleet is required to significantly reduce the noise impact of these aircraft.

Propeller and engine manufacturers have been engaged in the development of quiet concepts for military and V/STOL commercial applications, and some of the results have fed back to the general aviation industry. For example, current aircraft models generally have three-blade propellers rather than the old two-blade propellers, with a resulting noise reduction of 3 to 5 dBA. However, in the absence of definite goals (such as could be established by regulation), much of the noise reduction technology will not be systematically applied.

Noise Reduction Potential

A significant reduction in engine/exhaust noise for propeller aircraft is achievable with current technology, and a 10-dB reduction of propeller noise is feasible in the next 5 years. It appears that a maximum noise level objective in the range of 68 to 73 dBA at 1000 feet for new general aviation propeller aircraft is achievable in the 1980 time period. Similarly, noise levels of business jet aircraft could be reduced to nearly these levels if the technology developed for commercial jets were applied to the smaller business jet engines.

The achievement of these reduced exterior noise levels in general aviation aircraft will undoubtedly require regulatory action by the government, since the operator of this category of transportation cannot be expected to apply pressure on the manufacturer. Similarly, regulation would ensure the achievement of internal noise levels that are not potentially hazardous to hearing.

Highway Vehicles

The highway vehicle industry is strongly committed to the development of vehicles intended for specific segments of the consumer public. Each vehicle model is manufactured with a particular performance goal or overall image in mind. This image ranges from a luxury vehicle, wherein a quiet car is desired by the consumer, to a competition type vehicle that generally exhibits the highest legal noise level.

In its infancy, the automotive industry found it necessary to equip its engines with mufflers because the noise of the horseless carriage frightened horses on the road. Cities and towns began to require mufflers on cars in the 1920's, and the automobile muffler has improved significantly since then.

Trucks, utility and maintenance vehicles, and buses are generally manufactured to individual customer specifications that place major emphasis on performance, operating economy, and initial cost. Truck noise is often mistakenly associated with better economy and more power. Thus, there has been little purchaser pressure to reduce truck noise, although individual cities and towns have begun to demand quieter maintenance vehicles and buses. However, in the late 1950's realization of potential legislation to curtail truck noise led the industry to adopt a voluntary maximum exterior noise level standard.

The manufacturer's commitment to noise reduction is twofold: (1) a program of research and development to satisfy consumer requirements for a quiet car, for the passengers, and (2) an attempt to meet existing legislation on exterior noise levels. This legislation essentially takes the form of a short term noise requirement. These commitments are greatly complicated because the vehicle manufacturers face a number of differing noise laws, measurement standards, and time deadlines throughout the country for various noise limits on highway vehicles. Because of the time constraints contained in some of the laws, industry has frequently been required to exploit the so called "band-aid" type of problem solution, without having adequate time to incorporate the new requirements into a basic redesign.

Incorporation of appropriate noise reduction techniques into the design of highway vehicles proceeds slowly for a number of reasons, foremost of which is that the manufacturers are dealing with production units having a lead time of 3 to 5 years. Any refinement going into new vehicles requires modification that must be proven compatible with all design and production constraints.

There is potential for the reduction of noise associated with highway transportation through consideration of noise impact in route selection and by the use in certain instances of various types of noise barriers. Such barriers can cost from $50,000 to well over $100,000 per mile, depending on type of construction, and whether or not they were included in the original highway design. Similarly, engineering controls, such as use of depressed roadways and provision of sound insulation on buildings adjacent to heavy traffic offer possibilities of minimizing noise impact. Such measures may be even more effective as source control is applied.

Noise Reduction Programs

Passenger Cars. A great deal of noise reduction is currently incorporated into the majority of passenger vehicles. Much of this noise reduction is directed at reducing interior noise levels, and successful efforts often have been rewarded by increased sales.

The exterior noise levels of passenger cars, measured under various normal operating conditions along freeways, city streets, and rural roads, show that the noise of the newest vehicles is less than that of older vehicles. In statistical studies conducted on highway vehicle noise, the average noise level of vehicles in the category "1969 and newer" was found to be approximately 2 to 3 dB less than that of older vehicles.

According to testimony given at the San Francisco, Chicago, and Washington, D. C. noise hearings, the majority of passenger cars built in the U.S. since 1969 meet present California noise requirements. According to industry estimates, meeting future California regulations will increase new car prices by approximately $30 to $50 per vehicle.

Trucks. Adequate silencing treatment on new vehicles under maximum noise output conditions provides a substantial overall exhaust noise reduction, yielding overall vehicle noise levels in the 85 to 90 dBA range. However, the average heavy diesel truck will probably run over 500,000 miles in its lifetime. Over this time period, many of the components will be replaced either due to wear or to modification for individual operator needs. Consequently, the noise output of many heavy trucks may increase significantly from their original condition, negating noise reduction features incorporated into the original vehicle, particularly if muffler and tire replacements do not provide noise performance equal to that of the original equipment.

Costs associated with reducing truck noise are difficult to estimate, because of the variety of noise sources associated with each type of vehicle. Engine components, such as fans, gears, and transmissions and accessories, as well as the engine itself, are major noise sources. One engine manufacturer has estimated that there would be an increase in cost of $1,500 in the $5,000 base price of a 250 hp diesel engine to provide a 10 dBA noise reduction. Several truck manufacturers have estimated that costs to meet the 1973 California law requirements range from $20 to $125 per vehicle and to meet later requirements there may be as much as a 15 percent increase in costs, assuming all technical problems are resolved. It should be noted that in the absence of national standards, major manufacturers are using the California law as a design basis.

Buses. The principal emphasis in noise reduction for buses has been to satisfy the desire for more passenger comfort. Little emphasis has been placed on external noise, and presently there are no uniform criteria for external noise for buses other than recommended levels established by the Society of Automotive Engineers (SAE J366).

Utility and Maintenance Vehicles. Utility and maintenance vehicles differ from other similar highway vehicles only in their usage patterns and functions. They are most often operated at low road speeds and at medium to high engine speeds. Therefore, these vehicles, particularly the diesel powered units, generally produce high noise levels, even at low highway speeds. The engine for such vehicles is normally muffled, but noise associated with the performance of auxiliary functions is seldom considered. One notable exception is the experimental quiet refuse truck developed by a major U.S. auto manufacturer for the City of New York.

Noise Reduction Potential

Figure 3-3 illustrates the present ranges of noise levels for highway vehicles under both maximum noise conditions and highway cruise conditions. Also summarized in this figure are noise reduction goals deemed achievable with current technology in the near future for existing vehicle concepts and long term goals that could be met as a result of further research and development efforts. These goals are based on an extensive analysis of the subsources of vehicle noise and assume continuing advancement in the applicable noise reduction technology. For most vehicles, reduction of tire noise is the major technical challenge, except for the simple elimination of exceedingly noisy truck tire retread patterns. At low speeds, further reduction may require a change from the conventional reciprocating engine for propulsive power to new devices such as gas turbines or electric drive.

Recreation Vehicles

The annoyance caused by noise from outboard motors was recognized by industry long before any legislative bodies began to act to control its effect. Motivated by

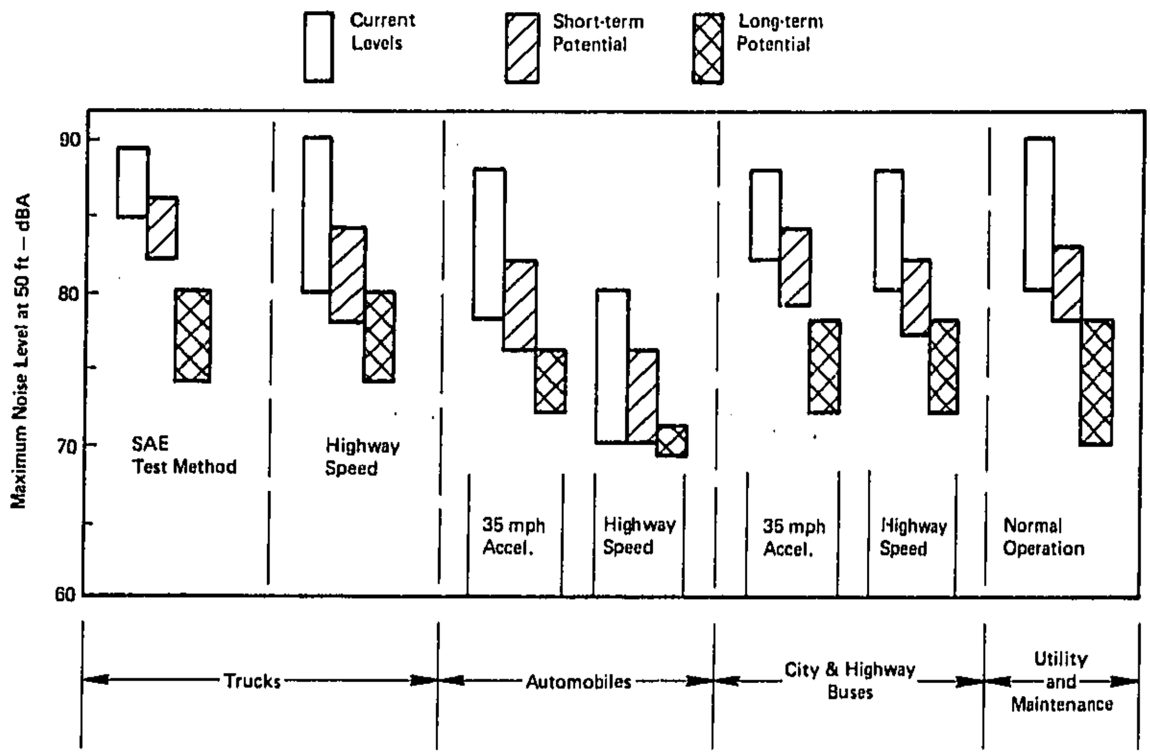


Figure 3-3. Potential Noise Reduction for Highway Vehicles

public pressure, manufacturers began experimenting in the late 1920's with underwater exhaust systems to reduce the noise output of outboard motors. Their success in the late 1940's was one of the factors leading to a dramatic growth in the market for motorboats. The current outboard probably represents the quietest application of a two-stroke engine for its power output on the market today.

Snowmobiles are relative newcomers on the leisure vehicle scene. Introduced in 1958 as a low-powered, lightweight utility snow vehicle, the snowmobile has evolved into a more refined, high performance, all-purpose recreation vehicle. The increased popularity of this vehicle has been accompanied by an evergrowing number of complaints about its noise. The primary source of this noise is a poorly muffled exhaust system usually resulting from attempts by the user to gain more engine power by reducing engine muffling. Newer model snowmobiles generate lower noise levels than earlier models, with measured noise levels of 1971 models generally ranging from 15 to 23 dB below levels of the early models. This is a significant accomplishment, particularly since there were no effective snowmobile noise regulations in effect prior to June 30, 1970.

Motorcycles also have a long history in the leisure field. Due to the design constraints of lightweight construction and maximum power output, motorcycles have continually produced excessive noise. The average motorcycle rider frequently associates noise with power and generally feels that high noise levels fit the motorcycle image. The major manufacturers have only recently taken steps to try to change these beliefs. All current motorcycles now intended for highway use are built to comply with California state noise regulations. In addition, most major manufacturers, under the guidance of the Motorcycle Industry Council, have agreed to place mufflers on all their off-road motorcycles to limit their noise output. The industry is currently in the process of trying to convince the consumer that noise does not necessarily mean power and that a reduction of the noise problem is necessary to the continuing enjoyment of motorcycling as a widespread recreational activity.

Noise Reduction Programs

The gross noise reductions of most current recreation vehicles have been accomplished through exhaust system treatment. Engine shielding and isolation have also been developed to a high degree on outboard motors, and this technology is gradually being applied to snowmobiles. Excluding motorcycles and some snowmobiles, the industry, as a whole, has nearly reached the stage in which exhaust treatment has been fully exploited, leaving further reduction efforts to be aimed toward intake silencing and engine noise itself. For motorcycles, most of the current noise reduction has been achieved on the engine exhaust; however, design constraints on packaging exhaust systems of sufficient size have yet to be overcome. Further research is required in this area.

Potential Noise Reduction

The current range of noise levels and the future noise reduction goals for recreation vehicles are summarized in Figure 3-4. Short term goals are considered achievable with current technology. The feasibility of long term goals is based on an analysis of contributing noise sources and the continuing advancement of the applicable noise reduction technology.

For pleasure boats, motorcycles, and snowmobiles, the exhaust is the principal noise source. The lightweight design of motorcycles and snowmobiles frequently does not allow for adequate exhaust treatment or intake silencer placement, and further development of exhaust mufflers will be necessary to achieve a substantial decrease beyond the best muffler technology currently available. The practice of deliberately disabling or completely removing exhaust mufflers must, of course, be totally discouraged.

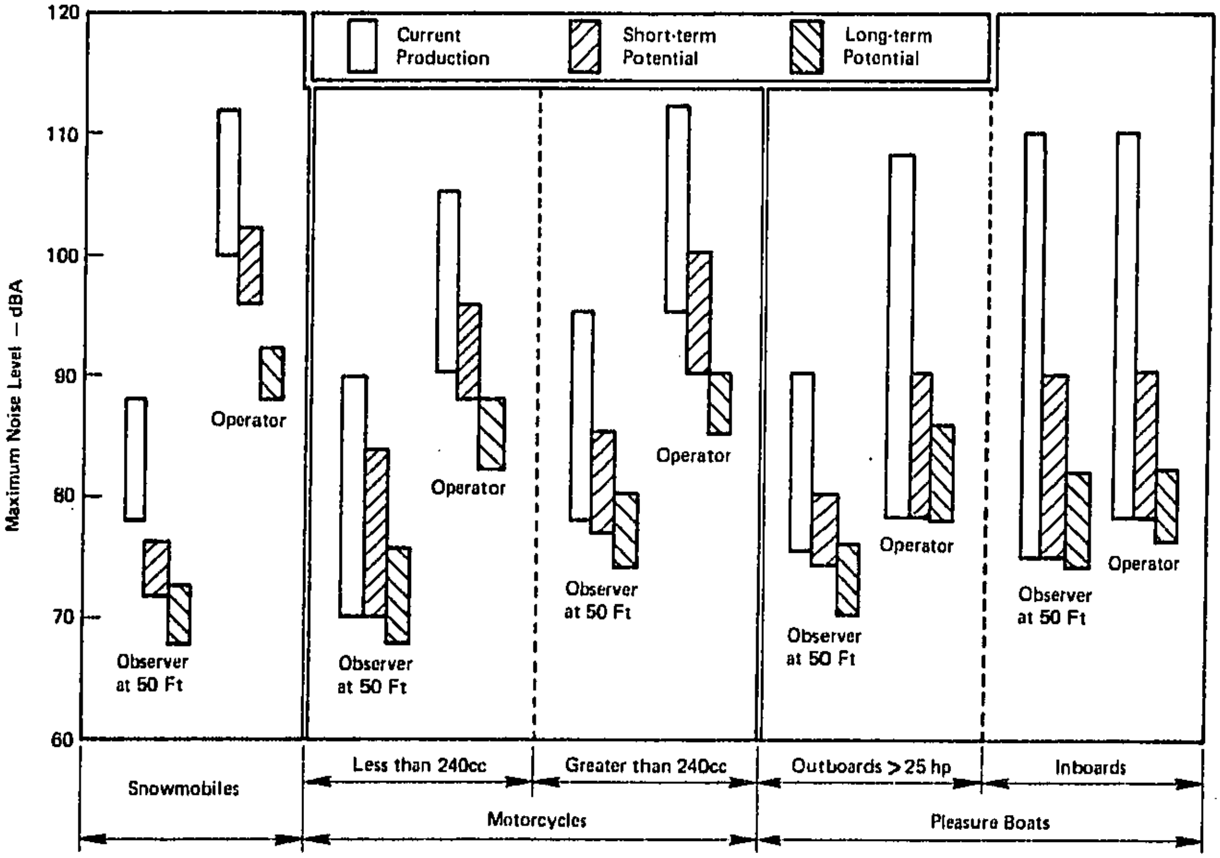


Figure 3-4. Potential Noise Reduction for Recreational Vehicles

For boats, a reduction in the transmission of noise through engine enclosures for inboard engines can be accomplished by application of the advanced state of acoustic enclosure design. Outboard engines pose a more difficult problem due to design constraints that employ high power-to-weight ratios.

Substantial reduction in engine noise for recreation vehicles beyond that available with current technology must result from internal engine redesign programs and modification to the intake and exhaust systems. Effort should also be made to reduce noise exposure levels for the vehicle operator and passenger.

Rail Systems

The incorporation of noise limiting requirements in the specifications for new rail vehicles has only recently caused industry to initiate noise abatement programs. Therefore, the majority of vehicles in operation today have not been affected by such programs.

The development of specifications for rapid transit vehicles is complicated by the division of responsibilities between the cognizant transit authority and the manufacturer. For example, a typical present-day specification does not include the noise produced by the wheel/rail interaction, which in most cases is the major contribution to the overall noise level, nor does it take into account the effect of noise reverberation in tunnels upon the interior noise levels in the vehicles. This means that the transit authority and the manufacturer may be required to pursue separate noise reduction programs to solve a common problem.

Noise Reduction Programs

Railroads. The impact of wheels on the joints of sectional rails can be reduced 5 dB or greater by the use of continuous welded rail. For intercity passenger systems, sectional tracks are frequently replaced by welded rails when the older rails wear out. Other techniques for reducing wheel/rail noise have included grinding the rails to eliminate surface irregularities and lubricating the wheels.

Noise abatement programs conducted by the railroad industry have concentrated mainly on the modern, high speed, intercity trains such as the Metroliner and the TurboTrain. The noise levels in these multiple-unit trains have been kept fairly low by carefully considering noise control details in the design. Due to their more substantial body structure and because they normally travel at lower speeds, locomotive-hauled passenger cars have similar or lower noise levels.

A small number of programs concerned with wayside noise from railroad equipment are in progress. These programs are concerned with the noise from diesel-electric locomotives. The introduction of more electric locomotives would reduce the noise impact from the propulsion system and would eliminate the typical pulsating sound of the diesel-electric to which many people object.

Noise control has generally not been a consideration, other than in the interior of the cab, in diesel-electric locomotives. The exhaust system has no muffler, and since this is the major source of noise, it is possible that mufflers could be designed to reduce the overall sound level. In addition, more substantial or modified casing around the diesel engine, together with the acoustically absorbent material, may be effective in reducing the noise from this source.

Rail Transit Systems. A number of noise abatement programs have been conducted by both equipment manufacturers and transit authorities. The work that has been done to date in connection with rail transit systems has shown that considerable noise reduction can be achieved with current technology. Some systems are noisy because of poor wheel and rail maintenance, lack of air-conditioning equipment in cars, and lack of acoustic absorption in the subways. Nearly all new cars are now air conditioned, allowing the windows to be permanently sealed, resulting in a 10-dBA reduction from the 90 to 93 dBA levels that exist in the noisier vehicles. It has also been shown in the Toronto system that a further reduction can be attained by the use of absorptive material on tunnel walls, and by proper attention to acoustics in the design of stations.

The most significant reduction in exterior and interior noise levels can be made in existing systems by careful maintenance of the wheels and rails. A summary of the noise reduction that is possible using current technology from related industries is shown in Table 3-3.

Noise Reduction Potential

The railroad and transit authorities, together with the manufacturers of rail equipment, are becoming increasingly aware of the noise problems associated with rail systems and are planning a number of programs for noise reduction. In most cases, however, the programs are not defined in terms of final objectives, but more to determine what reductions can be achieved using current technology. The following programs are among those planned.

Railroads

- A study of the noise characteristics of diesel-electric locomotives with a view toward eventual noise reduction.
- An improved suspension system for the TurboTrain that, it is estimated, may reduce interior noise levels from 74 dBA to 60 or 65 dBA. Due to the noise from the air-conditioning system, the noise reduction obtained may be less than this. The final levels may be in the range of 60 to 70 dBA, depending on the position in the car, unless the air-conditioning equipment noise is reduced.
- The replacement of old track by welded track. Only about 3000 miles of track per year are renewed in this manner.

Table 3-3

SUMMARY OF THE NOISE REDUCTION POTENTIAL BY APPLYING CURRENT TECHNOLOGY TO EXISTING TRANSIT VEHICLES

Existing Condition	Modified Condition	Estimated Noise Reduction, dBA	
		Car Interior	Car Exterior
Standard track, not regularly maintained	Welded track, ground	5-15	5-15
Concrete trackbed	Ballast trackbed	0-5	0
Bare concrete tunnel surfaces	Strips of absorbent material at wheel height	5-10	-
Bare concrete station surfaces	Limited absorbent material on wall surfaces and under platform overhang	-	5-10
Old type vehicles using open windows or vents for ventilation	New type cars with air conditioning	10-15	-
Standard doors and body	Improved door seals, body gasket holes plugged, et cetera	0-5	-
Standard steel wheels	Steel wheels with constrained damping layer	5-15	5-15
Standard type vehicles	Installation of a 4 ft. barrier alongside track	-	10-15
	Installation of a skirt on side of vehicles	-	6
Standard, noisy propulsion unit	Modified unit with skewed armature slots, random blower fan blade spacing, acoustically treated fan ducts	0-5	5

Note: The values of noise reduction are estimated for the particular source alone, assuming no contributions from other sources. The values therefore cannot be added to obtain an overall noise reduction.

Rail Transit Systems

- The application of spray-on acoustic absorption material on the ceilings and under the platform edges, together with noise barriers between tracks at a New York subway station.
- The replacement of old transit cars with more modern types incorporating air-conditioning, door and window seals, rubber suspension mounts, and vibration damping materials on the body.
- The replacement of old track with welded track in many transit systems.
- A study to determine whether improved sound insulation of transit cars can be achieved without increasing the mass of the car body.
- Design of an integrated heat transfer system for air conditioning equipment that uses cooling coils or fans that are operated while the train is out of the station area.

Future Changes in the Noise Environment

The current trend of the transportation industry relative to noise abatement has been outlined, and independent estimates have been presented for the noise reduction potential for each category. The net effect of this current trend, and of the changes that would result if the noise reduction potentials by source control were achieved, is reviewed in this discussion.

As a basis for projecting noise impact to the year 2000, a conservative model was chosen for growth of the existing transportation system. Major assumptions for the model included:

1. Conservative population growth of 1.15 percent per year from 1970 to 1985 and 1.05 percent thereafter.

2. Conservative estimates for numbers of highway and transit vehicles, with growth rates approaching urban population growth rates by the year 2000.
3. Conservative estimates for growth in total freeway miles and freeway traffic.

The change in noise levels generated by transportation system categories has been estimated for three possible options for future source noise reduction:

Option 1—No change in source noise levels after 1970 (baseline).

Option 2—Estimated noise reduction achieved with current industry trends by the year 1985 with no further reductions thereafter. This assumes no new noise control regulations by local, state, or Federal agencies or any change in consumer demand for quieter vehicles. Historically, these factors have provided the principal motivation for industry action to reduce noise.

Option 3—Projected noise reduction is achieved by implementation of an incremental regulatory program for a specified amount of noise reduction by the years 1975, 1980, and 1985. The examples of potential noise reduction utilized for Option 3 are summarized in Table 3-4 for the major transportation categories.

Change in Noise Energy Output

The approximate total A-weighted noise energy expended per day by the year 2000 for all units of a given transportation category, except aircraft, has been estimated for each of the three options. The results are summarized in Table 3-5. The estimated value for 1970, given in Chapter 2, is listed in the first column for reference. The second column, based on Option 1 (no noise reduction), shows the increase in noise energy per day due solely to the estimated increase in number and usage of sources. The third and fourth columns show the estimated trend in noise energy by the year 2000 for Option 2 (current industry trends) or Option 3 (possible noise regulation).

Table 3-4

EXAMPLES OF POSSIBLE NOISE REDUCTION GOALS FOR EXTERNALLY RADIATED NOISE FOR TRANSPORTATION SYSTEM CATEGORIES

Source	Effective Date		
	1975	1980	1985
HIGHWAY VEHICLE[1]			
Diesel Trucks	3	8	10
Utility Trucks	3	8	10
Light Trucks and Pickups	2	5	8
Highway Buses	3	8	10
City and School Buses	2	5	8
Standard Passenger Cars	2	4	5
Sport, Compact and Import Cars	6	8	9
Motorcycles (Highway)	2	7	10
AIRCRAFT			
Commercial Aircraft[2] (with turbofan engines)	4	7	10
General Aviation Prop Aircraft[3]	0	5	10
Heavy Transport Helicopters[3]	0	5	10
Light Turbine-Powered Helicopters[3]	5	12	17
Light Piston-Powered Helicopters[3]	10	15	20
RAILWAY[1]			
Locomotives	0	5	8
Existing Rapid Transit	5	10	13
RECREATIONAL VEHICLES[1]			
Snowmobiles	10	12	14
Off-Road Motorcycles and Minicycles	2	7	10
Outboard Motor Boats	2	4	6
Inboard Motor Boats	5	6	7

[1]Relative reduction in average noise levels in dBA at 50 feet.

[2]Relative reduction in EPNdB at FAR-36 Measurement Position for Takeoff.

[3]Relative reduction in EPNdB at 1000 feet from aircraft during takeoff.

Table 3-5

ESTIMATED FUTURE CHANGE IN NOISE ENERGY FOR TRANSPORTATION SYSTEM CATEGORIES WITH THREE OPTIONS FOR NOISE REDUCTION

Source	Noise Energy in Kilowatt-Hours/Day			
	1970	2000 — Option* —		
		1	2	3
HIGHWAY VEHICLES				
Medium and Heavy Trucks	5,000	10,000	4,000	800
Sports Cars, Import and Compacts	1,000	2,500	1,600	250
Passenger Cars (standard)	800	1,200	800	400
Light Trucks and Pickups	500	1,000	400	160
Motorcycles	250	800	320	80
City and School Buses	20	20	8	3
Highway Buses	12	12	5	1.2
RECREATION VEHICLES				
Motorcycles	800	2,500	NA	250
Snowmobiles	120	400	NA	16
Outboard Motorboats	100	160	NA	40
Inboard Motorboats	40	63	NA	12
RAIL VEHICLES				
Loçomotives	1,200	1,200	1,200	200
Existing R/T Systems	6	10	6.3	0.5

NA—Not available.

*Option 1—No noise reduction.
2—Estimate industry trend in noise reduction.
3—Example of possible incremental program of noise regulation.

Under Option 3, the noise energy by the year 2000 for all categories is always less than 1970 values. The reduction for Option 2, relative to Option 1, by the year 2000 reflects the current effort by the various industries to produce a quieter product, while the additional reduction indicated for Option 3 shows the significant additional benefit that could be obtained through noise regulation.

These values of noise energy provide a rough indication of changes in the relative magnitude of potential noise impact of transportation vehicles. By the year 2000, the noise energy value in Table 3-5 indicates a twofold increase from 1970 if no further action were taken to reduce noise. Assuming that current industry trends continue, little significant change in noise energy is indicated by the year 2000. However, by implementing positive regulatory program, a reduction in noise energy of nearly 4.5-to-1 over 1970 is indicated for Option 3.

Aircraft have been omitted from Table 3-5 since the overall noise impact of aircraft is more readily evaluated in terms of land area within a given Noise Exposure Forecast (NEF) contour or Community Noise Equivalent Level (CNEL) contour. This information is provided in Table 3-6.

Change in Residual Noise Level

The same model for residual noise levels utilized in Chapter 2 for 1970 has been applied to forecast trends for 1985 and 2000 as a function of the noise reduction options for only highway vehicles. The result of this projection, including the estimated residual levels for 1950 and 1960, is shown in Figure 3-5. The trend for Option 1 is clearly an upper bound and indicates an additional growth of about 2.5 dB in the residual level by the year 2000, due solely to the increase in noise sources. The lowest line for Option 3 represents the cumulative effect of achieving the three-step noise reduction values summarized in Table 3-5 and shows the net reduction in residual noise level to be 5 dB relative to today, or about 7 dB below the "no action" Option 1 trend for the year 2000.

Table 3-6

SUMMARY OF ESTIMATED NOISE IMPACTED LAND (WITHIN CNEL 65 CONTOUR) NEAR AIRPORTS AND FREEWAYS FROM 1955 TO THE YEAR 2000 WITH FUTURE ESTIMATES BASED ON OPTIONS 3 AND 2

	Impacted Land Area—Square Miles		
	Near Airports	Near Freeways	Total
1955	~20	8	28
1960	200	75	275
1965	760	285	1045
1970	1450	545	1995
1985	780 (870)*	400 (1470)*	1180 (2340)*
2000	240 (1210)	0 (2050)	240 (3260)

*Number in parentheses is the estimated impact area if no further regulatory action is taken (Option 2). It assumes FAR-36 remains in force for aircraft, no new limits established for highway vehicle noise, and no change in existing freeway design concepts to increase noise reduction. Numbers outside of parentheses assume FAR-36 minus 10 EPNdB for aircraft and additional combined noise reduction for freeways and highway vehicles of 3 dBA by 1985 and 5 dBA by the year 2000.

Change in Impacted Areas Near Freeways and Airports

Noise impact for land adjacent to freeways and airports was summarized in Chapter 2 for 1970 conditions. To indicate past and future trends, the total affected land area near freeways and airports has been estimated from 1955 to the year 2000. The resulting values, given in Table 3-6, represent the incompatible land area lying within a CNEL of 65. As defined in Chapter 1, this is equivalent to an NEF value of 30.

Estimates of noise impacted land areas are given for 1985 and the year 2000 for both Option 2 (values in parentheses) and Option 3, for which a marked reduction in

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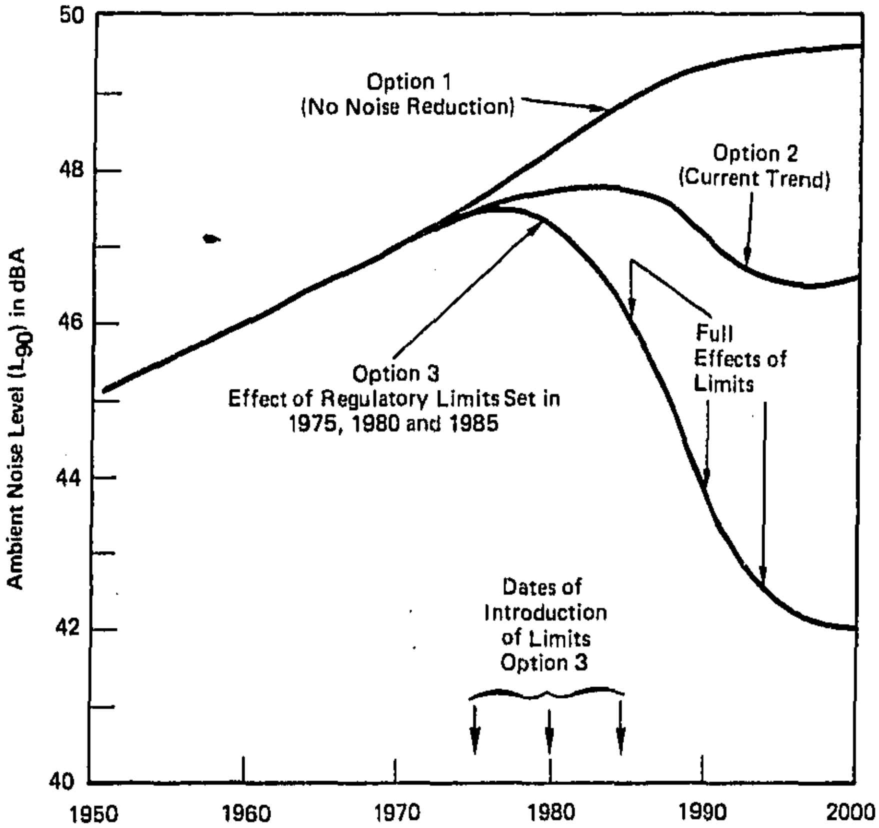

Figure 3-5. Estimated Long Term Trend in Daytime Residual Noise Levels in a Typical Residential Urban Community

impact is achieved. For Option 3, the estimated noise impacted land near airports is reduced by 83 percent from the 1970 value, assuming an annual fleet growth of 3 percent and no significant change in day-night operations mix or the ratio of freight to passenger aircraft operations. Based on a CNEL 65 boundary, noise impacted land near freeways is reduced to zero by the year 2000, assuming a net noise reduction in vehicle and freeway noise of about 5 dB below today's values.

The total noise impacted land by the year 2000 varies by a factor of over 13, depending on the choice of Option 2 (no further change beyond today's industry trends) or Option 3 (noise regulation). The striking effect of the decrease in noise impacted land near freeways due to a small (5 dBA) decrease in freeway noise is clear.

It is particularly important to note that the imposition of noise limits on aircraft by FAR-36 is resulting in at least a "holding action" regarding airport noise. However, without national policy concerning highway vehicles, the potential growth in noise impact near freeways is great.

Estimates have been made of the relative cost-effectiveness of alternate methods of reducing the noise impacted land. For airports having noise problems reduction of noise at the source (i.e., quieter engines) is clearly more cost-effective than reducing noise impact by land acquisition. For airports without noise problems, future problems should be prevented by complementary airport and land use planning. For future airports, environmental limits should be adopted in the planning stage for use in site selection and for assuring compatible uses of adjacent land.

For freeways, designs to increase barrier noise reduction is more cost-effective than land acquisition. Vehicle noise reduction is one potential means for reducing freeway noise and also provides benefits for the total urban population. Thus, a balanced approach for reducing highway transportation noise should emphasize vehicle noise reduction, improved freeway design, and community planning for compatible land uses.

However, the most effective noise prevention measures will be identified and implemented only by the use of balanced multimodal transportation systems, designed to move people and cargo economically, while minimizing total environmental impact of the transportation process. This transport planning process must be accompanied by planning and implementation of land use designs and building regulations which will prevent future noise problems and gradually resolve existing ones.

DEVICES POWERED BY INTERNAL COMBUSTION ENGINES

Historically, noise abatement has not been a primary consideration of manufacturers of small internal combustion engines, although unmuffled equipment has not been produced for many years because of buyer resistance to excessively noisy products. Public tolerance, combined with some noise control, has produced a compromise situation between the consumers and the manufacturers.

Noise reduction achieved by the engine manufacturers has resulted in reasonably quiet engines that make somewhat less noise than the equipment they are designed to power. Equipment manufacturers, however, are not completely convinced of this condition and tend to attribute noise to the engine. This is particularly characteristic of the small equipment manufacturer who purchases the engine from an outside source and has no involvement with engine design. In this category are large numbers of lawn care equipment units constructed of pressed sheet metal in production shops around the country.

Many manufacturers of equipment powered by internal combustion engines feel that they are being placed in the difficult position of being required to meet several divergent noise ordinances. Such laws are being established by individual cities and towns and are related to local economic and social conditions.

Noise Reduction Programs

The extent of noise reduction within the industries supplying small internal combustion engines has been directly related to its effect on sales and the existence of noise ordinances. With the exception of the small generator industry, buyer insistence on quiet equipment has not been sufficient to produce significant noise reduction efforts. Consequently, noise abatement programs have not been consistent. For instance, one manufacturer has demonstrated that a small generator, using a 3-horsepower engine with a vertical shaft within a complete enclosure, may be quieted to 70 decibels at an operator position of 6 feet from the engine. If this same treatment were applied to a lawn mower, it would achieve an improvement of approximately 20 dBA over current production models and would make the engine inaudible in the presence of a rotating blade. However, no serious plans exist for production of such a mower because of the high cost of the noise reduction treatment and the resulting small market potential, as estimated by the manufacturer.

Chain saw manufacturers recognize the existence of a serious noise problem regarding their equipment. The high power-to-weight ratio necessary in a hand-carried device requires a lightweight structure that is incapable of containing most of its own noise. Further, the noise produced by the chain is on the order of 100 dBA at the operator position, and reduction of the engine noise below this level would not reduce total output. Some experimental work is being done to reduce the noise of the chain, but costs rapidly become prohibitive when exotic materials are used to damp the response of the blade to the chain. Considerable engineering work has been expended to make chain saw mufflers more efficient within weight and size limitations, and some success has been demonstrated. Sound levels have been reduced to as low as 102 dBA by some special mechanical devices, with power losses of no more than 10 to 12 percent.

Noise control within the industry served by small internal combustion engines will continue to be affected by various local laws and ordinances. However, there will always be difficulty in encouraging noise abatement until public education advances to the point at which the charisma of noise is gone. When each person is convinced that his contribution to noise reduction is meaningful, he will then go to the manufacturer of the quietest machine and pay the extra money required and will take pride in his accomplishment. When this happens, as it has in the small generator field, manufacturers will probably respond accordingly. Interviews have shown that most manufacturers can respond but at present have found little market for quiet products when the public is asked to pay the price.

Potential Noise Reduction

The combined effort by the public in demanding quieter products powered by internal combustion engines, and successful response to this demand by the manufacturers, should provide a substantial decrease in annoyance from this equipment. The estimated potential noise reduction that might be expected for these devices is summarized in Table 3-7. The noise reduction values are relative to current noise levels and are specified in terms of potential reductions achievable by the 1975, 1980, and 1985 time periods.

Full accomplishment of these noise reductions would largely eliminate annoyance problems associated with use of lawn care equipment. However, the noise reduction potential for chain saws, using existing technology, is not sufficient to eliminate their annoyance characteristics or hearing damage risk for their operators. Further noise reduction research is necessary.

Table 3-7

ESTIMATED NOISE REDUCTION POTENTIAL FOR DEVICES POWERED BY INTERNAL COMBUSTION ENGINES

Source	Noise Reduction, dB*		
	1975	1980	1985
Lawn Care Equipment	10	13	15
Chain Saws	2	2	5
Generator Sets	5	7	17

*Noise reduction relative to typical current noise levels at 50 feet.

NOISE REDUCTION FOR INDUSTRIAL PLANTS

Industrial noise is a local problem, with each plant possessing individual intrusive characteristics. The plant location, community residual noise levels, and other noise sources such as major highways, airports, and construction activities contribute to the community noise environment. It appears that noise from construction, surface transportation, and aircraft generally contribute more to community annoyance, than do industrial plants. The contribution of industrial plant noise to the community residual levels may increase when the noise from the other sources is reduced. It is anticipated that, in general, industrial plant noise reaching the community will not increase in the near future but may, in fact, decrease, as noise abatement efforts required by the Occupational Safety and Health Act of 1970 become effective. However, it should be pointed out that at specific locations where interior plant noise is reduced by simply locating the noise sources outdoors, without adequate noise control measures, the impact upon the nearby community may increase.

Motivation

There are a number of significant factors that motivate industrial plant management to institute community noise reduction programs. The primary motivation is the desire to be good neighbors and to maintain good community relations. Through discussions with industrial plant management, it was found that the large national corporations are usually particularly sensitive to public opinion. Funds and personnel are usually made available to reduce noise that generates community complaints. Often, plant management anticipates community reaction.

The site selection and industrial plant design processes, together with the local government control of industrial zoning, provide the motivation and the early opportunity for noise abatement. During this early phase of industrial plant development, the most economical application of noise reduction techniques can be made. Local municipal pressures in the form of noise nuisance ordinances and, more recently, realistic zoning regulations have produced legal pressures to prevent plant noise.

An additional motivation to reduce plant noise, alluded to earlier, is the Occupational Safety and Health Act of 1970. This act forms the legal basis for the initiation of in-plant noise reduction programs. That these in-plant noise sources may be sufficiently high not only to be hazardous to employee hearing but, in addition, to contribute to the total industrial plant exterior noise picture, can be seen in Table 2-12.

Consumer pressures, which exist for other sources, are not a motivating factor for plant noise reduction. The purchaser is interested in the product and not in the manufacturing process.

Method of Approach

The potential for reducing interior and exterior noise of industrial plants is, in general, excellent. The engineering and architectural techniques for reducing this noise along its transmission paths are known. However, reducing the noise at its source may be difficult and expensive (particularly if not included in the original design of the equipment) and often results in the degradation of performance of the equipment, machine, or process.

For new plants, application of noise abatement techniques during site selection and plant design, together with realistic noise level requirements for new equipment being purchased, provide an economical and effective means for achieving noise level goals. Many companies are currently developing purchase specifications that contain noise level requirements. An example of this is the parent corporation of the automobile assembly plant discussed in Chapter 2. This corporation, one of the "big three" automobile manufacturers, requires suppliers to perform noise studies at the manufacturer's location under simulated production conditions prior to shipment, to assure compliance with company standards.

An existing plant must achieve noise reduction goals by application of noise reduction techniques to the acoustical transmission path, since it generally proves to be difficult and expensive to reduce the noise at the source. Noise of ventilation and blower systems that terminates outside a building may be reduced by application of mufflers, acoustical louvres, or simple barriers. Often, relocation of the intake or exhaust, to take advantage of noise directivity, solves the problem. Furnace noise evident at power plants and oil refineries has been reduced by redesigned burners, combined with mufflers at the inlet to the fire box.

Noise inside plants can be, and has been in many instances, effectively reduced by application of mufflers, vibration isolation, acoustical area treatment, or enclosures. A systems approach must be utilized to ensure that all the major noise sources are treated. If one noise source in a group of sources is left untreated, the results of the noise reduction program may prove to be insignificant.

Future Commitment

The case studies discussed in Chapter 2, though representing only a small portion of the total industrial activity in the country, illustrate the range of industrial involvement associated with noise reduction programs.

Projected Impact of Plant Noise

It is anticipated that the noise levels due to industrial plants will not increase in level or importance relative to the noise from construction activity, surface transportation, or aircraft. As in-plant noise abatement efforts motivated by the Occupation Safety and Health Act of 1970 succeed and local nuisance laws and zoning ordinances are adopted, noise levels will be reduced.

As noise abatement efforts successfully reduce the levels of transportation and construction activity noise, plant noise will become more important as a source of community annoyance. When this occurs, community pressures for noise abatement can be expected, and the necessary abatement programs may be expected to result in resolution at a local level.

CONSTRUCTION INDUSTRY EFFORTS*

The construction industry consists of two major sectors: equipment manufacturing and equipment operation (i.e., building construction). The functions of these two sectors of the industry are so different as to warrant separate discussion.

Equipment Operation

This sector of the construction inudstry is described in detail in Chapter 2, identifying types and phases of site activity and describing the areas in which noise abatement can be achieved. The construction industry has, until recently, been relatively uninvolved in efforts to quiet site operations. Its attitude may be attributed in part to the fact that quiet equipment has not yet been made generally available on a cost-effective basis; however, a limited capability does exist for quieting a site by relocating or rescheduling equipment. This sector has not exercised its influence as a consumer to bring pressure to bear on the equipment manufacturers, nor has it responded to public complaints. Thus, regulatory measures may be the only solution to the problem of construction site noise, and such regulations are imminent.

Equipment Manufacturers

There are approximately 2000 manufacturers** of construction equipment in the U.S. In total, these companies offer about 200 different products. For the purposes of assessing the state of noise control in this sector of the construction industry, 48 general types of products that are potentially significant noise sources were categorized. These product types may be grouped into three orders of classification: (1) class of noise problem anticipated, (2) relation of equipment to function at the

* See transcripts of EPA hearings held in Atlanta, San Francisco, and Washington, D. C.

** Defined by counting separately certain divisions of larger firms that have a highly identifiable product line.

site, and (3) specific equipment names. Manufacturers of construction equipment can be classified according to size/type of equipment produced as

- Large companies producing large volumes of essentially similar, large items of machinery.
- Medium-sized companies maintaining customized production runs of more limited numbers, usually of smaller machinery.
- Manufacturers of power hand tools and pneumatic equipment.

An overview of the equipment manufacturing industry showed that

1. Large companies employ methods closely resembling the Detroit assembly line manufacturing concept. They tend to have large engineering staffs and are advanced in their efforts toward developing quieter products. They are aware of the competitive advantage of quieting equipment but are also sensitive to price competition from smaller companies and foreign manufacturers.
2. Medium-size companies producing customized items tend to feel more keenly the competitive pressures of the market place. Competition comes not only from domestic and foreign companies but also from manufacturers of other types of equipment that can perform the same operation. Engineering staffs tend to be small and product oriented, interested only in improvements that incorporate new technology (e.g., hydraulic vs mechanical drive). Little effort has been made toward quieting products. The pressures of current and planned noise control legislation being passed on to suppliers of their components. They generally have no plans or see no need for further developing noise control technology.
3. Manufacturers of hand power tools and pneumatic equipment fall into two categories: large multiproduct companies that tend to mount considerable R&D efforts and smaller companies that are not so innovative but that

follow trends developed by the larger companies. Noise control has been pursued vigorously by these larger companies as part of their product improvement programs, but effective quieting of hand tools is difficult because of such practical constraints as size and weight.

In-depth interviews and testimony given at various EPA hearings revealed that in the past the industry's concern with noise problems has been directed primarily to protection of the equipment operator. The impetus for noise control concern came also from noise codes imposed by foreign countries, where some U.S. equipment has had to be reworked by foreign distributors. Three of eight large equipment companies queried during this report effort had previously quieted equipment to enter European markets. Switzerland and Belgium specify noise emission limits for such machinery; in addition, foreign manufacturers make quieter machines and set a competitive pace in foreign markets. American manufacturers seem to have met this competition by custom-designing equipment for export. There is an implication here, of course, that many American machines marketed abroad have been quieter than counterparts marketed domestically; however, this implication has not been adequately investigated.

Half the companies queried are currently undertaking their initial programs to quiet their products for the domestic market. Many of the present programs have been started this past year and are aimed primarily at protecting operators, so as to conform to impending legislation/regulation regarding occupational health and safety.* Only one of the companies indicated that purchasers complain about protection for operators on their own initiative, and only one case emerged in which a

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* Extensive testimony as to industry plans and current efforts in this regard was received at the EPA hearings held in Atlanta, Dallas, Chicago, Denver and Washington, D. C.

union had lodged a formal complaint. Six of the eight large companies described pressures on behalf of operators that originated with existing or proposed governmental action.

Many manufacturers feel that the efforts they are now making on behalf of equipment operators will pay off in meeting future noise limits designed to protect the public. One of the manufacturers of large equipment has charged design teams with the responsibility of integrating noise control into the overall design of the next generation of products and has set up review boards to evaluate new designs from all standpoints, including noise.

Four of the eight large companies are specifically influenced by the recently enacted Chicago noise ordinance as a contributor to their future objectives. The industry generally anticipates EPA-administered federal control; the visits of interviewers reinforced this feeling. The management of two companies believes that pressures for quieting will increase with time—apparently as a result of an increasing public awareness of noise as an environmental pollutant.

Although the industry has become increasingly aware of the pressures for noise control and has already made some efforts in this area, manufacturers must cope with economic pressures that argue against noise abatement.* For some companies, intensity of competition sets the limits on what price the market will bear. One of the industry's leaders was concerned that purchasers will continue using old equipment if prices rise significantly. Other industry leaders point out that foreign-made machines (some of them already quieted) will enter the American market if prices rise appreciably. One company predicted that a small rise in the price of truck-mounted

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* The following comments relative to economic aspects of noise control are in the main as applicable to other sources of noise as to the specific case of construction equipment.

concrete mixers would lead to the introduction of alternative methods for concrete delivery and production.

Companies who feel that the demand for their products is great enough to plan to pass quieting costs onto the consumer, although such threats as foreign competition and alternative methods, put limits on this process. The question involved is how fast the industry can afford to move. One limit on rapid movement is price competition. One company may be able to beat its competitors to the market with a quiet machine but may believe that it cannot raise prices substantially in the face of competition. Companies approach this problem differently. Most express the intention to meet or exceed the competition, but they feel that any great competitive advantage gained through an all-out effort to quiet their products would be short lived. One company sees its competition as being extremely severe and fears that it may not be prepared for the next round of quieting, while another company has actively launched a program designed to produce quieter machines at lower costs than the competitor will incur.

There is also the concern that often accompanies any industry leadership; i.e., a company may invest large sums to quiet equipment thus increasing the cost of products, while another company that refuses to quiet products may keep its prices low and may try to challenge noise regulation in the courts.

While all companies regard cost as an immediate—and perhaps the ultimate—constraint, two other constraints become paramount if, and as, costs diminish: time and technology. Three companies, each in a different fashion, reported that costs can be traded for development time; i.e., more time for development would reduce the cost of competition, allowing quieting techniques to be integrated into planned engineering efforts and to be an integral part of the seasonal progression of models. The very company that is setting out to achieve the most quieting for the least cost is the one that feels that technology will eventually supercede cost as the principal factor limiting quieter equipment. At another firm, the technical limitations were spelled out in terms of:

1. Loss of equipment power through increased muffling.
2. Increase in the difficulties and cost of maintenance.
3. Fire hazards through using insulating materials that can become oil-soaked.
4. Unsafe operation by suppressing or distorting the noise signals upon which operators depend for safety.
5. Ineffective operation, by disturbing these same signals, thus hindering the ability of the operator to tell how effectively he is operating.*

The industry also voiced concern over the feasibility of noise abatement where equipment and materials being interact to become prominent sources of noise; e.g., concrete mixers (where the structure may be the noise radiator); jack hammers (where the tool and its driving media may be the offender); riveters (where the structure of the building may be the primary source); and pile drivers (where both the structure and the media may be significant sources). This interaction-type noise source may be difficult to quiet.

No firm visited condemned noise limits out-of-hand, nor did they deny their inevitability. The management of six of the eight companies expressed the opinion that unless they quieted their products, their markets would disappear. Feelings varied from acceptance of the inevitable to enthusiastic approval of the trend.

Regulatory bodies outside the construction industry have begun to exercise some influence in the area of noise abatement. Within the industry, the Construction Industry Manufacturers Association, the Engine Manufacturers Association, and the national standards-setting bodies of American Society for Testing Materials and

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* See transcripts of EPA hearings held in Atlanta and Washington, D. C.

the Society of Automotive Engineers are actively addressing the problems of measuring equipment noise and recommending standards. The equipment manufacturing industry would like to coordinate its activities with those of its closely related standards-setting bodies. However, self-regulation via industry-initiated standards is more than somewhat hindered by federal anti-trust provisions.

As yet, no broad controls have been established. Industry tends to assume that the example set by the City of Chicago equipment noise ordinance will stimulate other similar action, eventually resulting in a proliferation of standards at the local level.

Projected Impact of Construction

Projecting conditions to the year 2000 involves a number of uncertainties. One of these is the exponential rate at which technology is evolving and affecting society. Technological innovation, however, is not the only factor to be considered. One cannot account for future changes in social attitudes. Although long-term predictions are fraught with such difficulties, one can still make educated guesses with a reasonable level of confidence. Rather than merely extrapolating existing conditions to the indefinite future, the following projections of the impact of noise are based on forecasts of population, family size, gross national product, and trends toward urbanization. Construction activities will continue to follow such growth patterns, although the character of construction may change significantly with greater use of prefabricated materials and the introduction of new kinds of equipment. Also, rather than trying to account for conflicting trends and changing attitudes, the projected extent of exposure is based on the assumption of no change in noise level for given equipment and considers only major trends that can be easily identified. (Obviously, by incorporating available technology, and with active regulatory participation at the various levels of government, the projected far-term impact could be avoided.)

The following U. S. Census Bureau data has been employed in projecting the increase in exposure to noise:

	1970	2000	Ratio
GNP (billions of 1958 dollars)	720	2240	3.2
Total Population (millions)	200	293	1.45
Total Number of Households (millions)	63	104	1.65
People per Household	3.17	2.8	0.9

Given the predicted increase in population and in financial resources, fairly extensive building activity can be expected. However, the urban areas have limited space available for new building; thus, the trend is for areas outside those now identified as central cities to become urbanized. Figure 3-6 illustrates this trend for single-family, multifamily, and nonresidential construction activities. With available land becoming more and more scarce within the central city, the building of single-family and multifamily dwellings will continue to decrease sharply. By the year 2000, we can expect to find approximately one-third the number of residential construction sites as were active in 1970. Nonresidential building is expected to increase. In areas outside the central cities, both residential and nonresidential construction should increase significantly. Nonresidential building activity is expected to increase by over 50 percent as the present suburbs become urbanized. With this general trend in mind, the data given above has been used to project the expected increase in exposure to noise from construction activities.

Nonresidential

The level of nonresidential construction activity in any given year is assumed to be proportional to the real Gross National Product (GNP) for that year. To find the nonresidential construction activity for any particular year, the ratio of the GNP for that year to the 1970 GNP is multiplied by the number of nonresidential sites built in

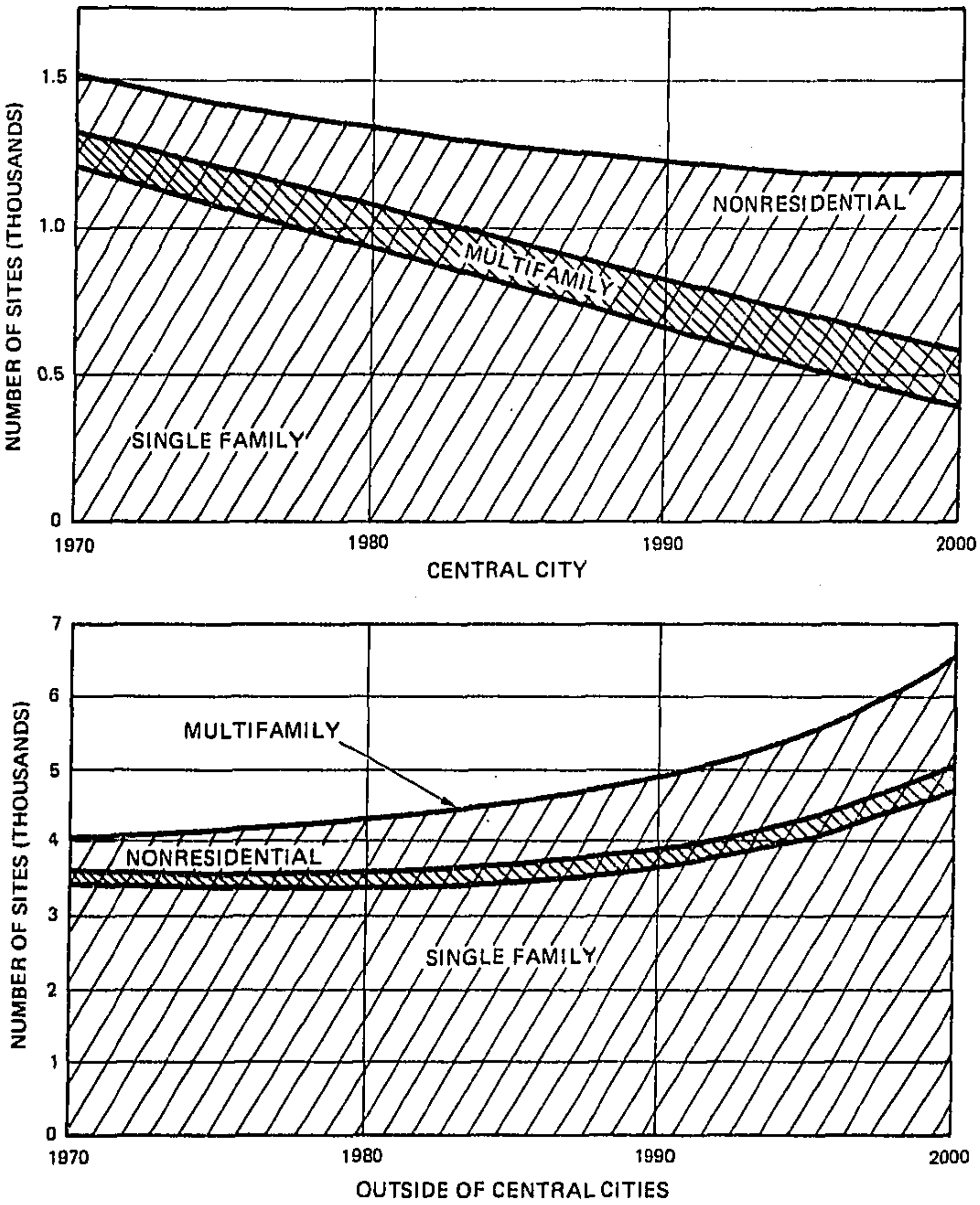

Figure 3-6. Number of Building Construction Sites Projected to the Year 2000

1970 (Table 3-8). The resulting total construction figures are apportioned between "central cities" and "other metropolitan areas" in the same proportions as occurred in 1970. Despite the expected decrease in total construction sites within the central city, nonresidential sites are expected to increase.

Residential

It is assumed that the population and population density of central cities will remain at their present levels until the year 2000 and that most residential construction in central cities will be for the purpose of replacing decayed units rather than for housing additional population. The number of construction sites will decrease due to the established trend toward an increasing number of multifamily dwellings over single-family dwellings. (Two- to four-family houses, which represent a negligible fraction of total construction, are included in the total for single-family housing.)

For metropolitan areas other than suburbs, it is assumed that the number of units constructed in any one year will be proportional to the population increase in the previous 10 years. To estimate this increase, the total metropolitan population is projected by multiplying the projected total national population by the estimated proportion of the population living in metropolitan areas. All the increase in metropolitan area population for a particular year is ascribed to noncentral city areas.

Roads

A simple but plausible indication of road construction activity, is the population level. Clearly, additional people will require additional roads, the capability of rapid transit being small at present. However, the urban areas have limited space for new roads, and urban residents are expressing increasing opposition to new road construction on grounds of aesthetics, pollution, and the community dismemberment concomitant with the installation of limited access highways. Thus, it would seem unlikely

Table 3-8

ANNUAL CONSTRUCTION ACTIVITY — 1970*

Metropolitan Regions	Residential Buildings (no. of sites)	Nonresidential Buildings (no. of sites)	Municipal Streets (miles)	Public Works (miles)
Large high-density central cities	8,708	1,952	273	398
Large low-density central cities	21,578	4,903	2,150	3,140
Other central cities	102,559	12,021	6,000	8,700
Urban fringe	262,800	30,915	11,800	16,865
Met. area outside urban fringe	118,779	13,758	21,700	31,550
Total	514,424	62,549	41,923	60,653

*All figures x 10^3.

that road construction will rise as fast as other measures such as the GNP. Therefore, the future level of road construction has been obtained by multiplying the present level of activity by the ratio of the projected population, divided by the current population.

The number of people affected by construction site noise is computed in the manner described in Chapter 2. Population densities for all metropolitan areas were assumed to be constant with time—4500 people/square mile for central cities and 2400 people/square mile for other metropolitan areas. At any one site, people are apportioned to specific transmission loss intervals as shown in Figure 3-7.

The resulting exposure to construction noise is given in Figure 3-8 in person-hours. In this figure, multifamily residential construction is included with nonresidential construction, since these types of building activites are similar. Note that the number of people exposed to noise from single-family dwelling construction declines steadily with time. This trend is more than compensated for by the rapid increase in nonresidential and multifamily sites—for which the duration of construction is typically six times greater than the duration for single-family houses. Thus, the number of person-hours of exposure is expected to increase by about 50 percent in the next 30 years.

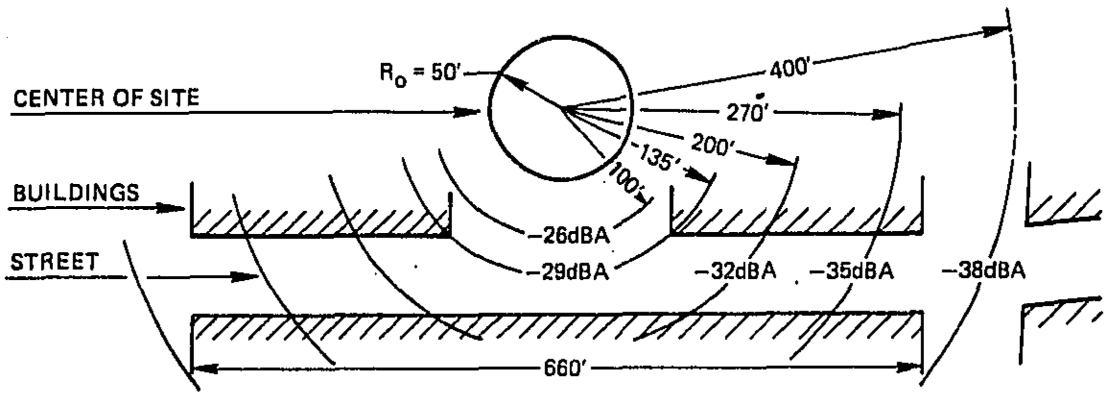

Figure 3-7. Construction Site Geometry and Transmission Loss Contours for Stationary Population

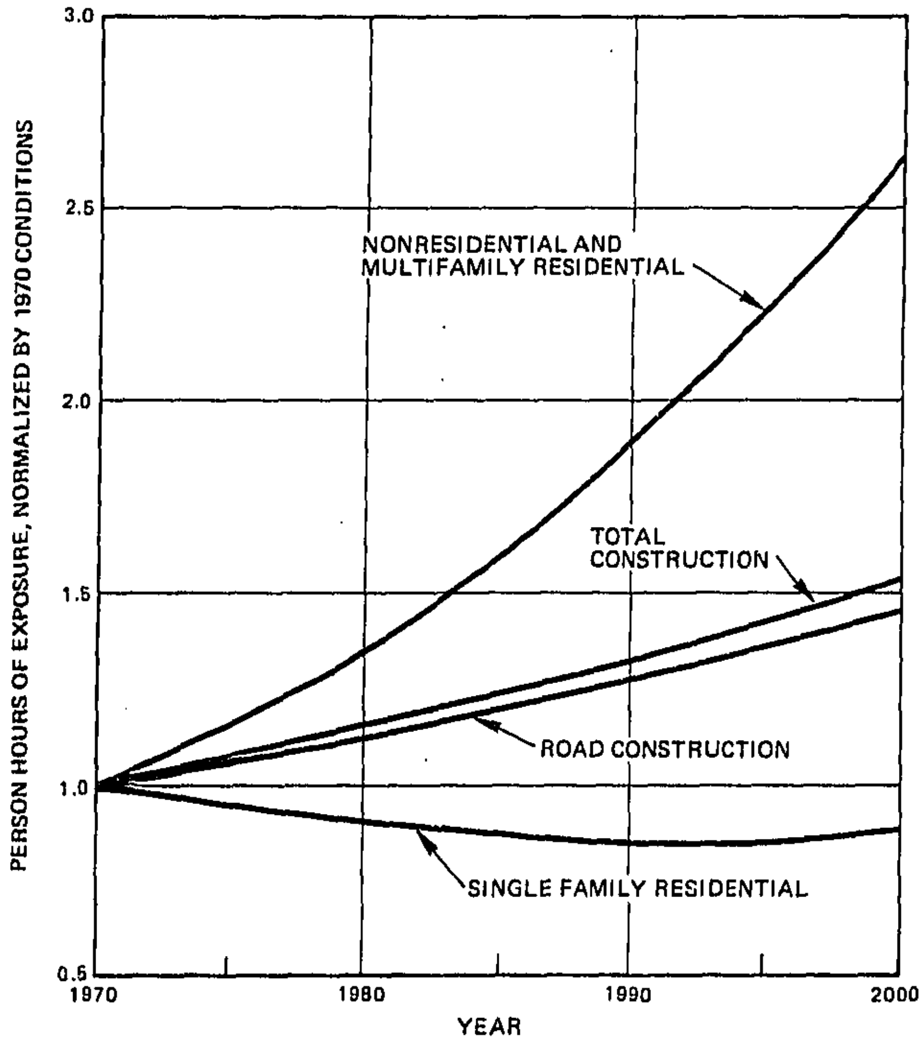

Figure 3-8. Projected Change in Exposure to Construction Noise, Assuming No Change in Noise Levels

APPLIANCE INDUSTRY EFFORTS*

In general, the industry's attitude toward noise control is so direct a function of market place pressure that noise control technology often exceeds application. Appliance manufacturers tend to maintain R&D and product engineering staffs that are capable of delivering more noise reduction than market strategy can justify. In fact, some companies have tried—unsuccessfully—to market quiet products, such as vacuum cleaners, blenders, and hair dryers; others have developed a number of quiet prototypes that were not put into production.

Consumer research shows low noise levels are not highly valued by many customers. Several companies keep systematic track of customer correspondence, while the industry itself maintains a Major Appliance Consumer Action Panel (MACAP) that acts as a clearinghouse for complaints. These records, all of which concern major appliances, show relatively little complaint about noise. For example, only 5 percent of the letters to MACAP in the first 8 months of 1971 concerned noise.

The objectives for quieting household appliances seem to vary with the market pressures on particular products. With this observation in mind, a discussion of noise control efforts is organized around the problem appliances that have been identified.

Air Conditioners

There is probably more market pressure to quiet air conditioners than to quiet any other household appliance. Since air conditioners emit noise both indoors and out, they frequently affect not only the purchaser and his family but also neighbors and passersby. Both kinds of emissions generate pressure for noise reduction.

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* See transcripts of EPA hearings held in Dallas and San Francisco regarding appliance noise.

Pressure from neighbors takes the form of local noise ordinances that specify maximum sound-emission levels at a property line; this pressure is passed on to the manufacturer, as one company pointed out, by dealers or marketing men who are aware of the ordinances.

One such company reports spending 3 man-years per year on air conditioner noise control; 1 man-year per year was a more frequently mentioned level of effort. While the product policy people generally reported that they were making maximal use of available quieting technology, the study-project acousticians who initiated the interviews felt that current state-of-the-art technology was not being universally applied.

Two estimates were received indicating that quieting room air conditioners adds 10 to 15 percent to the price. There may also be an inherent tradeoff between quietness and efficiency (since one way to reduce air noise is to decrease air velocity). Sometimes, quieting results in increasing the air conditioner's physical dimensions, thus detracting from appearance as well as from convenience and ease of installation. There may also be a trend toward model lines differentiated by noise output; i.e., and expensive quiet air condition and a cheaper noisier model. One manager pointed out that there are antitrust constraints against organizing industry consensus on noise levels.

Dishwashers and Food Disposers

The mechanical differences between dishwashers and disposers do not alter the fact that noise control pressures are similar and that the manufacturers' approach to quieting is similar. Quiet is a saleable characteristic in dishwashers and disposers, although the pressures for quieting are not so great as for air conditioners. While no advertising campaigns built exclusively on quiet are apparent, it is advertised with the same prominence given to power and reliability.

Dishwashers and disposer noise are not currently under public regulation, hence the incentive for quiet comes almost exclusively from the purchaser. This gives rise to marked differences between models; if one wishes, one can buy an inexpensive, noisy dishwasher or disposer. Reports from the industry indicate that landlords frequently do just that.

Dishwashers present a promising example of industry's response to the purchaser's desire for lower noise levels. In a 1970 survey by the United States Steel Co., 48 percent of dishwasher owners had no complaints about their appliance, but of those who did, more complained about noise than about any other aspect of its operation. Both survey data and marketing lore indicate that the purchaser who has previously used these appliances puts a higher value on quietness than does the new user.

The costs of quieting were estimated by one dishwasher manufacturer to be 10 percent and by another to add $1.00 to $2.00 to manufacturing costs. A disposer manufacturer felt that quieting would add 12 percent to a product cost, whereas a retailer of disposers estimated 18 percent. It was felt that quieting these machines might deny their availability to those least able to pay.

In the case of dishwashers, one manufacturer indicated the possibility of tradeoffs between noise and maintenance costs and reliability. Another manufacturer indicated a tradeoff between water velocity and quiet but expressed the opinion that there are no serious technical restraints to quieting dishwashers.

In the case of disposers, industry claims inherent problems with water and grinding noise (especially with the noise of grinding bones). Some noise is considered necessary to the user's safety, so he will know when the disposer is operating and when it has finished grinding.

Vacuum Cleaners

The manufacturers of vacuum cleaners believe that the market pressures are for noisy machines. The three manufacturers and one large retailer interviewed are all convinced that customers use noise as the basis for judging a machine's power. For example, after concentrated technical effort, a manufacturer had significantly reduced the noise from a canister model without reducing its cleaning capability. Housewives who participated in a marketing trial wanted to know if the machines were really cleaning. Neither of the large private label retailers consulted during this report effort mention quiet as a design goal. One company that carefully analyzes its correspondence from customers finds virtually no noise complaints about vacuum cleaners or any of its other portable appliances.

A reasonable level of engineering effort has produced feasible solutions to vacuum cleaner noise; according to all interviewed, however, these solutions are not being applied to products that are sold, because vacuum cleaner manufacturers and retailers do not sense a demand for quieter products. In fact, the sale of upright cleaners, whose beaters make them noisier, is growing at the expense of the canister models. Apparently, the beater action of upright cleaners can better handle the new deep-pile weaves that make modern carpets harder to clean. There are technological limits to the quieting of upright vacuum cleaners, because of the interaction between the beater and the carpet, but the noise levels of production models seem to be determined by customer usage demand rather than by technological limitations.

Other Major Appliances

Quieter clothes washers, clothes dryers, and refrigerators tend to be byproducts of engineering originally undertaken with other objectives in mind. The classic case is a washing machine model that was incidentally quieted when two gears were removed from the power train to save cost. In the context of product improvement, noise is generally treated as a secondary design goal, although manufacturers are concerned that engineering changes may produce noisier products. For example, refrigerators are becoming larger and noisier as manufacturers seek to meet the demand for special options such as ice makers; a spinner-type washing machine produced higher noise levels when spinner speed was increased to 2000 rpm.

Two of four manufacturers interviewed make quiet models of washing machines that sell at a $10 to $20 premium; sales for both lines are disappointing. None of the other models of these companies are marketed on the basis of quiet nor do the mail-order catalogues feature quiet. The single exception is a spinner-type washer in which "quiet operation" appears in the small-type description. There is, then, relatively little evidence of pressure for quieting appliances of this type.

Yet, despite the weakness of market pressure, considerable quieting effort has gone into the design of these appliances, especially washing machines. One manufacturer mentioned six different quieting projects that have recently been completed or are underway. A refrigerator manufacturer mentioned an effort to avoid strange or unidentifiable noise. No specific efforts to quiet dryers were uncovered.

So far, a number of sophisticated techniques have been applied to dishwashers: isolation, damping, and part redesign. Manufacturers of both dishwashers and disposers have tried to improve the quality of installation by providing carefully drawn instructions and flexible fittings. One company has reduced noise on its top-line dishwasher from 82 to 76 dB(A) (at an unspecified distance) since 1967 and plans a further reduction in the next few years. Another manufacturer expressed only the desire to keep abreast of the competition; this company tests each machine for noise, rejecting under 1 percent.

None of the manufacturers interviewed intends to give up his noisier economy lines; goals did not seem to be appreciably influenced by the prospects of noise regulation. The company representatives interviewed claimed to have adequate acoustic test facilities, although the efforts devoted to testing and to development varied widely in quantity and quality.

Small Appliances

During the interviews, incidental information was gathered from five different companies concerning 11 small appliances: blenders, can openers, coffee mills, electric knives, fans, hair dryers, ice crushers, knife sharpeners, mixers, oral lavages, and electric tooth brushes. Manufacturers feel that there is public pressure for these appliances to sound as though they are "really doing their jobs." One manufacturer offered the generalization that, in the small appliance field, the quality of the sound is more important than the quantity. An appliance must sound right. Some must sound powerful, some reliable, and none as though they are malfunctioning or undergoing excessive wear. This manufacturer expressed the belief that an accurate interpretation of the customers' desires in these areas is a condition for remaining in business.

This market pressure leads to diverse noise-control objectives, both among companies and between product lines produced by a single company. Customer complaints were reported concerning the noise from fans and hair dryers, and one marketing executive was quoted as believing that quiet is a saleable aspect of mixers. One company that does not manufacture the ice crusher sold under its label put a fairly high value on quietness in selecting the model it sells. Yet, none of these small appliances were described as quiet in either of the two mail-order catalogues that we examined. Blenders and electric can openers were specifically described by the managers interviewed as being appropriately noisy. A company that was not interview was cited as having quieted a blender; in so doing, they slowed it down so that it became less efficient. At least one laboratory is seeking entirely new ways of comminuting foods that could be both quieter and cheaper than blenders. Another is designing a screw-type crushing tool that will substitute a growling sound for the raucous sound of the chipper employed in ice crushers.

There is also a search for fan blade configurations that will eliminate certain predominant frequencies and that will produce a more pleasing sound. In addition to room fans, this experimentation includes hair dryers, for which quieter designs for air passages are also being sought.

Rubber feet have been added to electric coffee mills to reduce vibration noise, but shielding is not being used because of its adverse effects on costs, size, and aesthetic design. Plastic beaters for mixers promise to reduce both noise and costs.

Many of these appliances are powered by universal-type motors, which are inexpensive, powerful for their size, but noisy. The size-power ratio is considered important in such appliances as hand mixers, electric knives, can openers, and motor-in-the-bonnet hair dryers. Conventional hair dryers also embody a tradeoff between speed and quiet; one hair dryer model that was marketed as "quiet" took 30 to 75 minutes longer to dry hair than faster, noisier models.

Speed or the potential power that speed permits was cited as important in electric knives, can openers, and blenders. In the case of blenders, one engineer argued that, if they were slowed down, the intensity of the noise would simply be traded for noise duration, with no lessening of resulting impact. There is also reported to be a. tradeoff for electric tooth brushes between noise and cleansing effectiveness.

Cases of limitations on quieting were pointed out for knife sharpeners in which there is grinder-blade interaction, as well as for blenders in which rotating knives are essential and a glass casing is necessary if the housewife is to visually monitor process. In the case of blenders, there is hesitation to experiment with consumer preferences, since the already intense domestic competition is being raised by the entrance of foreign products into the market.

Small appliance manufacturers make frequent use of subjective noise judgments in their developmental work. Their product laboratories tend to be less sophisticated than those for major appliances, although many have access to highly sophisticated central acoustical laboratories. One small appliance manufacturer tests new products in his employees' homes. If employees object to the noise the new model makes, they are asked if they would be willing to pay for a quieter product. The general result of this approach is to make this manufacturer pessimistic about the economic payoff from quieter products.

Although specific noise goals are hard to identify in the appliance industry and although some manufacturers seem discouraged with the return on their efforts to date, all those interviewed plan to persist in quieting their products. Technological limits have not yet been reached. One manufacturer believes that the earlier competition that emphasized compactness has now been replaced with an emphasis on quiet. Accordingly, industry generally plans to hold the size of future models constant and to concentrate on producing quieter models, while presumably keeping prices within competitive limits.

Projected Impact of Appliance Noise

It is assumed that the probability of future appliance ownership as a function of income level will remain the same and that appliance costs will remain approximately the same in current dollars. With these assumptions in mind, approximation of appliance use was based on projected population, family income, and income distribution.

This estimation is probably conservative, since some appliances are continuing to increase their acceptance in all income levels, although their growth of acceptance is low at the higher income levels, in which some appliances have nearly saturated the market. For those appliances for which insufficient information is available on appliance possession at the various income levels, future possession was estimated from current marketing information on percentage of replacement sales and on market penetration.

In projecting future impact, it was estimated that appliance usage will remain approximately at current levels and that there would be no change in their noise levels. Supporting the usage assumption is the little deviation shown in average time spent by homemakers in using appliances over the last 40 years.

Figure 3-9 illustrates the increase in exposure to appliance noise by plotting hearing-impairment risk and speech and sleep interference in person-hours of exposure. As explained in Chapter 2, these three effects are among the most salient and tangible consequences of noise exposure and can thus be most readily interpreted in nontechnical terms. As can be seen on Figure 3-9, the number of person-hours during which people will be exposed to the risk of hearing damage will more than double in the next 30 years, as will the number of person-hours during which normal conversation will be difficult and during which people will be either awakened or prevented from falling asleep. Obviously, by incorporating available technology the projected impact can be avoided.

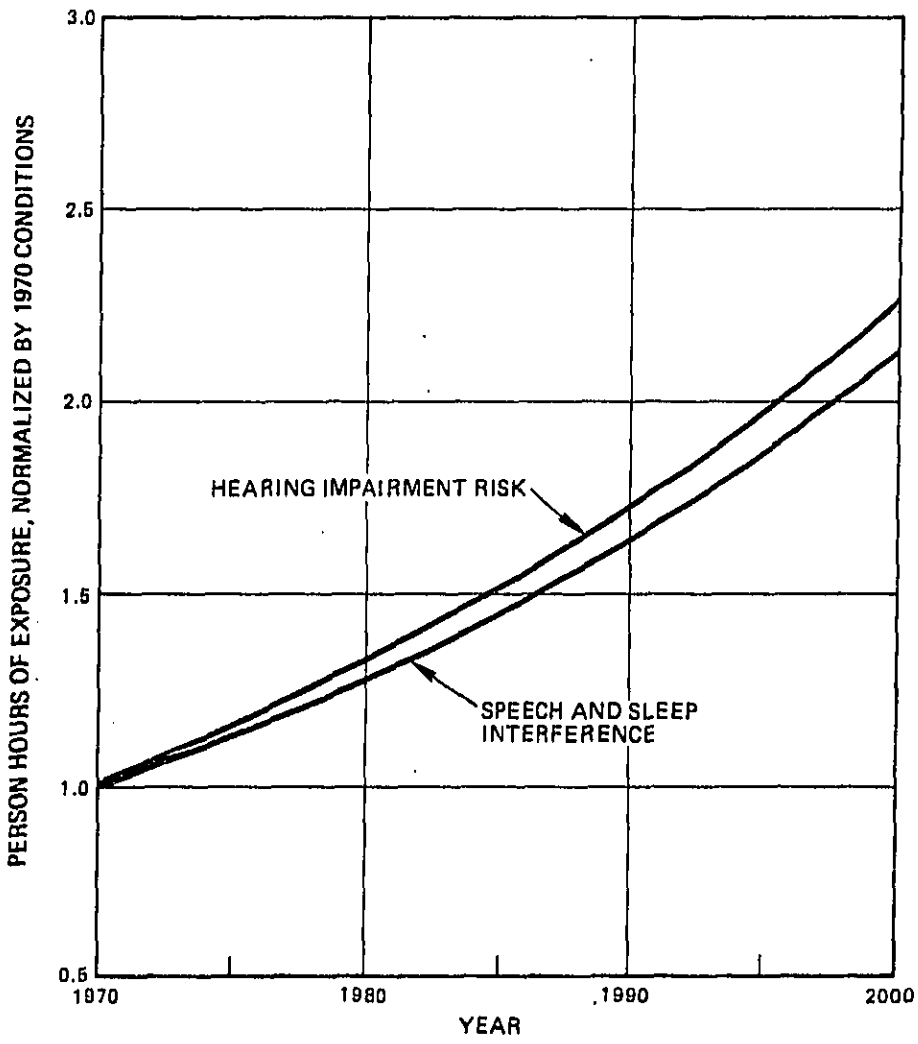

Figure 3-9. Projected Change in Exposure to Appliance Noise, Assuming No Change in Noise Levels

ECONOMIC ASPECTS OF NOISE ABATEMENT

Information on the adverse effects of noise and the costs associated with various types of abatement measures is contained in several chapters of this Report. Much of the information obtained during public hearings held by EPA under PL91-604 also addressed the economic aspects of noise. However, at this time, the rudimentary state of knowledge regarding costs, benefits, and the impact of abatement expenditures upon the national economy makes it extremely difficult to undertake an economic analysis related to this problem.

As background material for this Report, EPA commissioned a study of the economic impact of noise, NTID300.14 referenced at the beginning of this chapter. This study provides a general overview of some aspects of the problem, discusses the limitations of existing data, and indicates the need for additional research and analysis in this area.

To evaluate alternative noise abatement strategies, there are three major types of economic considerations to be evaluated:

1. The magnitude of the benefits derived in terms of damages avoided and positive gains attained.
2. The costs of attaining various levels of control included.
3. The impact of abatement costs on the economy.

With a better understanding of these economic factors, it should be possible in the future to evaluate alternative control strategies and to identify cost-effective solutions.

SUMMARY

Much of the strength of the nation's economy, and the accompanying high standard of living, result from technical innovation and its utilization by industry in the development of new and better machines. Generally, the performance criteria for these machines are defined in terms of the useful work that they will accomplish and the value of this work with respect to its cost. The success of any new product is determined in the market place primarily in terms of the potential economic value of the product to the customer relative to its total cost, including both initial and operating costs.

In the case of acoustical devices such as musical instruments, hi-fi sets, and speech communication equipment, sound characteristics are a primary performance criterion. However, for the other devices, noise is generally an unwanted byproduct not associated with the primary performance criteria. Only when a need for less noise is articulated (through customer preference, industry awareness, or public action) does noise become one of the primary performance criteria. The information feedback process from the public to industry generally takes many years and often presents a conflicting set of needs. For example, the purchasers of devices such as motorcycles, some construction equipment, trucks, and cap pistols consider noise as a positive indicator of high performance. For the same reasons, the owners of many types of devices purposely operate them in their noisiest mode. In such cases, in which the consumer and public interests diverge, industry responds to the consumer until the offended public articulates its requirements.

One of the best examples of the possible long-term noise accommodation among industry, public, and the market place is the standard American passenger car. In its 60-year history, it has evolved from a noisy, sputtering, crude, low-powered vehicle to a relatively quiet efficient high-powered vehicle. Mufflers were

installed before World War I to prevent scaring horses and thus win a wider acceptance in the market place. Cities and towns set regulations requiring that all cars be muffled in the 1920's, primarily to ensure that owners retained the original mufflers in good working order. Without further action in the public sector, industry has made continuous progress toward quieting the automobile interior to gain wider acceptability in the market place; and in so doing has also attained reasonably acceptable exterior noise levels.

However, in most product areas, there has not been any method of placing before the consuming public the necessary data to provide for consumer choices between alternatives. Thus, industry has not been able to ascertain what purchasing habits the public might adopt, given factual alternatives. One means of allowing the public to express its requirements for quiet would be to provide information on product noise emission, perhaps by direct product labeling.

During the last few years, various governmental bodies have begun to effect the public concern by developing and implementing noise regulations for various sources. With the exception of aircraft noise, for which the federal government has begun to act, many of the remaining sources are being subjected to a series of separated, uncoordinated, and often conflicting regulations. These actions by the public, as well as the data presented in this report, show clear evidence of the need for noise reduction.

Most of the sources discussed in this chapter have additional noise reduction potential that can be attained with application of today's technology. In many cases, these potential improvements will probably be sufficient to control noise in the public interest. However, in some cases, present control technology is clearly insufficent to provide necessary noise control, and research is needed. In any case, the eventual reduction of noise in the nation requires establishment of a balanced set of noise goals that will enable priorities to be set for systematic exploitation of existing technology and development of new technology.

Together with these goals, source noise standards and implementing regulations should be promulgated for those products which are capable of causing excessive noise. Such standards should have time scales for achievement that are consistent with industrial design, prototype test, and production cycles to encourage the most economical and effective incorporation of noise performance criteria into the total design of the product.

Priority should be given to the sources that may constitute a potential hazard for hearing, which include most of the recreational vehicles, internal combustion powered lawn care equipment, and some transportation vehicles. In addition, priority should be given to all types of aircraft and large highway vehicles associated with the airport and freeway noise. Finally, priority should be given to construction equipment and the noisier elements of city traffic, so that the people living in major cities will eventually be able to enjoy relaxed conversation outdoors. Without an effective local, state, and Federal regulatory program, today's noise problems will affect an ever increasing number of people. The technical components of an effective noise abatement plan must include both control of noise at its source and preventive intervention in terms of balanced transportation system planning, land use planning and upgrading of building construction quality. Such a program, to be effective, requires active regulatory partnership between the federal government on the one hand and state and local government on the other, with active participation from industry and the public at large.
federal government on the one hand and state and local governments on the other, with active participation from industry and the public at large.

CHAPTER 4

LAWS AND REGULATORY SCHEMES FOR NOISE ABATEMENT *

Legislative interest and action in the area of environmental noise abatement and control is increasing as the magnitude of the general problem becomes more obvious. Despite this increased awareness, regulatory schemes on all levels of government are not fully successful. Generally, the problem can be attributed to two factors, acting separately or in combination:

1. Poorly written laws that do not provide the needed authority or incentive to alleviate the problem and that are technically deficient regarding acoustics and noise measurements.
2. Poor enforcement of existing laws due to lack of available personnel and to the lack of knowledge on the part of enforcement officers as to sound measurement equipment and techniques.

The following discussion provides an overview of the entire legal structure regarding noise abatement and control.

* This report is based on data prepared by the Staff of EPA, Office of Noise Abatement & Control and on EPA Technical Information Document NTID 300.4, "Laws and Regulatory Schemes for Noise Abatement" (EPA Contract 68-04-0032, George Washington University). See Appendix A regarding procurement of this source material, which contains bibliographic information.

CURRENT GOVERNMENTAL NOISE REGULATION

Noise Abatement Regulation at the Federal Level

General Policy for Federal Noise Abatement and Control

The Noise Pollution and Abatement Act of 1970 was the first legislation to provide a central focus for overall environmental noise abatement at the Federal level. This Act required that an Office of Noise Abatement and Control be established in the Environmental Protection Agency (EPA) to carry on research and investigations into environmental noise. The act further directed, in Section 402(c) that, following a determination by the Administrator of EPA that noise related to a Federal agency's activity or its sponsored activities is a public nuisance or is otherwise objectionable, the Federal department or agency sponsoring such activity must consult with the Administrator of EPA to determine possible ways of abating such noise. Previous Federal legislation had been directed to noise abatement with respect to specific noise sources (such as aircraft noise) or in regard to special environmental situations (such as occupational exposure or transportation planning).

Further, the National Environmental Policy Act of 1969 has required, since 1 January 1970, that Federal agencies use an interdisciplinary approach to integrate the "environmental design arts" into the decision making process (Section 102(2) (A&B)). Initially, this new approach to decision making has taken the form of environmental impact statements required pursuant to Section 102(2) (C) on all "Federal actions" significantly affecting the human environment. Such statements should, therefore, include consideration of environmental noise. Sections 102(2) (A&B) are intended to bring about the synthesis of an environmental awareness within Federal agency decision making processes.

Noise Abatement and Control of Military and Internal Federal Activities: A Microcosm Example of the General Noise Problems

Preliminary examination of activities of the Federal government to control the noise produced in the very act of governing and providing protection to the general society is enlightening. In the military context, many of the noise problems that occur in the public and private sectors are also experienced. The military services have been active for a great number of years in noise abatement, and the documents discussed below are only examples of the many military regulations whose implementation is described more fully in this report in Chapter 5.

In the nature of a general approach to noise abatement, the Department of Defense has issued Military Standard (MIL-STD)-1472A to set human design criteria for all new military systems, equipment, and facilities. This standard adopts certain publications of the various military branches and is intended to operate concurrently with all other related military regulations; however, MIL-STD-1472A takes precedence whenever other regulations conflict with it. Primarily, the standard promulgates objective limits on noise in areas in which speech communication is necessary.

Under MIL-STD-008806B, 21 September 1970 (applicable to all services but used herein with respect only to the Air Force); Air Force Manual (AFM) 86-5, 1 October 1964; and Air Force Regulation (AFR) 55-34, 5 February 1971)* the Air Force has policies to reduce noise impact. The first document establishes sound levels that must be achieved in aircraft cabin spaces. The latter two documents address airbase noise and direct Air Force efforts to encourage compatible land uses by communities adjacent to military airfields and to promote community noise impact reduction programs, respectively. MIL-N-83155A, 25 March 1970, covers noise suppressors on engine

* The current version of AFR 55-34 is an updated revision of the directive first issued in 1962.

test cells and is a revision of an earlier directive on this subject. AFM 160-25, 1957, "Engineering Data, Preventive Medicine, and Occupational Health Program," contains instructions for environmental engineering, evaluation, and control of community noise.

Other noise sources considered by the Federal government in military operations and in operation of the government itself are occupational and construction noise. In the area of occupational noise, the Air Force, Navy, and Army have respective hearing conservation programs under AFR 160-3 29 October 1956, as amended through 7 February 1967; BUMEDINST 6260.6B, 5 March 1970; and EM 385-1-1, 1 March 1967. These programs are primarily designed to protect the hearing of those exposed to the noise.

In this discussion, construction noise can be broken down into the acoustical characteristic standards that must be achieved in Federal buildings built under contract with the Federal government and the actual site noise generated during the construction process. For the first of these noise considerations, the General Services Administration (GSA), under PBS P3410.5, 12 June 1968; PBS P 3460.1C, 12 June 1968; PBS 4-0950, November 1970; PBS 4-1021, February 1970; and PBS 4-1515-71, April 1971, has established certain objective standards to be met in various segments of government buildings constructed under GSA contract. These standards are designed to reduce the impact of noise by providing a buffer between the noise source and the receiver. While specifications delineate the allowable sound transmission for areas near such noise sources as mechanical and electrical equipment, there is no attempt to regulate noise by establishing standards for the equipment itself.

As far as the actual construction site noise is concerned, the Army, in EC 1110-2-109, 15 June 1970; ETL 1110-3-141, 30 November 1970; and CE-1300, May 1970, has adopted regulations for noise abatement on both civil and military construction projects. The previously cited Air Force Manual 160-25 contained noise criteria to be considered in design of USAF buildings and structures.

With respect to construction contracts for Federal buildings, the Occupational Safety and Health Act (OSHA) noise standards have been applied by the Department of Labor pursuant to the Construction Safety Act of 1969. However, there may be a question as to whether OSHA standards can be applied to construction noise in view of fundamental differences in physical environment between an open, multistory construction site and a closed factory work place. In a closed factory environment, one can assume that the factory owner has control of the entire noise exposure of his workers. However, on an open construction site, the contractor cannot control many of the noises that affect his workers. Thus, the engineering controls open to him are limited, if not nonexistent. There is no reason that hearing protection devices could not be used, however, to reduce the noise impact to meet the exposure standards. A pilot project is underway, via a GSA contract, to develop baseline data to these and other questions concerning the applicability of the regulations.

As pointed out earlier in this discussion, the military and internal Federal noise control operations provide an excellent overview of the noise problems encountered by the Federal government, as well as other governmental levels. These external Federal control measures will now be considered in terms of the general category of the particular noise source.

Transportation Noise Abatement and Control

Federal efforts to bring about transportation noise abatement are directed at aircraft and highway noise, with the former receiving the greater attention. But concern and action in the highway noise area are also significant and increasing.

<u>Aircraft Noise</u>. The Department of Transportation (DOT) Act of 1966 was the first statutory authority relevant to aircraft noise. Section 4(a) of the Act directed the Secretary of Transportation to "promote and undertake research and development relating to transportation, including noise abatement, with particular attention to aircraft noise." Although some efforts were undertaken by the Federal Aviation Administration (FAA) as early as 1960, it was not until the 1968 enactment of Section 611 (PL 90-411), relating to Control of Aircraft Noise and Sonic Boom, as an amendment to the Federal Aviation Act of 1958, that the Federal government undertook an active program of civil aircraft noise abatement. Considerable impetus to the enactment of this legislation resulted from the Office of Science and Technology study on jet aircraft noise near airports, completed in 1966. Implementation of this effort to abate noise at the source began 1 December 1969, with regulations made applicable to new subsonic aircraft. Regulations with respect to retrofit, sonic boom, SST type certification, and STOL/VTOL type certification are still in the development stages.

In the Airport and Airways Development Act of 1970, the FAA has a valuable tool that could be used to abate noise with respect to airports, since the Act declares the "national policy that airport development projects authorized pursuant to this part shall provide for the protection and enhancement of the natural resources and the quality of environment of the Nation." The airport certification provisions of Section 51(b)(1) direct the Administrator of the FAA to set minimum operational safety standards for airports served by Civil Aeronautics Board (CAB)-certified air carriers, but do not apply to the regulation of airport noise levels. The Act is applicable to all projects involving new airports and runways or extension of existing runways; thus, relatively few airport developments that might create additional noise escape consideration. State and local governments gain two leverage mechanisms with respect to such projects: first, the community acceptance provision of the Act requires that the project be accepted by communities around the airport before DOT may give its approval;

second, under the state air and water quality certification section, the governor of the state in which the airport is located must certify that there is "reasonable assurance that the project . . . will comply with applicable air and water quality standards" before Federal approval. Since some states have included noise as an air contaminant, the noise standards of these states will figure in the development of airports via this provision of the Act. Unfortunately, the more sophisticated state noise laws are not generally under such an air quality framework, but, rather, are given separate consideration. Thus, these states do not have the input potential provided under the Act.

Highway Noise. Beginning in 1965, the Secretary of Commerce (duties transferred to the Secretary of Transportation since 1966) was required to "cooperate with the States . . . in the development of long range highway plans . . . which are formulated with due consideration to their probable effect on the future development of urban areas of more than fifty thousand population." The first active consideration of highway noise at the Federal level was Policy and Procedures Memorandum 20-8 of the Bureau of Public Roads, issued January 14, 1969. Environmental effects, which must be considered by the state or local sponsor seeking Federal aid, are defined to include "noise, air, and water pollution." Pursuant to a 1970 amendment to the Federal-aid Highway Act (PL 91-605), the Secretary of Transportation is directed "to assure that possible adverse economic, social, and environmental effects have been considered in developing . . . /and Federally aided highway/ project . . ." Further, he is to "develop and promulgate standards for highway noise levels compatible with different land uses after July 1, 1972."

Occupational Noise Abatement and Control

Following the lead provided under Federal supply and construction contracts, discussed earlier, by the Department of Labor regulations under the Walsh-Healey Public Contracts Act and the Construction Safety Act, the Secretary of Labor carried over these regulations under OSHA. The standards under all three acts are the same. While the Walsh-Healey regulations carry only a potential penalty of removal of the contractor from the eligible bidder list for 3 years, the Occupational Safety and Health Act provides for both civil and criminal penalties.

An interesting feature of the new Act is that a state may take over regulation of a particular matter through a program of application and acceptance by the Secretary of Labor. This may provide a technique deserving broader application in the noise abatement area, to avoid potential preemption problems.

The Atomic Energy Commission (AEC), in AEC Manual 0550-01 OS, 25 February 1970, and the Department of Interior, pursuant to the Coal Mine Health and Safety Act of 1969, have also adopted the OSHA standards for occupational noise programs. The AEC program is intended, ". . . for the protection of AEC and AEC contractor employees, the general public, and the environment. . . ." The Department of Interior, through the Bureau of Mines, applies the standards to some 1900 licensed underground coal mines.

Construction Noise Abatement and Control

Construction Site Noise. The only Federal activity directed toward noise abatement at construction sites has been considered under the discussion of the Federal military and in-house government activities. Construction site noises are covered by the Occupational Safety and Health Act as being a business affecting interstate commerce, and the standards adopted for noise exposure by the Department of Labor under that Act apply to construction sites. Construction activities are enforced in the Occupational Safety and Health Administration.

Acoustical Characteristics of Buildings. Regarding acoustical characteristics of buildings, the Department of Housing and Urban Development (HUD) has issued Policy Circular 1390.2, 4 August 1971, concerning acoustical acceptability of new sites and existing buildings to be aided by HUD monies. This circular applies noise standards to programs where none existed previously and replaces the standards of the Federal Housing Administration (FHA), which is under HUD, to the extent that programs, ". . . have less demanding noise exposure requirements." The existing noise abatement programs of FHA now must be reviewed concerning their continued applicability. These programs relate to:

1. Mortgage underwriting in noisy areas near airports (FHA Manual, Vol. VII, Book 1, §71453 – new development not be considered for mortgage underwriting, if site within NEF-40 contour, pro and con evaluation for NEF-35, site approved without further consideration for NEF-30 or less.
2. Minimum property standards for multifamily dwellings for which FHA financial assistance is sought (FHA #2600, reissued February 1971, setting sound transmission standards and impact noise standards for partitions and floors/ceilings for developments of multifamily residences supported by FHA money).

Other Noise Sources Controlled at the Federal Level

The Federal Power Commission, acting under the authority of the Natural Gas Act of 1938 (15 U.S.C. §717), has directed in 18 C.F.R. §2.69, 1971 (first appearing on 16 July 1970 in 35 Fed. Reg. 11389) that compressors, when used above ground in connection with gas pipelines, must be located and treated so as to reduce the noise impact on the environment.

Noise Sources Regulated at the State Level

Many states are entering the noise control field in earnest, as demonstrated by the large number of recently enacted state laws in this area (nine during the first half of 1971 alone). It is increasingly common for states to establish environmental departments to deal with noise and other pollutants, and the number of noise sources being regulated by any single state is growing. The states are also becoming more sophisticated in the writing of noise laws and are beginning to substitute specific decibel limits for subjective standards such as "unnecessary" and "unreasonable," although such standards have by no means disappeared. A growing number of states are also setting standards for noise from new vehicles and equipment, forbidding the sale of any that fail to conform to the standards.

Five states (Florida, Hawaii, Illinois, New York, and North Dakota) have delegated, to departments dealing with environmental affairs, the power to set standards for the limitation of noise from many sources. All of these states are currently preparing for or conducting hearings on standards, many of which will probably be promulgated in late 1971 or during 1972. California and Illinois have declared their policy to be to reduce noise, and both require environmental reports from state agencies. Illinois has declared it unlawful to create unreasonable and unnecessary noise on one's property, while Colorado has established decibel limits on noise permitted to emanate from any premises.

Following development and adoption of standards in late 1971 and early 1972, the state programs to combat noise will enter a new phase. The success of these programs will be determined by the ability of the states to enforce their new laws.

Transportation

California has developed a complex regulatory scheme for controlling airport noise. The law requires airport operators to monitor takeoff and landing noise and to establish a noise impact boundary around the airport, with noise at this boundary to be reduced over the next 15 years. Also, the airport operator must set noise limits on single takeoffs and landings and must report violations to county enforcement officials. Those airports failing to come within the noise limits may lose their licenses or face other state sanctions. The legal basis for the law is the state's licensing power over airports and the asserted proprietary rights of airports vis-a-vis the scheduled airlines and other users. Discussions of the legality of this law and the problem of Federal preemption are presented elsewhere in this chapter.

The states have long provided statutory restrictions on noise from motor vehicles, with 43 states requiring mufflers on vehicles and 15 restricting noise from horns. Five states set limits on the total vehicle noise, based on subjective standards. Connecticut has recently empowered its Commissioner of Motor Vehicles to set noise limits not to exceed 90 dBA, and New York and Idaho set decibel limits on the operation of vehicles. California sets standards on noise from the operation of vehicles as well as noise limits on new vehicles. Colorado and Minnesota have recently enacted legislation patterned closely after the California law. Of these laws, the Idaho law specifies a limit of 92 dBA measured at 20 feet, while the others provide limits in the range of 88 to 92 dBA measured at 50 feet. California, Colorado, and Minnesota have provisions for lower limits to take effect in several years.

Five states specifically require mufflers on motorcycles, while California, Colorado, and Minnesota set overall noise limits on these vehicles. As with automobiles and trucks, the standards will become stricter over time.

Five states require mufflers on boats. Wisconsin delegates to its communities the power to regulate motorboats.

Snowmobiles have been given increased attention by the states. Maine and Wisconsin require mufflers, while Colorado, Massachusetts, Montana, and New York set limits on new snowmobiles. Colorado and Massachusetts also regulate noise from the operation of snowmobiles.

Occupational Noise

Twenty five states have reported existing occupational noise standards of some kind. These reports were made to the Secretary of Labor pursuant to the Occupational Safety & Health Act of 1970 and its program for state substitution for the Federal regulatory framework under the Act. California, as an example of these state frameworks, has adopted the same standard as that promulgated by the Secretary of Labor under the Walsh-Healey Public Contracts Act. Responses have yet to be received by the Secretary from 12 states (nine of which plan to exercise their takeover option and three of which have decided not to enter into temporary agreements with the Department of Labor to continue enforcement on the state level during the takeover period).

Construction Site Noise

Colorado alone sets decibel limits on noise from construction sites, namely 80 dBA measured at 25 feet from the source from 7:00 a.m. to 7:00 p.m. and 75 dBA measured at 25 feet between 7:00 p.m. and 7:00 a.m.

Acoustical Treatment of Buildings

The small amount of state regulation in the construction field is directed primarily toward shielding individuals from noise rather than toward restricting noise at its source. The New York State building code sets standards for sound retardation in new apartment buildings. Hawaii requires school officials to acoustically treat schools so as to insulate students from the effects of transportation noise. California forbids new freeways that increase the noise in existing schools, although state officials may acoustically treat the schools so as to prevent an increase in the noise experienced by students.

Other Noise Sources

Noise that disturbs the peace is specifically prohibited in 20 states, with 14 delegating this authority to municipalities. The states provide penalties for violations to a greater degree in this area than any other. A few states regulate commercial noise in some way. Mississippi, New Jersey, and Nevada delegate this power to localities, while Delaware and Texas restrict noise from businesses dealing in alcoholic beverages.

Trends and Gaps in State Legislation

More states are entering the field of noise regulation. The number of sources restricted by any one state is also expanding. The trend in the area of state regulation is toward more sophisticated, objective laws enforced by environmental agencies. States tend to adopt laws that set progressively stricter standards over specified time periods and often direct their laws at the manufacturers.

Despite these encouraging signs, there are still gaps in state regulation. Aircraft noise is not restricted except in California.* Colorado has taken the steps only in the direction of control of railroad and construction site noise, and industrial and commercial noise is hardly regulated on the state level. This is also true of household noise.

With some exceptions, states have not been experimenting with new methods of regulating noise. In particular, there has been a noticeable failure to employ land use policies to limit the effects of noise. The single exception to this appears to be the Minnesota statute, which provides for state control over zoning around new state-owned airports. This type of implementation technique could be used to a much larger degree by state governments.

Noise Sources Regulated at the Regional Level

The only significant regional regulation of noise sources is the limit on aircraft takeoff noise imposed by the Port of New York Authority, which operates Kennedy, La Guardia, Newark, and Teterboro Airports in the New York City vicinity. Takeoffs are not permitted if atmospheric conditions and operating procedures would cause a limit of 112 PNdB to be exceeded at certain measuring points near the airport.**

* But see following discussions regarding division of Federal, state and local powers.

** The suitability of these rules as effective measures has been challenged by nearby communities.

Noise Sources Regulated on the Local Level

The information in this portion of the report is based on data gathered from 83 local governments. Many large cities are represented, as well as smaller communities.

General Noise Laws

Better than two-thirds (69 percent) of the 83 cities examined have either no noise laws whatever (12 cities) or only general laws covering noise from any source. The most popular type of general law is that patterned after the Model Ordinance Prohibiting Unnecessary Noises, issued by the National Institute of Municipal Law Officers (NIMLO). Over one-third of the cities examined have laws similar to this model ordinance. The model employs subjective criteria and prohibits loud, unnecessary, and unusual noise. Three cities have ordinances that differ from the NIMLO model but that apply similar subjective standards. Two other cities set a limit of 80 dBA at 20 feet, or 20 feet from the property line of the noise source. A number of cities combat noise through the use of public nuisance laws that label excessive noise as a public nuisance and provide for its abatement.

One of the most popular methods of noise control on the local level is the zoning ordinance, which sets limits on noise in designated residential, commercial, or industrial zones. Cities often include quantitative noise level standards in their zoning ordinances.

Transportation Noise

<u>Aircraft Noise</u>. Six of the cities in this survey place some restriction on noise from aircraft. These ordinances are of two types:

1. Those that undertake to limit nonflight activity.
2. Those that purport to limit operating noise from aircraft in flight.

In the first category, Denver restricts noise not necessary to flight, while Salt Lake City regulates noise in ground runup areas. In the second category, Santa Barbara, California, limits noise to takeoffs and landings as well as noise from runup areas and sonic booms. Scottsbluff, Nebraska, forbids any flight below 2000 feet. Park Ridge, Illinois, prohibits noise over 95 dBC in designated areas extending from the runways of O'Hare Airport. Portland, Oregon, limits noise from helicopters. A discussion of the validity of laws in the second category is presented elsewhere in this chapter.

Motor Vehicle Noise. Thirty-three municipalities examined require mufflers on motor vehicles, while 22 restrict horn noise and 12 cities set subjective limits, such as "unnecessary," on the total noise from vehicles. Three cities set objective limits in the 90- to 95-dBA range measured at 20 or 25 feet. Chicago and Minneapolis, in recently enacted legislation, set stricter noise limits on vehicle operation, as well as noise emission standards for new vehicles.

Specific provisions concerning noise from motorcycles were made by four of the cities examined. Missoula, Montana, and Detroit set subjective limits, while the new Chicago and Minneapolis laws restrict noise from operation and set a limit on noise from new motorcycles.

Other Transportation Noise Sources. Chicago regulates noise from boats in its new law, and Detroit restricts noise from whistles of steamers using its harbor. Generally cities have been slow to respond to snowmobiles as new noise sources. Chicago sets objective limits on these vehicles, while Dillon, Colorado, allows them only on marked trails – of which there are none.

Commercial Noise

Noise from commercial establishments or individuals acting in business capacities is widely regulated at the local level. The nonadvertising regulation in this area can be divided into five categories:

1. Regulation of business establishments (either all business or particular businesses).
2. Regulation of some particular accessory or device used by the business (such as noisy air-conditioning equipment) or some noisy aspect of the commercial operation (such as loading or unloading materials).
3. Regulation of musicians.
4. Regulation of music-producing machines.
5. Regulation of sound equipment.

Noise from advertising, especially the use of sound-producing or sound-amplifying equipment, is heavily regulated on the local level. Itinerant peddlars calling their wares, stationary sound equipment, and sound equipment mounted on vehicles and aircraft are either prohibited or subject to strict controls.

Occupational Noise

Two cities have objective decibel limits on the amount of noise to which workers may be subjected. The Detroit standards are identical to the Walsh-Healey limits previously discussed. Philadelphia has adopted standards that are less strict than the old Walsh-Healey limits, with the exception of the maximum limit placed on impact noise.

Construction Noise

Many cities regulate noise from construction sites, using curfews and zoning restrictions. Minneapolis sets a noise limit on the entire construction operation, while Chicago specifies noise limits on most types of construction equipment.

Acoustical Treatment of Buildings

Several cities have requirements concerning the acoustical treatment of buildings. The new New York City law on multifamily residential buildings sets limits on the noise that can be allowed to travel between two apartments and between apartments and public areas of the building. These objective limits are based on measurement standards adopted by various associations, such as the United States of American Standards Institute. Before a permit is issued approving the opening of the building to occupants, the Department of Buildings must be satisfied, as a result of either its tests or those of an independent firm, that the new building conforms to the limits.

Other Noise Sources Controlled at the Local Level

Disturbing the peace is heavily regulated on the local level. Some cities simply prohibit such behavior, while others impose curfew and zoning regulations. Domestic noise is beginning to come under regulation at the local level. The recent Chicago noise laws cover noise from various home products such as lawnmowers, power tools, and snowblowers by setting decibel limits for new products. Minneapolis sets a curfew on this equipment if noise from it causes the noise level at property lines to exceed specified standards. Sound equipment used for noncommercial activities is also heavily regulated. Some cities ban its use, while others require permits or set curfew and zoning restrictions. There are also local ordinances pertaining to noisy animals.

As with the states, more cities are developing programs to cope with excessive noise. Some have established noise abatement offices with special noise monitoring teams. City noise laws are becoming more sophisticated, substituting decibel limits for the former subjective standards. These laws also provide for tougher standards over time. As is true for the states, the success of city antinoise programs will depend upon enforcement of the new laws. Unfortunately, enforcement strains the already overburdened budgets of many of the nation's cities.

Trends and Gaps in Local Legislation

Noise has traditionally been regulated more often at the local level. However, with the increase in the general environmental noise levels of American cities in recent years, local governments have begun to adopt new laws to deal with this phenomenon. Like the states, cities have developed more sophisticated laws covering more noise sources. These laws are tending to include tougher standards over time and are often directed at manufacturers. Although the major noise sources are regulated at the local level, any one city does not have laws governing noise from every type of noise source. More cities must expand the number of regulated noise sources if local control of noise is to be more effective.

ANALYSIS OF EXISTING REGULATORY STRUCTURE FOR ENVIRONMENTAL NOISE ABATEMENT AND CONTROL

Legal Basis for Environmental Noise Abatement and Control Through Private Actions

Private Actions: Private Sector Noise Sources

The more conventional legal theories for abatement and control of noise in the judicial areas have been nuisance, physical trespass, inverse condemnation, and constitutional damaging. A plaintiff can recover damages on the nuisance theory if noise generated by the defendant results in a substantial interference with the use and enjoyment of the plaintiff's land, the usual measure of damages being the decrease in the value of such property. However, such determinations are made in the context of the particular case wherein the social utility of the noise-maker's activity must be weighed against the gravity of the harm to the plaintiff. In general, private actions in nuisance for damages or for injunctive relief have proved to be an inadequate means of controlling environmental pollution, including excessive and unnecessary noise. Industrial and commercial noise makers have been permitted, in effect, to treat such pollution as a social cost to be assumed by the general public, since the number and amount of court judgments against offending noise sources have not induced a substantial reduction in noise. In brief, such actions have been effective only to the extent that they have served as incentives for polluting activities to apply new managerial techniques or technological innovations to the abatement of adverse social impacts.

Private Actions: Government Sector of Government Authorized Noise Sources

In those situations wherein the government is the manager of facilities or the operator of activities producing noise or has formally sanctioned the operation of facilities or activities by private participants or entities, resort to the theory of inverse condemnation or the allegation of a constitutional taking has been increasingly employed as an alternative to a nuisance suit. The defense of legalized nuisance has proved a formidible barrier to recovery on the nuisance theory. The theory of inverse condemnation is a means of avoiding the obstacle of sovereign immunity. While inverse condemnation suits have been successful in several situations involving aircraft noise, controversy persists as to whether noise alone (as contrasted with physical trespass) is sufficient to justify recovery and, if so, whether noise-violated adjacent landowners can recover where no overflight takes place. A mild trend is perceptible toward recoveries for noise intrusion, especially in states having constitutional "taken or damaged" provisions, including recovery by adjacent landowners whose property has not been officially taken. It is necessary, however, to prove that the injury is peculiar to such adjacent landowner and not simply that he shares such intrusion with the community at-large.

Formal Authority for Governmental Control Over Noise Sources and Noise Effects

In view of the limitations of private suits in providing an adequate environmental noise quality control technique, various municipal and some state regulatory efforts have been undertaken, as noted previously; and more comprehensive regulatory schemes are now under consideration at all governmental levels. It is probable that the commerce power affords the Federal government sufficient authority to regulate most, if not all, noise sources at the national level. The traditional police power provides the basic formal authority for noise abatement and control measures at the state and local level. States have considerable latitude in the exercise of the police power, the essential test being whether there is a perceived public need to be satisfied and whether the means selected is reasonably appropriate to the achievement of this purpose. The exercise of the police power is subject to the further limitation that private property cannot be taken for public use without just compensation, a problem that has frequently posed difficulties for the courts. However, the development of adequate regulatory schemes for the control of noise should not raise serious questions with respect to Constitutional authority.

Distribution of Formal Authority Among Federal, State, and Local Jurisdictions

Illustrative Cases and Materials Relevant to the Commerce Clause and the Police Power

Assuming the basic authority of the commerce power (Federal) and police power (state/local) to impose effective controls over environmental noise sources, the question remains as to which level of government has authority to prescribe and apply which regulatory measures (ranging from source control to zoning and building codes) and under what circumstances. Useful guidelines as to appropriate distribution of authority between the Federal and state/local levels are provided by Supreme Court decisions following primarily the doctrine of "Cooley vs Wardens of the Port of Philadelphia" (1851). In determining whether the power of the Congress to regulate foreign and interstate commerce was exclusive or might be in part shared with the states, the Court in "Cooley" adopted a rule that placed a share of the control in the states, the test being whether a particular subject or activity of commerce requires uniform national control or whether it is sufficiently local (and unique) in character as to be more appropriate for state/local regulation. For example, a strong national interest has been asserted in railway regulation. In "Southern Pacific Co. vs Arizona" (1945), the Supreme Court, relying on the "Cooley" doctrine, held that the Arizona Train Limit Law (limiting train length) contravened the Commerce Clause, the majority opinion stating that "Here examination of all the relevant factors makes it plain that the state interest is outweighed by the interest of the nation in an adequate, economical, efficient railway transportation service, which must prevail." But a strong state/local interest has been recognized in the regulation of the use of interstate as well as state highways. In "South Carolina State Highway Department vs Barnwell

Bros." (1938), a state statute limiting the width and weight of motor trucks, which was more restrictive than those of most other states, was held not be an undue burden on interstate commerce even though "Interstate carriage by motor trucks has become a national industry." The Court stated: "Few subjects of state regulation are so peculiarly of local concern as is the use of state highways." But compare "Bibb vs Navajo Freight Lines, Inc." (1959), wherein the Supreme Court found an Illinois contour mudguard requirement for motor freight carriers to be in conflict with the Commerce Clause even though such local safety measures are normally not found to place an unconstitutional burden on interstate commerce.

The "states and their instrumentalities may act, in many areas of interstate commerce, . . . concurrently with the Federal government' and "Evenhanded local regulation to effectuate a legitimate local public interest is valid unless preempted by Federal action, . . . or unduly burdensome on . . . interstate commerce . . . ." In general, preemption by Federal legislation is not to be inferred "unless the act of Congress, fairly interpreted, is in actual conflict with the law of the state."

Illustrative Federal Environmental Quality Control Legislation

Evolving regulatory schemes for the abatement and control of environmental noise will be shaped not only by the authoritative Constitutional decisions apportioning Federal-state-local power but also by emerging public attitudes as expressed in formal governmental policies toward environmental quality and the recent legislation designed to institutionalize effective supporting programs. The implementation of the National Environmental Policy Act of 1969, requiring the submission of environmental impact statements on all Federal actions significantly affecting the quality of the human environment, has given strong impetus to the consideration of environmental effects of public programs. The Airport and Airway Development Act of 1970 will certainly require consideration of the noise factor when new airports are located or existing facilities are modified. Provision for citizen suits in Section 304 of the Clean Air Amendments of 1970 establishes a regularized channel for formally asserting complaints.

Most of the new environmental quality legislation pays appropriate respect to state and local prerogatives as does, for example, the Environmental Quality Improvement Act of 1970, which states that "The primary responsibility for implementing this policy rests with state and local governments." But a striking characteristic of the new legislation is the emphasis placed on cooperative efforts among agencies at the same level of government, among the various levels of government, and between public and private sector entities, as illustrated by the Water Resources Planning Act of 1965. Whether this intent will mature into effective inter-entity working relationships is, of course, another matter. Since the Federal government is establishing national standards in given areas (for example, ambient air quality standards and standards regarding emissions of air pollutants from aircraft), it is to be anticipated that difficult problems of preemption or of conflict arising from other formal or informal actions may arise unless there is, in fact, dedicated and knowledgeable cooperation among the various levels of government.

Distribution of Power Among Federal-State-Local Jurisdictions with Respect to Environmental Noise Abatement and Control

Regulatory Scheme for Aircraft Noise Abatement

Federal Aircraft Noise Abatement Policy and Regulations. As discussed earlier in this chapter, the authority to prescribe rules and regulations for the control and abatement of aircraft noise was granted the Administrator of the FAA by amendment of Title VI of the Federal Aviation Act of 1958 (Public Law 90-411). One of his first acts was initiating the noise abatement regulatory program of the FAA by promulgating Part 36, an amendment to the Federal Aviation Regulations, prescribing noise standards for the type certification of subsonic aircraft.

State Aircraft Noise Regulation – Including Transportation Authorities. The general policy guidance at the Federal level for distribution of authority among Federal, state, local, and private entities with respect to the abatement and control of aircraft noise has not been adequate to decide many practical questions such as: who can control what by applying which techniques, under what circumstances, and pursuant to what authority? The situation tends to be further confused by considerable loose language in both official reports (policy statements) and in the legal-regulatory commentaries concerning "control over aircraft noise." Frequently, little effort is made to distinguish abatement at the source (noise emitted from the aircraft), abatement through operational procedures, abatement of the effects of aircraft noise through specific implementation techniques, abatement of airport noise through multiple techniques, penalties for noncompliance with airport regulations, and remedies for damage caused by aircraft noise.

A few states have undertaken to establish some measure of regulation over the effects of aircraft noise despite the risks of their eventual negation through a judicial finding of Federal preemption or of conflict with the Commerce Clause. One technique has been to establish an authority (intrastate or interstate) that operates an airport or airports in a proprietary capacity, as distinguished from governmental operation, so as to take advantage of the legal concept that a state or municipality can fix permissible levels of aircraft noise as the proprietor of an airport that it would not have the authority to fix in its governmental-legislative capacity. The sensitivity of the states to Federal preemptive legislation regarding air traffic safety (in-flight, takeoff, and landing operations) and aircraft noise standards (§611) is illustrated by the comprehensive California regulations on noise standards for airports, which are "based on two separate legal grounds: (1) the power of airport proprietors to impose noise ceilings and other limitations on the use of the airport, and (2) the power of the state to act to an extent not prohibited by federal law." This effort goes primarily to the encouragement of compatible land use near airports, so as to preserve the utility of the airport to the community while achieving environmental compatibility.

Regulation of Aircraft Noise by Private Actions and Local Ordinances. If states are seriously inhibited from control over aircraft noise sources, it is evident that local governments and private citizens can expect little success with the legal recourses of municipal ordinances and common law remedies. Judicial experience since the early 1950's tends to confirm this proposition. Several local ordinances undertaking to regulate the altitude (and thus flight patterns) of scheduled interstate aircraft have been struck down (commencing with "All American Airways, Inc. vs Village of Cedarhurst" (1953), wherein the municipality had enacted an ordinance making it a criminal offense to fly aircraft over the village at altitudes under 1000 feet, on the rationale that the Federal government has preempted the regulation of such flight in the interest of safety and that such local restrictions place an undue burden on interstate commerce. While a few courts have demonstrated a degree of tolerance for local ordinances establishing nighttime curfews under special circumstances (small airport with no interstate scheduled air carriers, for example), courts that have considered such ordinances tend to be highly sensitive to the interstate commerce implications, especially if scheduled interstate air carriers use the airport. Stress is often given to such propositions as "air traffic is unique and should be controlled on the national level" or that "solution of problems in air transportation at the local level just does not work. It has to be done on a national basis because it is a national operation."

It is of interest to note that in the context of the "Griggs" case of 1962 (wherein the plaintiff, in a private action based on inverse condemnation, recovered damages from the airport owner-operator by alleging that the flights of commercial aircraft over the plaintiff's home caused excessive noise, fear, and physical damage) the Supreme Court majority minimized the Federal regulatory role and emphasized the function of the airport owner-operator in the design, implementation (including the acquisition of navigational easements), and operations of the airport. But even though there have been several successful inverse condemnation cases, it is obvious that this remedy is not suitable for coping with the distress suffered by large numbers of people residing in or near busy airports. As the court concluded in the 1969 New Jersey case of "Township of Hanover vs The Town of Morristown" (wherein the plaintiffs sought to enjoin the Town of Morristown from enlarging its airport because of the anticipated increased noise): "private compensatory damage suits do not accomplish the end objective of noise suppression."

The likely invalidity of control by local ordinance and the general inadequacy of spasmodic private suits in inverse condemnation to provide adequate noise regulation has pressed many airport operators into the application of alternative abatement measures such as the use of preferential runways. This, of course, is also a marginal means of noise suppression. Thus, certain high density air traffic states such as California have taken or considered action that will make some small further contribution to aircraft and airport noise abatement.

Implications of the Griggs Doctrine: Federal, State, Local and Private. The "Griggs" decision placed the locus of liability for aircraft noise on the airport operator and thus relieved the Federal government and the scheduled air carriers from liability. Thus, there was no pressing incentive for either the Federal government or the air carriers to take drastic noise abatement action, even though both recognized the growing seriousness of the problem. A Congressional report conceded in 1962 that the lack of a "maximum noise" criterion established by the Federal government was a "deterrent to manufacturers to achieve greater noise suppression." Competitive considerations precluded the allocation of substantial research support to noise abatement by the aircraft engine manufacturers, the objective being to "build engines and aircraft (with) maximum performance characteristics without regard to noise." In short, the authority of the "Griggs" decision obstructed the coordinated efforts required of all affected participants called for by the Office of Science and Technology Jet Aircraft Noise Panel in 1966. Further, Congress has given careful attention to the possibility of the Federal government's indemnifying all airport operators throughout the U.S. against judgments obtained against them for noise damage alleged under the "Griggs" doctrine and has found this to be "impracticable." Not until the promulgations of the FAA noise standard regulations of 1 December 1969, pursuant to §611, did the aircraft engine manufacturers and the airlines have a compelling incentive to introduce noise reduction criteria into their planning and operations.

The Relationship of the Proprietorship Doctrine of Control to Alternative Aircraft Noise Abatement Techniques. Pervasive Federal regulation of air transportation has essentially precluded effective control over the abatement of aircraft noise by State and local governments. On the other hand, the Federal government has not accepted a level of responsibility for aircraft noise abatement (in terms of timely R&D and regulatory measures to reduce noise at the source) that corresponds to the magnitude of control it exercises over air transportation. Yet, the "Griggs" doctrine places liability for aircraft noise on the airport owner-operator, who is, in most situations, a State or local governmental entity. Furthermore, the threat of massive damage awards is clearly increasing for the obvious reasons that the aircraft noise situation is worsening in many areas and that complainants are finding that some courts share a growing sympathy with their situation. While it may be generally agreed that air transportation must be regulated at the national level, the lack of a corresponding national effort to abate one of its most distressing side-effects encourages resort to the courts as the only means of prodding, indirectly, the Federal system into action.

However, since the states and municipalities, as airport owners-operators, must bear the direct and immediate burden of complaints from the public, they have seized upon whatever interstitial measures are available (governmental, technical, economic, etc.) to lessen the impact of community complaints and noise damage judgments. Notable in this connection is the doctrine of proprietary control over airport operations, which has its source in ownership or operational status as distinguished from the operation of the airport by a State or local governmental entity in its governmental capacity. While the Port of New York Authority has been able to maintain noise standards set by itself (less stringent, however, than FAA standards for new aircraft) and the California regulations on noise standards for airports are essentially grounded on the "power of airport proprietors," this regulatory technique is severely limited. This is particularly true for short-term relief, since most major hub ports are now situated in densely populated areas and proprietor control over noise reduction at the source is essentially nonexistent. The FAA has clearly preempted aircraft operations as to safety. As to noise, the airport operator is left with whatever marginal control he can exercise through such a measure as "planning runway utilization schedules to take into account adjacent residential areas, noise characteristics of aircraft and noise sensitive time periods," which is provided, among other methods, in the new California noise regulations for airports. While the proprietary doctrine may provide the airport operator some small but useful bargaining leverage vis a vis the Federal government in the present evolutionary phase of aircraft noise regulation, it is based on an anomalous legal assumption, the future efficacy of which is in doubt; namely, that an instrumentality of the state, acting in a private, nongovernmental capacity, has a degree of control over the activities prescribed in its state-originated charter that the state itself is precluded from exercising in particular preemptive situations; i.e., regulation of aircraft operations.

Regulatory Schemes for Abatement and Control of Environmental Noise Sources and Effects other than Aircraft Noise

The Analytical Framework. The analysis of existing modes of environmental noise regulation and the evaluation of the design of new regulatory schemes requires that a structured set of questions be addressed involving such factors as formal authority, limitations on authority, and implications of the proposed action. These inquiries will differ somewhat, depending upon the governmental level proposing noise source and effects regulation. Relevant questions at the State level might include:

1. Authority asserted to justify enactment of the legislation?
2. Limitations of authority likely to be asserted with respect to such statutory schemes?
   a. Preemption by Federal legislation?
      (1) Field completely preempted?
      (2) More stringent standards precluded?
   b. Due Process limitations?
      (1) Not reasonable means to a legitimate end
      (2) Discriminatory and violative of equal protection
      (3) Vagueness
   c. Encroachment on free expression?
   d. Encroachment on other individual liberties?
   e. Threat to other significant social values such as safety, efficiency of operation, community economic well-being, etc. ?
   f. Technological feasibility?

g. Economic reasonableness?

h. Undue burden on interstate commerce?

3. Implications for local noise regulation with respect to:

a. Criteria and standards?

b. Participants affected?

c. Implementing techniques?

d. Enforcement procedures?

e. Remedies and penalties?

f. Local ambient noise levels?

4. Implications of noise level standards on judicial determinations of a Constitutional taking or of a State constitutional "taking or damaging."

Private Actions: Suits Grounded in Nuisance, Trespass, and Compensable Taking or Damaging. It is clear that private civil actions at best can constitute only one important means, among many, for effective regulation of noise. Courts have been wary of extending recognition to noise intrusions. Some courts consider noise to be an incident of living in a technologically oriented society and that noise is an inconvenience that is, and must be, shared by all. Other courts are more disposed to recognize noise abuse but are troubled by the problem of limiting liability, such as by determining satisfactorily which claimants suffer special damages. Further, noise disturbances from many of the more serious noise producing sources, such as the construction and use of highways, cannot be alleged as the basis for damages in certain states since such states provide that "nothing which is done or maintained under the express authority of a statute, can be deemed a nuisance." Nevertheless, over the years numerous suits have been initiated against a variety of community noise producing sources that interfere with the use and enjoyment of property.

There is a more perceptible trend for courts to recognize damages resulting from noise intrusion in taking or inverse condemnation suits, particularly with reference to highway construction and use. However, most courts have held that noise from this source is not compensable where there has been no physical taking of any part of the complainant's property. Where there has been an actual taking or severance of the claimant's property, there is a split in court decisions among the various states. The tendency seems to be, however, to consider noise as a factor in determining consequential damages where there has been a taking. In the 1968 "Dennison" case the New York Court of Appeals stated that "where there has been a partial taking of property of the kind taken here, the noise element may be considered as one of several factors in determining consequential damages." The type of property taken may be decisive, noise more likely to be considered as a factor in the overall diminution of the value of the property if the property's purposes are devoted to seclusion and quietude. What impact the aircraft noise cases recognizing noise intrusion with respect to adjacent landowners will have on the recognition of claims of abutting landowners to highway construction and use is still uncertain. Florida has rewarded the aircraft noise claimant but denied recovery to the highway noise claimant.

Noise Regulation through Municipal Ordinances. Local ordinances directed explicitly to, or inclusive of, noise pollution include those designed to preserve the public peace and tranquility, to abate noise as a nuisance, or to control noise levels through zoning. Where an ordinance is directed to noises or noise sources in general, the elements of a common law nuisance must ordinarily be shown to justify damages or injunctive relief. Noise ordinances may face various legal challenges: whether the standard is unconstitutionally vague or discriminatory or is administered in a discriminatory manner; whether the ordinance encroaches upon the freedom of expression or other individual rights; whether the ordinance seriously interferes with the safety of operations of the noise source or comes in conflict with other priority social values; whether the requirements of the ordinance are technologically feasible and economically reasonable; whether the ordinance addresses an area of activity that has been preempted by the state or Federal government; or whether the ordinance, absent Federal legislation, imposes such a heavy burden on a national activity or interest, such as the free flow of commerce, that it constitutes an unreasonable burden.

Ordinances regulating sound trucks raise many of the foregoing questions. However, the Supreme Court held in the 1949 Sound Truck case, "Kovacs vs. Cooper", that the standard of "loud and raucous" was not so vague and indefinite as to be properly enforced, since it conveyed to any interested person a sufficiently accurate concept of what was forbidden. Quantitative standards (prescribed decibel sound levels in decibels) avoid the problem of unconstitutional vagueness but do not necessarily facilitate the enforcement of noise standards. The cases show that verbal (subjective) standards such as "unusual and excessive" have generally been upheld as applied to both local ordinances and state statutes requiring mufflers or relating to the operation of motor vehicles. While the reported cases do not specifically deal with traffic routing within urban areas in terms of noise, such ordinances have been upheld unless the state, by terms of its constitution or by legislation, has preempted control over vehicular traffic, even within municipalities.

Comprehensive city codes, such as that proposed for New York City, attempt to retain the benefit of common law nuisance precedents by prohibiting unnecessary noise while at the same time setting specific decibel limits for the principal noise producing devices or sources. Provision for noise-sensitive zones is an attempt to assure that future land use planning will be environmentally sound with respect to noise. Many provisions of such codes, being new, are still to be litigated.

It appears that most of the challenges to local noise ordinances as undue burdens on interstate commerce have arisen in the air transportation field. Such ordinances in other areas, if not clearly unreasonable burdens as applied by one community, may be judged by the test of whether a given ordinance, if adopted by a large number of municipalities, would impose unlawful burdens.

State Environmental Noise Regulatory Schemes. State regulation of noise has been relatively minor until recent years, with the exception of vehicle muffler and exhaust noises. An interesting question is arising, with the shift from verbal to quantitative standards, as to the efficacy of the older statutes (left undisturbed by new legislation) prohibiting excessive or unusual noise. The New York Court of Appeals has held that in such circumstances "the two (statutes) stand side by side. One now sets a limit beyond which no vehicle noise may go while the other requires each motorist to minimize the noise his particular vehicle makes within that limit." This interpretation raises interesting possibilities for more stringent and refined control over noise sources than set by maximum allowable decibel levels. However, state control over vehicular noise has raised serious questions (and confusion) in several states as to preemption of local control, especially in instances where the state standard is clearly inadequate for the monitoring and control of urban vehicular noise. Where states do undertake comprehensive environmental noise regulation, the preemption status should be clarified. However, some new State legislation completely ignores preemption implications for local governments.

New State environmental noise legislation should also give careful consideration to the implications for interstate commerce. Operators of trucks and busses (moving interstate noise sources) are particularly concerned about the possible lack of uniformity, arguing that they "should not be faced with an increasing problem of having wide variations in noise limits, test procedures, equipment and interpretation of the regulations." Reference to "Bibb v. Navajo Freight Lines, Inc." suggests that even though local safety measures (and presumably, environmental quality measures) are not normally found to place an unconstitutional burden on interstate commerce, unless the states should enact approximately equivalent vehicular noise standards (as to decibel levels and effective dates), that litigation involving the Commerce Clause is likely to arise. But in addition to the test of whether a given ordinance or state statute undertakes to regulate matters "admitting of diversity of treatment, according to the special requirements of local conditions," are the factors of delay or inconvenience to interstate carriers, safety, technological feasibility, economic reasonableness (including the availability, cost and effectiveness of alternative protective measures), and "the nature of the menace against which (the ordinance or statute) will protect.". . ."Legislation, and implementing standards-setting administrative procedure, which does not take these factors into account may well be vulnerable to either Due Process or Commerce Clause challenge.

Federal Environmental Noise Regulatory Schemes. In addition to the §611 amendment to the Federal Aviation Act of 1958, the Walsh-Healey requirements, the Occupational Safety and Health Act of 1970, and the 1970 amendment to the Federal-aid Highway Act (PL 91-605), the Federal government has given notice of impending, comprehensive environmental noise legislation in the Noise Pollution and Abatement Act of 1970. Of major interest is the present status of the Administration's proposed legislation (HR-5275, S-1016—The Noise Control Act of 1971). The Administration proposed to give EPA overview and veto authority regarding aircraft noise. However, this proposed legislation has been revised by the House Committee on Interstate Commerce to provide only for a consultative EPA role concerning that agency's dealings with the FAA regarding the solution of this major noise problem.

EFFECTIVENESS OF EXISTING NOISE CONTROL REGULATIONS

Effectiveness of Existing Federal Regulations

Aircraft Noise

FAA Type Certification of commercial aircraft delivered after 1 December 1969, under Part 36 of the FAA Aircraft Regulations, is the most significant Federal action for control of aircraft noise. The DC-10 and Cessna Citation 500 have been certificated, and the L-1011 and all subsequent subsonic aircraft will have to comply with Part 36. The Boeing 747 was granted a type certificate in December 1969, which allowed noise levels in excess of the requirements of Appendix C of Part 36 of the FAA regulations. However, aircraft produced after December 1, 1971 must comply with Part 36, Appendix C. Allowable Noise Level Limits.

Projections by the Air Transport Association estimate that by 1975 only 18.6 percent of the fleet will have been certificated under Part 36, and even this is probably optimistic given present economic conditions that will retard aircraft replacements. Thus, to the extent that it depends upon type certification as presently structured, the noise problem will have been only slightly relieved by 1975 and, indeed, could still be significant as late as 1990.

Noise has an environmental impact and must be considered in 102(2) (C) Environmental Impact Statements for airport development and modification.* While there are

* The reader is referred to testimony before EPA hearings held in San Francisco regarding views on the efficacy of the 102(2)(C) statement provisions.

no Federal noise standards for airports, the Airport and Airways Development Act requires consideration of environmental interest of communities near airports and provides for public hearings, if requested, on airport projects. But examination of project proposals on file with the FAA reveals that hearings have been held in only 29 percent of the cases, and in few of these has noise been raised as an issue. This suggests that whereas public hostility to proposed or expanded airports near already congested aviation hubs is high and growing, communities in other parts of the country are still more alert to potential economic benefits from airports than to possible noise problems. This may tend to prevent full utilization of promising planning and zoning techniques for controlling future noise problems.

Highway Noise

Environmental Impact Statements must also be provided for proposed highways. The 1970 Amendments to the Federal-Aid Highway Act requires the Secretary of Transportation to withhold approval of highways until specifications include adequate implementation of appropriate noise standards. Noise guidelines will not be issued until 1 July 1972, but early drafts are promising. Only 4 percent of the National Interstate and Defense Highway System remains in preliminary stages as of 30 June 1971, but an Urban System (funded for FY 1972 at $100 million) will be built under the new standards.

Occupational Noise

Regulations of May 20, 1969, pursuant to the Walsh-Healey Public Contracts Act, set noise limits for employees of Federal Supply Contractors. These apply to 75,000 plant locations (about 27 million workers). As of 27 August 1971, the Walsh-Healey noise standards have been extended by the Occupational Safety and Health Act of 1970 to all employees in businesses affecting interstate commerce (55 million additional workers).

Since 7 July 1971, the Bureau of Mines, under the Federal Coal Mine Health and Safety Act of 1969, has imposed mandatory noise limits (identical to the Walsh-Healey standards) for approximately 100,000 miners in 1900 registered underground mines. Regular monitoring is assigned to mine operators, with the Bureau of Mines providing their training and providing a check through noise surveys conducted during quarterly safety and health inspections.

Effectiveness of Existing State Regulations

Airport Noise

California has taken the lead in setting overall noise limits around airports by legislation (1969) empowering the State Department of Aeronautics to set standards both for overall airport noise and for single-event noise. These regulations were to become effective on December 1, 1971 but have been held in abeyance by the 1971 legislature. When put into effect, they will allow large airports 15 years to shrink noise contours to what has been defined as the acceptable level applicable to all airports under the statutory standards of "noise acceptable to a reasonable person living near the airport" and "economically and technologically feasible." Some difficulties with enforcement and effectiveness can be foreseen.

Some airport officials allege that, unless the fleet is substantially converted to quieter planes within this 15 year period, it may be necessary to curtail operations considerably or else to make major purchases of land. The former measure would have major repercussions for national air transportation patterns, while the latter could lie well beyond the financial capacity of the airport.

The law may be challenged in court by the airlines on the grounds of Federal preemption and unreasonable burden on interstate commerce. California holds that there is no preemption in the absence of Federal rule making on airport noise levels and that the standards are firmly grounded on the proprietorship of airport owners and the right to the state to license airports.

There is a possibility that acceptable noise contours established by the regulations will be used by courts as evidence for inverse condemnation, although the Act provides that they shall not be so used. The California Law Revision Committee favors a three-year moratorium on such use and a bill to establish this moratorium was passed by the state legislature.

The single-event limit was deliberately set so high as to be effective only in controlling operating procedures of existing aircraft, rather than as a push for technological improvement. Enforcement is left to the county in which the airport is located. In many states, unfortunately, airport noise impacts most detrimentally on counties adjacent to, but not containing, the airport; and in considering similar legislation states should take this into account.

A number of other states, in considering similar legislation, appear to be awaiting the outcome of California's pioneering effort. With the reservations noted above, this model may be widely adaptable to states with significant airport noise problems.

Twenty-five states own and operate airports, of which some 300 are served by scheduled air carriers, and can exercise some control over them as proprietor. The bistate Port of New York Authority has done the most in this area, by establishing maximum noise levels. This regulation is effective in terms of compliance, the overall rate for which is 99.5 percent, with 80 percent of takeoffs below 105 dBA. Violation rates are much higher, however, for heavily loaded transoceanic jets. In terms of noise reduction, however, it is only marginally effective; the violation rate is low because the limit is high.* There is also alleged to be systematic cheating by aircraft, in which they momentarily cut power as they pass the monitoring equipment. Furthermore, airport operators have no authority over landing procedures, since these are controlled by FAA — and landings, due to long glide paths, subject larger numbers of people to noise than takeoffs. The Port of New York Authority reports that 80 percent of complaints are produced by landings.

Restrictions on the number of night flights are effective in reducing complaints but are seriously restrictive of transportation because of national and international time differences. Moreover, congestion at some airports has reached a point at which safety considerations may dictate more, rather than fewer, night flights.

The fiscal conditions of most state and local governments, the shortage of housing in large metropolitan areas, and the large land areas that are noise-impacted combine to limit the effectiveness of land purchase or strict zoning of land around existing

* Testimony received at the EPA hearing in Hempstead, Long Island indicates that no punitive enforcement actions have ever been taken against any airline.

airports. In the case of new airports, however, land-use techniques such as industrial buffer zones appear to have considerable promise. *

Vehicle Noise Programs

Most states prohibit modified or defective mufflers, but few or none systematically enforce this prohibition in spite of quantitative evidence that rigorous enforcement would significantly reduce vehicle noise levels. California has the most comprehensive operating vehicle noise law, but the level of enforcement even there is low, since 6 two-man teams are responsible for 162,303 miles of highways. During a 12-month period, 600,000 vehicles were monitored and violations were charged for 0.5 percent: 0.1 percent of passenger cars, 1.2 percent of trucks, and 2.0 percent of motorcycles. (California had 11,980,000 registered motor vehicles in 1970.) There is no record of the number of cases taken to court (this is a minor offense carrying a fine of $25 or less), but the Highway Patrol states that most citations have resulted in convictions. Through July 1971, some 2,200 citations were issued within California for excessive vehicle noise. The state population is greater than 20 million. The low percentage of violations probably does not indicate the effectiveness of the law but indicates the inadequacy of the standards set. The Highway Patrol has indicated that it would support standards that would cause 7 to 8 percent of presently operating vehicles to be in violation, on the grounds that 93-percent compliance indicates technical feasibility. The legislature is presently considering these and even stricter standards.

* An extensive discussion of past, present, and future land use planning efforts at major airports is contained in the transcript of the EPA Noise Hearing, Washington, D. C.

A similar law in New York State has a lower level of enforcement. No special enforcement teams are provided, and one observer puts the number of summons issued at six in the first 2 years.

California sets noise emission limits for new vehicles, but requires testing only when an operating violation has been charged to a new or current-year model. Some vehicles have been recalled for fitting with improved mufflers, but the manufacturers' right to sell has not yet been revoked for excessive noise emissions. Vehicle laws of two other states are too new for comment on their effectiveness.

Besides the insufficient strictness of standards, existing state controls on noise from operating motor vehicles appear to be ineffective because of:

1. Technical difficulties in monitoring noise sources. In New York, statutory limits apply to vehicles traveling at less than 35 mph, rather than to vehicles in zones with speed limits of 35 mph (as in California). By using zones, the enforcing officer can presume rather than prove the speed of the vehicle being cited for violation. A more serious constraint is the California requirement of 100 feet of free space around both the monitoring microphone and the monitored vehicle; and (in California and New York) the requirement that noise be measured at a distance of 50 feet from the center line of the highway. Both requirements are for the purpose of separating and identifying specific noise sources and avoiding reflected sound from nearby buildings or other objects. but both make it difficult or impossible to monitor vehicles on city streets where the worst problem exists. Idaho has tried to make its muffler law more effective by specifying that mufflers must prevent noise over 92 dBA at a specified

distance, but the law is not enforced because vehicle inspection is done in state-licensed commercial garages where there is no sound measuring equipment.

2. Assignment of enforcement responsibility to regular police officers. State and local police universally give higher priority to safety and criminal investigation and apprehension than to noise control; observers also report that police rapidly lose proficiency with sound measuring equipment when it is seldom used, and then become even more reluctant to use it. *

3. Disregard of noise sources other than that from engines and exhaust systems. There is substantial evidence that much of vehicle noise comes from tires and running gear, but California police (contrary to statutory provisions) do not cite where noise is attributable to such causes; this is probably true in other jurisdictions also.

4. Low probability of monitoring and apprehension and relatively insignificant penalties. This is probably the most important cause of ineffectiveness.

Other Antinoise Regulation by States

State laws defining noise as a nuisance are generally enforced infrequently, and seldom or never against major sources of noise such as factories, transportation equipment, and construction sites. Statutory noise limits on leisure vehicles such as

* The reader is referred to testimony given at EPA hearings in Dallas, Atlanta, San Francisco, and New York regarding police officer attitudes on assignment of noise responsibilities.

snowmobiles are most often enforced by game inspectors and conservation officials, and there is no data available on levels of enforcement. Some snowmobile clubs are enforcing noise limits on their members to moderate or avoid public reaction to these noisy vehicles.

Effectiveness of Existing Local Noise Control Regulation

In dealing with noise problems, local governments frequently express a need for technical assistance in the form of advice, guidelines, model ordinances, and financial aid from states or the Federal government. However, they are also jealous of their prerogatives in setting stricter standards than the larger jurisdictions may choose.

Aircraft Noise

Except for a few curfew laws, attempts by local governments to prohibit or restrict aircraft noise have generally been struck down. A few remain on the books but are not enforced. There are over 1,000 pending noise suits against airports; usually a local government is the defendant in such a suit, and in some cases the plaintiff is another (neighboring) local government.

Vehicle Noise

In Hawaii and (it is generally assumed) in California and New York, local governments are preempted by the state from control of vehicle noise, although state laws in the latter two states are poorly enforced for reasons given previously. In Colorado, local governments may now adopt noise standards provided in State law.

The relatively few municipalities that have quantified noise standards for vehicles report the following problems with enforcement:

1. Difficulty in setting standards that are both technically feasible and yet strict enough to be effective, particularly because cities have limited budgets and a great scarcity of technically trained personnel. City officials frequently express a need for Federal or state guidelines and technical assistance in setting standards, as well as in establishing enforcement procedures.
2. Technical difficulties in separating and identifying individual noise sources on crowded city streets with a generally high ambient noise level. These difficulties also prevent enforcement of State noise laws on city streets.
3. Lack of personnel and equipment for systematic monitoring and enforcement. Again, as has been pointed out, police place higher priority on other duties.

Some local governments are experimenting with new vehicle noise standards. But here they face a particular difficulty in that a large fraction of the vehicles using the city streets are probably purchased elsewhere: within metropolitan areas there are generally many local governments, many contain several counties, and some straddle state boundaries.

Levels of enforcement of muffler or horn-blowing laws and general nuisance laws (as used against vehicles) vary widely. Few cities can provide data on enforcement actions, since there is generally no index of general citations and usually no compilation of city court cases. Where a high level of enforcement and effectiveness is reported (as in Memphis and Boulder), city officials attribute this to a high level of priority on the part of city officials and police, and an educational campaign to sensitize the public to vehicle noise. Such educational programs are reported to have lasting effects on driving habits.

Mass Transit Noise

This is a major factor in large cities. Mass transit facilities often represent a large capital investment in aging and deteriorating stock and equipment, for which the cost of acoustical treatment would be very high. For example, in New York City, an effective method has been developed for reducing subway noise by replacement of track—but only four miles are replaced each year out of a total of 750 miles of track.*

General Nuisance Laws

Few statistics are kept by cities on enforcement of nuisance laws. Police control noise on the basis of complaints, and frequently depend on persuasion and warning rather than official action. Where enforcement against unnecessary noise or excessive noise depends on discretion (in the absence of quantitative standards) statutes are sometimes struck down. Decibel limits, where tried, suffer from the difficulties outlined above for vehicle noise standards. And it is even more difficult to establish reasonable limits for the variety of sources covered in general noise laws. Educational programs can greatly enhance the effectiveness of noise laws by sensitizing citizens both to their duties and to their rights to a quiet community.

Comprehensive Noise Ordinances and Offices of Noise Abatement

These represent a new and small, but growing, trend for municipalities as small as Inglewood, California (population 90,000) or as large as New York City. They offer the following advantages:

* Details are contained in testimony given at EPA hearings held in New York City.

1. A directorate whose primary responsibility is noise abatement.

2. Investigators specifically responsible for responding to noise complaints.

3. A staff with initiative to seek out noise violations and proficiency in using sound measuring equipment.

4. A focal point for mounting a public education campaign.

Costs of such operations are not necessarily large ($60,000 annually in Inglewood and $300,000 currently in New York City) but may nevertheless be a strain on limited municipal budgets. Both New York City and Chicago plan to use about 40 to 50 investigators for noise enforcement.

*Zoning and Building Codes**

Inclusion of noise standards in zoning codes is generally recent, and most are not well enforced. Many cities with quantitative noise limits in zoning codes have no measuring equipment for enforcement purposes, and there is again a need for guidelines in formulating workable standards. Standards are useful for planning and zoning commissions in screening applicants for industrial locations. Few cities have noise standards in building codes. New York City has them, but no buildings completed under the new code have yet been occupied.

Construction Noise

Experience with local control of construction noise is largely restricted to curfew laws, which are often relaxed on a plea of convenience, particularly where daytime traffic is a problem. This is one of the biggest gaps in local noise control.

* The reader is referred to detailed testimony on this subject given at EPA hearings held in Dallas, San Francisco, and New York City.

SUMMARY

There are some general observations that can be made regarding the laws and regulatory schemes for noise abatement and control:

- With regard to aircraft noise, there is a jurisdictional problem.
- State statutes exhibit increased technical proficiency in understanding the evolving technologies for noise control as compared with city ordinances. However, states are constrained in many instances by Federal preemption of the regulatory field (an example being aircraft) or conflicts with interstate commerce matters or other Federal constitutional powers.
- City ordinances are, in general, vague and technically deficient. However, as the awareness of the noise problem increases, some city ordinances are becoming more sophisticated through the use of objective standards with decibel levels.
- The courts are becoming increasingly involved in the controversies over noise control. In general, however, private suits for money damages have not accomplished a great deal regarding noise suppression.

One of the major problems on the state and local levels of government is that of enforcement. In general, noise statutes, no matter how well written, are rendered ineffective because most state and local programs are insufficiently funded and staffed.

CHAPTER 5

GOVERNMENT, INDUSTRY, PROFESSIONAL AND VOLUNTARY ASSOCIATION PROGRAMS *

FEDERAL GOVERNMENT PROGRAMS

To discover the present extent of Federal activity in noise abatement and control and to accurately assess that activity, the Environmental Protection Agency's Office of Noise Abatement and Control conducted a survey of Federal agencies and departments. On the basis of program size and authority, the 17 agencies and departments were grouped into three general categories according to relative magnitude of programs: significant, moderate or minor. It was found that in addition to the Environmental Protection Agency, departments with significant involvement in noise included:

1. Department of Defense
2. Health, Education and Welfare
3. Housing and Urban Department
4. Department of Labor
5. The National Aeronautics and Space Administration
6. Department of Transportation

* This Chapter is based on data contained in EPA Technical Information Documents NTID300.8, "State and Municipal Non-Occupational Noise Programs;" NTID300.9, "Noise Programs of Professional/Industrial Organizations, Universities, and Colleges;" and NTID300.10, "Summary of Noise Programs in the Federal Government." See Appendix A regarding procurement of this source material.

Agencies having more moderate programs are:

1. Department of Agriculture
2. Department of Commerce
3. General Services Administration
4. Department of the Interior
5. National Science Foundation
6. The Postal Service Commission

Finally, agencies reporting relatively minor programs were:

1. Atomic Energy Commission
2. Federal Power Commission
3. State Department
4. Tennessee Valley Authority
5. Treasury Department

Significant Federal Involvement

Table 5-1 illustrates the extent of Federal research and development activity in the noise field. Responsibility (authority) and funding for fiscal year 1972 is in thousands of dollars. The scope of federal activities includes the areas of hearing conservation, non-auditory effects, aircraft noise suppression, community noise problems, and standardization of sound measuring equipment.

The Environmental Protection Agency (EPA)

EPA established its Office of Noise Abatement and Control in April, 1971, just 4 months after the Agency's formation. Under Title IV of PL 91-604, the EPA Administrator was authorized and directed to establish an Office of Noise Abatement and Control (ONAC) to deal with problems of excessive noise. The statute further required the office to prepare a report on environmental noise for submission to Congress no later than 31 December 1971. This document fulfills that requirement.

Table 5-1

SUMMARY OF FEDERAL NOISE RESEARCH ACTIVITY

FEDERAL AGENCY	TYPE OF R & D	RESPONSIBILITY (AUTHORITY)	APPROX. FY72 $(THOUSANDS)
Atomic Energy Commission	None		
Department of Agriculture	Noise emission, control & abatement in rural areas — equipment noise, attenuation by vegation screens.	Clark McNary-Act, 1942; McSweeny-McNary Forest Research Act, 1928; Agricultural Experimental Station (Smith-Lever), 1955.	250
Department of Commerce			
National Bureau of Standards	Noise abatement & control program; building acoustics, standardization of sound equipment.	------	500
National Oceanic & Atmospheric Administration	Atmospheric acoustics & sound propogation.		
Department of Defense			
Army	Biomedical, physiological, psychological effects of noise; noise generation control of equipment; hearing conservation.	Army Regulations	1,064
Air Force	Aircraft noise control & abatement; hearing conservation; noise effects upon personnel.	Section 8011, Title 10, U.S. Code and AF Regulations.	6,654
Navy	Aircraft noise reduction; engine noise suppression.	Navy Orders, regulations.	---
Environmental Protection Agency Office of Noise Abatement & Control	Effects of noise on public health & welfare (report to Congress)	Title IV, PL-91-604	509
Department of Health, Education & Welfare			
Social Security Admin.	Hearing conservation	Occupational Safety & Health Act	21
National Institutes of Health	Psychological & Physiological effects of noise.		
Health Services & Mental Hygiene Administration	Nonoccupational noise hearing loss	Public Health Service Act	

Table 5-1 (Cont)

SUMMARY OF FEDERAL NOISE RESEARCH ACTIVITY

FEDERAL AGENCY	TYPE OF R & D	RESPONSIBILITY (AUTHORITY)	APPROX. FY72 $(THOUSANDS)
Department of Housing & Urban Development	Metropolitan aircraft noise abatement; policy & stnds. for construction sites; structural characteristics, urban noise survey methodology.	HUD Circular 1390.2	500
Department of Interior Park Service Bureau of Mines	Sonic boom monitoring in National Parks Hearing loss & noise problems in mines	Federal Coal Mine Health & Safety Act; 1969 & 1936; regulations in 41CFR14; 50CFR4; 36CFR1; 30CFR1; 43CFR2; 30CFR1(F)(70)	214
Department of Labor	None		
Department of State	None		
Department of Transportation Federal Aviation Agency Administration Federal Highway Administration Transportation Systems Center	Aircraft noise Suppression; sonic boom effects Traffic noise measurement & abatement Community noise	DOT Act, PL-89-670; Fed Aid for Highways (1970); FAA regulations FAA regulations and orders	9,944
Department of Treasury Secret Service Bureau of the Mint	Hearing conservation Noise emmission from equipment		
Federal Power Commission	None		
General Services Administrator	Construction & demolition noise abatement; quieter products procurement requirements.		

Table 5-1 (Cont)

SUMMARY OF FEDERAL NOISE RESEARCH ACTIVITY

FEDERAL AGENCY	TYPE OF R & D	RESPONSIBILITY (AUTHORITY)	APPROX. FY72 $(THOUSANDS)
National Aeronautical & Space Administration	Aircraft noise abatement & control.	Space Act PL 85-568	25,000
National Science Foundation	General research of noise effects & noise control		
Postal Service Commission	Noise control of equipment		170
Tennessee Valley Authority	Community noise effects		

In the preparation of this report, contracts with universities and acoustical engineering firms were let for assistance in assembling data on different aspects of the noise problem. Public hearings were conducted in major cities during the summer and autumn of 1971 in an effort to gather testimony from industrialists, local and state government officials, scientific experts, conservationists, public and private organizations, and private citizens.*

Title IV of Public Law 91-604 (Section 402c) requires Federal agencies to consult with the Administrator of the Environmental Protection Agency on their current noise generating activities that may constitute a nuisance or be otherwise objectionable. The Environmental Protection Agency is in the process of issuing the appropriate guidelines to implement these requirements. The Agency has held consultations with these agencies on preliminary guidelines, and has obtained information from the agencies on their operations which engender public complaints.

Section 102(C) of the National Environmental Policy Act (PL 91-190) requires all agencies of the Federal government to provide statements specifying the environmental impact of all proposed projects, legislation or comments on legislation. The Environmental Protection Agency is required by law to comment on all such statements. Environmental impact statements involving potential noise problems are currently being reviewed by the Agency. The proposed guidelines, mentioned above, will provide for an integration of approach between the two laws.

Under Title IV, EPA also is undertaking other actions including demonstrations, exhibits and follow-on actions indicated by the report to Congress and the testimony received at the public hearings.

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* See Appendix C for information as to scope of hearings, locations, and subject matter. Testimony received will be published as verbatim transcripts.

Congress is now considering noise legislation as a major environmental concern. The Administration's proposed Noise Control Act of 1971 provides for the following (See also Appendix B):

1. A comprehensive Federal noise control and research program, with the Environmental Protection Agency serving as the coordinator of Federal activity.
2. Federal standards, promulgated by the Environmental Protection Agency for transportation and construction equipment, electric motors, internal combustion engines.
3. A labelling system to identify products as to noise producing characteristics for the benefit of the prospective consumer.
4. A provision prohibiting states and their political subdivisions from establishing noise emission standards where Federal standards have been established; states would be permitted (and would be encouraged to establish) use, operation and movement regulations of noise-producing machines.
5. A broad, EPA-sponsored research and development program to fill the gap in other Federal agencies' research activities.
6. A comprehensive technical assistance program, including provisions for assistance on noise enforcement.
7. A vigorous and effective enforcement scheme.
8. Finally, the Environmental Protection Agency would have authority to review existing Federal Aviation Administration regulations and be authorized to request the Administrator of the FAA to make changes. EPA approval would also be required for any new regulations on aircraft noise.

At the present writing, this last revision on aircraft noise has been modified in committee to provide only for consultation between the Administrators of the FAA and EPA.

The Department of Defense (DOD)

Noise abatement efforts by DOD have been both considerable and longstanding. The armed services particularly are involved in research on noise and noise abatement procedures. The primary DOD thrusts are concentrated in four main areas:

1. Occupational noise control and hearing conservation.
2. Operational aircraft noise abatement.
3. Noise signature elimination in weapons system.
4. Construction specifications for noise control.

At present, noise programs are conducted within each of the three military branches to meet specific operational requirements. An enumeration of the separate efforts is contained in the following paragraphs.

Army Noise Efforts. Army noise programs are executed through the following agencies:

- Office of the Chief of Engineers, U.S. Army. This office is conducting a study ($82,000) on noise induced hearing loss and the effects of noise on the efficiency of soldiers' performance.
- Office of Corps of Engineers, U.S. Army. The Corps Office conducts research on the control of noise generation and the application of measures to eliminate noise levels that may have adverse effects upon human beings. Current investigations include work in establishing criteria for the location of certain military activities relative to residential areas and the identification of causes of noise pollution and control criteria during construction

activities. Fiscal support for noise-related work within the Corps cannot be determined. No personnel are specifically assigned to noise control programs.

- Army Medical Research and Development Command. This command conducts programs and research concerned with biomedical effects of noise, noise reductions, noise exposure, and the physiological and psychological effects of noise. Current programs include traumatic origins of hearing losses, auditory perception and psychophysics, and the aviation audiometry program. The operating budget for fiscal 1972 is $464,300.
- Army Environmental Hygiene Agency and Environmental Health Engineering Services. Both agencies conduct programs to assure the health of personnel. Current programs include the Hearing Conservation Program for the surveillance of occupational hearing loss and studies of effects of noise on individuals at military installations. The operating expenditures for the noise program cannot be determined.
- Army Materiel Command. Under this Command, programs and research are carried out under contract for noise reduction of equipment, rotary wing aircraft noise reduction, and human capabilities. Expenditures for fiscal 1972 are approximately $650,000.

Air Force Noise Programs. The Air Force conducts research under authority of Section 8011, Title 10, U.S. Code. Program activities related to noise include the conservation of hearing program (AFR 160-3; Hazardous Noise Exposure), with an operational expenditure of $509,300 for fiscal 1972. Research programs are conducted at the Aero Propulsion Laboratory, the Flight Dynamics Laboratory, the 6570th Aerospace Medical Research Laboratory, and the Weapons Laboratory, all laboratories of the Air Force Systems Command. Contracted research is maintained by the Air Force Office of Scientific Research. There are no laboratories presently devoting full resources to noise research. Less than 3 percent of the total resources of laboratories having noise research programs is allocated to that end. The Office of Scientific Research conducts research on aircraft noise generation processes. Estimated funding for the project is $80,000. The Flight Dynamics Laboratory is conducting development work on aircraft acoustics, including noise control within vehicle interiors and sonic fatigue, with current expenditures of $290,000 per year. The Aerospace Medical Research Laboratory conducts research on the effects of noise on Air Force personnel. Specializing in bioacoustical research, this Laboratory is unique among Federal noise research programs. Expenditures for such research are $410,000 per year. The Aero Propulsion Laboratory, with expenditures of $475,000, is concerned with noise abatement in aircraft propulsion systems. The Air Force Weapons Laboratory is researching computerized noise exposure forecasting and has expenditures of $80,000. Total expenditures for research are $1,255,000. Additionally, the Air Force has a program for the development and acquisition of sound suppressors for ground runup of jet aircraft engines. This work is done entirely by contract at an expenditure of $4,810,000.

Navy Noise Program. The Navy noise abatement program concerns aircraft and related ground facilities and equipment and is divided into the areas of:

- Noise reduction of operating aircraft.
- Noise suppression for ground runup of engines.
- Noise suppression for overhaul and maintenance testing.

In addition, an exploratory development program concerning a semi-portable noise suppressor for gas turbine engines is underway. A contract for $187,000 has been awarded for the exploratory development program in fiscal 1972.

Department of Health, Education and Welfare (HEW)

The Occupational Safety and Health Act provides authority for the National Institute for Occupational Safety and Health to undertake research with the objectives of: (a) defining occupational noise limits for conserving hearing, (b) assessing industrial noise effects on overall health, safety and performance capability, (c) considering differential diagnoses of noise-induced hearing loss cases and (d) training and demonstration projects bearing on industrial noise control and hearing conservation. Funding for these assorted activities in FY 1972 will be in excess of $400,000.

Likewise, the National Institute of Health (NIH) is vested with authority to conduct research in noise as part of its broad mission in health. NIH sponsored studies are being conducted largely on the physiological mechanisms underlying noise-induced hearing loss and aspects of speech perception in noise through grants totaling nearly $1,000,000 awarded to various universities and laboratories.

HEW conducts a hearing conservation program for its own employees as part of its occupational health activities. Program objectives are to assess and remove hazardous noise sources and otherwise protect employees from adverse noise effects. Other concerns include the isolation and evaluation of noise-producing equipment. Occupational medical guidelines described in PL 658 (79th Congress) and DOD circular A-71 govern the administration of the program.

Department of Housing and Urban Development (HUD)

Noise control and abatement is not a separate program within HUD; however, the Secretary has established noise control requirements for HUD programs (HUD Circular 1390.2). Noise problems arising in housing site selection, structural characteristics of buildings, and land use planning, are included. Development of comprehensive urban noise survey methodologies, metropolitan aircraft noise abatement policy studies, and technical support for operational noise abatement programs are major activities of the department.* Plans for future consideration include extension of the Comprehensive Urban Noise Survey Program, measurement instrumentation for determining site noise exposure, site noise exposure techniques, development of model ordinances and building code sections, and noise emission ratings for appliances and equipment. Approximately $500,000 has been programmed for noise research and development activities in HUD for FY 1972.

Department of Labor (DOL)

The main DOL emphasis on noise is in two areas: The Walsh Healey Contracts Act, which covered health standards for employees engaged in Federal contract work exceeding $10,000, and The 1970 Occupational Safety and Health Act, extending coverage to all businesses engaged in interstate commerce. Worker exposure standards under the two acts are identical. There are approximately 80 million Americans composing the work force; the overwhelming bulk of these is somehow engaged in interstate commerce. Hearing loss due to noise is, of course, one of the health considerations covered under the 1970 legislation. Regulations limiting noise exposure of workers were adopted by DOL under authority of the Act; these limits were published in the Federal Register.

National Aeronautics and Space Administration (NASA)

The NASA (as well as its predecessor, NACA) has been deeply involved in aircraft noise research for many years. The Fiscal Year 1972 program includes contract and in-house research totaling $25 million in the areas of reduction of aircraft noise at the source, noise propagation, effects on receptors, sonic boom, and approach trajectory modification. Of this total, $12.6 million is contracted research, $5.4 million covers

* A notable example of the Department's activities is the issuance in 1971 of its "Noise Assessment Guidelines" to be used by nontechnical persons to assess present and future noise exposures of housing sites.

test equipment and instrumentation for the in-house research, and $7 million is budgeted for research and program management (chiefly in-house research manpower costs). Construction of a new aircraft noise reduction laboratory is underway at the NASA Langley Research Center, and the laboratory, costing about $5.8 million and scheduled for completion late in 1972, will provide a major expansion of the national capability.

In addition to research activities, NASA provides noise protection for its employees through work site surveillance and audiometric testing, supplemented by general medical protection.

Department of Transportation (DOT)

In accordance with the Department of Transportation Act of 1966 (P.L. 89-670), Section 4, DOT is engaged in research and development relating to transportation noise, particularly aircraft noise. Additionally, PL 90-411 provided for noise certification of aircraft by the Federal Aviation Administration. A separate office of Noise Abatement administers the noise program within DOT. Its programs are concerned with: 1. evaluating community response to aircraft and transportation noise, 2. developing transport noise measurement criteria, 3. evaluating transportation noise sources, 4. developing mathematical models for estimating noise and evaluating the impact of transportation noise. The office's many technical research programs include investigation of truck engine noise and jet noise as well as the development of measurement equipment and procedures. Twenty percent of the office's budget is spent in the utilization of the technical capabilities of the Transportation Systems Center at Cambridge, Massachusetts as well as those of outside contractors. The Center investigations, amounting to $900,000, include measurement and simulation modeling of community noise levels caused by transportation related sources and research of mechanisms of noise generation in jet engine exhaust V/STOL aircraft, and internal combustion engines.

Included within the DOT research and development effort is that of the Federal Aviation Administration in which aircraft noise suppression and adverse effects of sonic boom are heavily emphasized. Expenditures for this program total $3,150,000.

Finally, the Federal Highway Administration conducts a noise research program whose scope includes traffic noise measurements, evaluation and abatement. Expenditures for this effort total $149,000.

Moderate Federal Involvement

Department of Agriculture (USDA)

The USDA is engaged in eight specific noise reduction programs. The overall objective of these programs is to determine noise levels emanating from agricultural sources. As a part of this effort, USDA conducts research on noise propagation and attenuation from vegetative screens through grants totaling $250,000 to state agricultural experiment stations. Authority for this research is located in the Clark-McNary Act of 1942; the McSweeney-McNary Forest Research Act of 1928, and the Agricultural Experimental Station (Smith-Lever) Act of 1955. Moreover, USDA and the U.S. Air Force participated in a mutual research effort on the effects of noise on chickens, cows, and swine.

Department of Commerce (DOC)

Within DOC, research and measurement programs in acoustics are conducted by both the National Bureau of Standards (NBS) and the National Oceanic and Atmospheric Administration (NOAA). Only programs of the former division, however, are specifically directed toward noise abatement.

Within NBS, the Institute for Basic Standards (IBS) is currently involved in two noise-related projects:

1. An investigation of reverberant sound fields with an aim of developing new, improved methods for measurement of sound absorption and sound power in reverberation chambers.
2. A study of current methods for measuring the subjective factors of loudness, noisiness and annoyance and the development of new methods for subject measurement.

In addition to these two programs, IBS is also engaged in basic research including the development and standardization of calibration procedures for various sound measuring equipments. Additionally, the National Bureau of Standards in a joint effort with the DOT has undertaken research on truck tire noise. It has also joined with HUD on a project called "Operation Breakthrough" to measure noise levels at building sites.

The Bureau is also concerned with passenger car tire noise and has made investigations into the subjective assessment of this unwanted sound. It also tests noise characteristics of toys and of postal mail sorting machines.

Also under NBS, the Institute for Applied Technology is conducting a variety of research programs concerning noise abatement in buildings. The development of improved test methods is emphasized both for measuring sound transmission and for rating and testing the overall acoustical performance of entire buildings.

In addition to these direct research projects, NBS presently has a working budget of about $465,000 for programs sponsored by eight other agencies (including EPA).

The current operating budget is $500,000 of which approximately $200,000 is applied directly toward noise abatement research. A $200,000 increase in funding is requested for fiscal 1973, which would allow NBS to expand its efforts in noise control. Contracts totalling $41,000 have been negotiated with two private organizations to obtain data relating to noise in European environments and to gather information concerning the acoustical properties of doors and windows. This latter data is expected to provide architects with valuable information in practical design. DOC has no authority in the area of noise regulation or certification.

General Services Administration (GSA)

The magnitude of GSA operations requires its inclusion in this discussion. Although it has no formal noise abatement program, GSA is developing noise abatement procedures for construction and demolition activities.

Maximum sound level criteria for mechanical building equipment were established in 1970, and are included in specifications for major construction projects. These levels are more stringent than those established by the Department of Labor under the Occupational Safety and Health Act. Constructional noise currently is being monitored at the site of the building now under construction in Philadelphia, Pa., to determine possible criteria for future development of noise abatement standards. As for space already occupied, GSA is continuously developing sound level criteria to improve the acoustical environments of buildings. Finally, GSA is amending procurement specifications to require quieter products. This agency will have a profound impression in noise reduction through its vast purchasing power. Data on funds for support of these activities was unavailable at the time this report was prepared (GSA's noise abatement program is not budgeted separately.)

Department of the Interior (DOI)

This agency is currently involved in conducting three specific noise programs:

1. An FAA funded project for monitoring the frequency and characteristics of sonic booms in certain national parks.
2. A Bureau of Mines instituted training program for inspectors who will survey noise conditions in mines.

3. A research program instituted by the Bureau of Mines and HEW to study noise problems in mines and related hearing loss suffered by miners. Only the Bureau of Mines program has been specifically budgeted for noise abatement and control. Estimates include $45,000 for research and $19,000 for an acoustical research inventory. Future DOI program plans in the noise field are almost entirely limited to this program.

DOI legislative authority for noise research together with regulations for the further definition of that authority are contained in: The Federal Coal Mine Health and Safety Act of 1969 and the Act of May 28, 1936, and regulations found in 41 CFR 14; 50 CFR 4; 36 CFR 1; 30 CFR 1; 43 CFR 2 and 30 CFR 1(F) (70).

National Science Foundation

From 1968 through 1971, the Foundation funded equipment purchases for noise research amounting to $99,200. The Special Engineering Program director and his staff spend about 15 percent of their time on acoustics and noise control. Time is also committed to the noise area in the psychobiology and neurobiology programs. Similarly, a number of projects on noise research are funded through contracts or grants. Total research expenditures for noise projects in fiscal 1971 were $175,000. While no projections for future noise research have been made, the Foundation has stated that it expects to fund additional projects in noise problems and acoustics.

The Postal Service Commission (PSC)

The newly formed PSC is currently involved in three specific programs designed to reduce noise in the workroom area. Two research projects aimed at identifying existing noise sources, determining noise abatement procedures, and implementing prototype modifications have been initiated. On a trial basis, special Postal Service Specifications have been issued on the development of new equipment to ensure that operator noise levels do not exceed a given level. Expenditures for personnel and contracts amounted to $250,000.

PSC has no individual assigned to noise abatement programs on a full time basis. Moreover, it reports no legislative requirements and states that future noise control plans will depend largely on the results of current projects.

Minor Involvement

Atomic Energy Commission (AEC)

In the process of obtaining licensing for a nuclear power plants, the AEC, under procedures issued by the Director of Regulations, provides assurance that noise is considered, as required by Section 102(2)(c) of the National Environmental Act of 1969. Other than this, the AEC has no activities related directly to noise control.

Federal Power Commission (FPC)

The FPC, in the exercise of its authority for licensing hydroelectric projects and other power-generating sources, considers noise as an environmental factor.

Department of State

The State Department, in its general mission as the institutional representative of this nation to foreign countries, has widespread contacts with foreign governments on environmental matters, including noise. Additionally, State intends to work closely with the GSA in determining and enforcing noise level tolerances for facilities it uses.

Tennessee Valley Authority (TVA)

The TVA is planning to undertake a study on the effects of gas turbine generating plants on community noise levels, to be funded from the General Industrial Hygiene budget. TVA intends to develop standards and criteria for use by design and operating organizations in community noise control. An expenditure of $45,000 for fiscal 1971 was reported for community noise efforts and noise measuring instrumentation.

Treasury Department

The Bureau of the Mint reports three sources of external noise generation causing public complaint:

1. Melting furnace exhausts at the Philadelphia mint.
2. Rolling mills at the Denver mint.
3. Presses at the San Francisco Assay Office, where coins are currently minted.

The Bureau reports a continuing, independent effort to solve these problems.

Research Activities*

Of some $34 million expended by the Federal agencies in fiscal 1970, approximately 78 percent, or $26 million, went for research and development. Most of this research has been on aircraft noise.

The following list of major Federal laboratories involved in noise and noise-related problem research should serve to indicate the nature and extent of Federal agency research involved.

- <u>Department of Agriculture</u>
  1. Agriculture Engineering Research Division, Bethesda, Maryland
  2. Forest Products Laboratory, Madison, Wisconsin
- <u>Department of Commerce</u>
  1. Environmental Research Laboratories, Boulder, Colorado
  2. Institute of Applied Technology, NBS, Gaithersburg, Maryland
  3. Institute of Basic Standards, NBS, Gaithersburg, Maryland
  4. National Bureau of Standards, Boulder, Colorado
  5. Wave Propagation Laboratory, Boulder, Colorado

* A detailed listing of principal research activities at these labs is contained in NTID300.10.

- Department of Defense

1. Air Force

   (a) Flight Dynamics Laboratory, Wright-Patterson AFB, Dayton, Ohio

   (b) Aero Propulsion Laboratory, Wright-Patterson AFB, Dayton, Ohio

   (c) Aerospace Medical Research Laboratory, Wright-Patterson AFB, Dayton, Ohio

   (d) School of Aerospace Medicine, Brooks AFB, Texas

   (e) Weapons Laboratory, Kirtland AFB, Albuquerque, New Mexico

2. Army

   (a) Environmental Health Engineering Services

   (b) Environmental Hygiene Agency, Edgewood Arsenal, Maryland

   (c) Human Engineering Laboratories, Aberdeen Proving Grounds, Maryland

   (d) Medical Research Laboratory, Fort Knox, Kentucky

   (e) Natick Laboratories, Natick, Massachusetts

3. Navy

   (a) Missile Center, Pt. Mugu, California

   (b) Naval Aerospace Medical Research Laboratory, Pennsecola, Florida

   (c) Naval Air Engineering Center, Philadelphia, Pennsylvania

   (d) Naval Air Propulsion Test Center

   (e) Naval Medical Submarine Research Center, Groton, Connecticut

   (f) Naval Undersea Research and Development Center, San Diego, California

   (g) Naval Undersea Warfare Laboratory, Pasadena, California

   (h) Ship Research and Development Center, Washington, D. C.

- National Aeronautics and Space Administration

  1. Ames Research Center, Moffettfield, California
  2. Flight Research Center, Edwards, California
  3. Jet Propulsion Laboratory, Pasadena, California
  4. Langley Research Center, Hampton, Virginia
  5. Lewis Research Center, Cleveland, Ohio
  6. Marshall Space Flight Center, Huntsville, Alabama

- Public Health Service

  1. Occupational Health Research and Training Facility (PHS), Cincinnati, Ohio

- Department of Transportation

  1. Civil Aeromedical Institute, Oklahoma City, Oklahoma
  2. Transportation Systems Center, Cambridge, Massachusetts

Aircraft Research

The reduction of aircraft noise and its suppression at the source were investigated in FY 1971 by NASA and the Departments of Defense and Transportation. NASA funding in FY 1971 totaled nearly $21 million, of which about $11.1 million was for contract research, $3.3 million was for test equipment and instrumentation for the in-house research, and $6.4 million was for research and program management. This program included research in source noise, noise propagation, receptor noise, sonic boom, and approach trajectory modifications.

Other Noise Research Activities

The remaining extent of Federal program activity in noise control can be briefly summarized. The DOD, HUD, and DOT, as well as NASA, conduct research in areas such as land use planning, high speed equipment noise reduction, metropolitan noise abatement, and noise in building structures. Work is also being carried out in subway noise, urban vehicular noise, and tire acoustics.

In 1971, DOD spent $600,000 for research on the effects of noise on human beings. DOT and HEW spent $40,000 and $200,000, respectively, on this general problem, including a study of the psychological effects of continuous noise exposure, impulsive noise, noise and performance, acceptability of aircraft noise, and other related subjects.

Interagency Committees and Studies

Early attempts to achieve some measure of coordination on a Federal level among the many noise abatement programs came in two forms: studies and interagency committees. In the former area, five reports were of particular significance. The reports were:

1. Noise – Sound Without Value, Committee on Environmental Quality of the Federal Council for Science and Technology (September, 1968).
2. The Noise Around Us, Panel on Noise Abatement, Commerce Technical Advisory Board, U.S. Department of Commerce (September, 1970). This report recommended the establishment of an Office of Noise Abatement within EPA.
3. Transportation Noise Pollution: Control and Abatement, NASA Langley Research Center and Old Dominion University (1970); NASA contract NGT 47-003-028.
4. Report to the Council on Environmental Quality by an Ad Hoc Committee on Noise, 1969. This Committee issued recommendations that resulted in the Administration's proposed legislation on noise now pending in Congress.
5. A Study of the Magnitude of Transportation Noise Generation and Potential Abatement, Department of Transportation (1970); Report No. DOT-ONA-71-1.

There are important interagency groups concerned with noise. These include:

1. CHABA (the NAS-NRC Committee on Hearing, Bioacoustics and Biomechanics). Sponsored by the National Academy of Sciences, it includes representatives from academia, industry, and government. The government organizations represented are: The Army, Navy, Air Force, NASA, FAA, EPA, HEW, NIH, DOT (Highway Safety Council). Services and activities of CHABA include: literature reviews, reports on special problem areas, evaluations of research proposals, on going research projects and the opportunity for mutual interaction between the several agencies.
2. The Federal Council for Science and Technology's ad hoc committee on Environmental Quality Research and Development. It is in its last phase and will probably be terminated before the end of the year. This interagency committee investigated the Federal government's involvement (Research and Development and demonstration programs) in all areas of environmental quality. Noise was, of course, included in the investigation.
3. Under the U.S. Public Health Service, the Occupational Health Research and Training Facility has interagency activities, primarily with DOL, DOI's Bureau of Mines and recently, the Department of Standards. Most of its activity centers upon the evaluation of hearing losses produced by occupational noise exposures and the evaluation of new equipment according to present acoustical standards. In the past, the facility was involved with FAA in studies of the physiological and psychological effects of noise, and of non-occupational hearing loss from airport noise. Presently a study is being conducted with the Bureau of Mines to survey prevalence of hearing loss among miners exposed to mining equipment of assorted types.

4. Interagency Aircraft Noise Abatement Program: This committee is one of the few programs which has successfully incorporated a wide variety of agency interests and authorities. Perhaps, it has been the most active of the various interagency groups. Not only the aircraft oriented groups are represented (DOT, DOD, FAA, NASA) but also such groups as the Department of Commerce, Department of Health, Education and Welfare, the National Academy of Sciences, HUD and DOI. IANAP was organized just after the office of Noise Abatement in the Department of Transportation was created (about 1968). The program includes an executive group (from DOT) and eight panels (from a wide variety of departments). Under IANAP's auspices, much information on aircraft noise has been compiled and published; recently, it was proposed that its scope be extended to include all areas of transportation noise.

STATE AND MUNICIPAL NON-OCCUPATIONAL NOISE ABATEMENT AND CONTROL PROGRAMS

This discussion of state and municipal programs in non-occupational noise abatement and control is based on information received, up to the time this report was prepared, from 114 of a possible 153 cities having a population of over 100,000 and from 41 of a possible 53 states and territories.

Responsible Agencies

Noise abatement and control has received only recently broad national attention; and therefore, it is not surprising that approximately one half of the states and cities do not have an agency responsible for noise abatement programs as shown in Tables 5-2 and 5-3.

Of those cities and states that do have some type of program, responsibility for these programs is fragmented throughout several agencies. With a few exceptions, these programs are staffed by on demand, part-time personnel, often having no acoustical background and drawn from several agencies. Perhaps as a function of the local nature of many of the noise problems, a greater percentage of the cities, as compared to the states, have specific noise programs and personnel assigned to them on a continuous basis.

Current Programs

Most programs now functioning are devoted to:

- Increased enforcement of existing nuisance ordinances.
- Establishment of governmental channels to respond to individual complaints.
- Studies and surveys of noise-related issues in order to develop enforceable laws, regulations, and ordinances that will include specific criteria and noise level standards for facility and community requirements.

Table 5-2

RESPONSIBLE CITY AGENCIES AND PROGRAM CLASSIFICATION

Population (in 1,000)	Total Number of Cities	Responsible Agency: None	Health	Bldg. Inspection	Environmental	Noise Abatement	City Government	Nature of Program: Complaint Answer	Survey/Monitoring	Developing Ordinance	Enforcing Ordinance	Research (Training)	Public Education
100-200	90	37	9	14	2	1	2	11	5	3	7	6(1)	-
200-300	15	7	-	1	2	-	1	3	-	1	1	2	1
300-400	17	3	5	1	3	-	1	3	3	2	1	2	-
400-500	5	2	1	-	-	-	1	-	-	-	1	2	-
500-600	8	5	2	2	-	-	-	1	1	2	-	1	-
600-700	5	4	-	-	1	-	-	-	-	1	1	-	-
700-800	5	2	1	-	1	-	-	1	1	-	-	-	-
800-900	2	-	2	1	-	-	-	1	1	-	-	-	-
more 1,000	6	1	2	-	1	1	-	2	4	2	-	1	1
Total	153	61	22	19	10	2	5	22	15	11	11	14(1)	2

Table 5-3

RESPONSIBLE STATE AGENCIES & PROGRAM CLASSIFICATION

Population (in 1,000)	Total Number of States	Responsible Agency: None	Health Dept.	Bldg. Inspection	Environmental	Noise Abatement	State Government	Nature of Program: Complaint Answer	Survey/Monitoring	Developing Regulations	Enforcing Regulations	Research (Training)	Other
300-900	11	6	3	-	-	-	-	-	-	2	-	1	-
900-1,000	2	2	-	-	-	-	-	-	-	-	-	-	-
1,000-2,000	6	3	-	-	2	-	-	1	1	-	-	-	1
2,000-3,000	7	3	-	-	1	-	1	-	-	2	-	2	3
3,000-4,000	8	2	4	-	2	-	-	-	-	-	-	1	1
4,000-6,000	7	4	3	-	-	-	-	-	1	1	2	-	-
6,000-11,000	4	2	-	-	1	-	-	-	-	2	-	1	-
11,000-19,000	5	1	1	-	2	-	-	1	1	1	1	1	-
Total	50	23	11	0	8	0	1	2	3	8	3	6	5

The few exceptional situations in which specific noise standards and regulations (as opposed to general nuisance ordinances) have been promulgated and enforced, include:

- Control of highway vehicular noise according to noise level standards.
- Restriction of the time of day when scheduled airlines may use airport facilities.
- Prohibition, in terms of both sales and use, of specific recreational vehicles in wilderness areas.

Research and Testing Facilities

Those agencies carrying out noise related activities have equipment ranging from a single sound level meter to several sets of equipment including a spectrum analyzer and several cars. As an exceptional example, the California Highway Patrol is extensively equipped to monitor noise. During one 12-month period (1970-1971), the noise levels of 1 million highway vehicles were measured. However, most local governments have not reported any testing facilities or inspection stations.

Current Funding

In most cases, funding for non-occupational noise abatement is part of the operational budget of several agencies and not specifically allocated to a program of noise abatement. However, for five cities allocating funds specifically for noise abatement programs, the cost of current programs varies from approximately $.02 to $.04 per resident per year as shown by Table 5-4.

California and Illinois have allocated respectively $.01 and $.025 per resident.

Table 5-4

BUDGET OF CURRENT (1971) NOISE ABATEMENT PROGRAMS IN 5 CITIES

City	Approx. Pop. (1,000,000)	Program Cost Per Resident (cents)
New York, N. Y.	8.0	4
Boston, Mass.	0.6	4
Columbia, S. C.	0.1	2
Fremont, Calif.	0.1	2
Philadelphia, Pa.	1.9	1.6

Although a few city governments have estimated future budgetary requirements (New York City has $1 million budgeted for 1973 . . . $.12 to $.15 per resident), most did not have an available estimate of cost for noise abatement programs.

Estimation of Potential Nationwide Budget of State and City Non-Occupational Noise Control Programs

Through extrapolation of information based on the existing budgets of state and local governments already actively addressing the noise problem, a rough estimate of the possible state and local government budget that could be devoted to the initial stages of noise abatement and control is $3 to $13 million per year. It would appear, however, that this estimate of potential expenditure by state and local governments would probably still be less than the lower bound for a comprehensive and effective noise abatement program. This viewpoint is somewhat verified by the responses from state and local government officials, which indicate that they are unable to evaluate the effectiveness of their respective noise abatement programs. State and local governments could greatly benefit if a set of national noise and abatement objectives and goals were established to which they could relate their programming.

Potential Use of Federal Funds

Because of the difficulty of enforcing nuisance laws, most city and state governments would prefer to see Federal funds used to develop noise criteria. This would allow the local governments to develop and implement meaningful programs in 3 to 5 years.

Summary of State and Local Efforts

- Over half of the states and cities have no agency responsible for noise abatement.
- Of those local governments that do have some type of program, responsibility for such programs is fragmented throughout several agencies.
- Reflecting the local nature of many of the noise problems, a greater percentage of the cities, as compared to the states, have specific noise programs and personnel assigned to them on a continuous basis.
- The broad power given to the courts under the general category of nuisance laws concerning noise has had limited success in reducing noise. However, most local governments feel that if noise criteria, involving such issues as land use and human reaction to noise, were available in measurable terms, they could develop and implement more meaningful programs appropriate to their local requirements within 3 to 5 years.
- Those governments having active programs have noted that Federal funds could be used to improve their staffs and facilities and to enlarge their program scopes.
- Reflecting the recent concern for noise, local programs have been initiated within the last 1 to 2 years but their success or failure has not as yet been evaluated. It should be noted that in a 12-month period during 1970 and 1971,

California, having promulgated noise standards for road vehicles, measured the sound level of 1 million highway vehicles and cited 1.5 percent of these vehicles for violations.

INDUSTRIAL, PROFESSIONAL AND VOLUNTARY ASSOCIATIONS

Introduction

The importance of the effects of noise abatement and control is reflected by the concerted efforts of many industrial, professional and voluntary associations throughout the country. Their noise abatement research and development programs, their programs in hearing conservation for the protection and well-being of personnel, and their initiative in establishing criteria and standards reflect not only an awareness of a significant problem, but a willingness and ability to attack the problem so it may be resolved or controlled. The efforts of these organizations reflect the absence of governmental influence. Furthermore, their efforts have not been a mere reflex reaction to overtures and public dissatisfaction with noise problems that have been projected in recent years. Instead, the efforts of many of the organizations reflect active engagement during the past 15 to 20 years.

Activities

Interest in noise and noise related problems is demonstrated by the activities of over 100 professional/industrial organizations. Some of these organizations, of course, have a direct interest while others may have a tangential one. The Acoustical Society of America is perhaps one of the larger professional societies that is directly engaged in a broad spectrum of noise and acoustical problems. It is currently developing a program for its Coordinating Committee on Environmental Acoustics. This program will establish means for defining environmental problems in societal and technical terms and for disseminating information to the problem-solving community. The Society of Automotive Engineers and the American Society of Mechanical Engineers are two societies that have directed efforts over the years to preparing suggested standards for the safety and protection of the public. The Department of Labor has adopted for its use certain of the proposed standards recommended by the American Society of Mechanical Engineers. The Society of Automotive Engineers publishes relative material in the form of information reports (e.g., methods of comparing aircraft takeoff and approach noise; jet noise prediction) and recommended practices (e.g., procedures for computing the perceived noise level of aircraft noise) for advice and voluntary use of others. They have published approximately twenty of these types of reports related to noise and acoustics.

Hearing conservation, since 1947, has received the primary emphasis from the Subcommittee on Noise in Industry of the American Academy of Ophthalmology and Otolaryngology. This group has prepared and distributed guides and manuals, and participated in symposia concerned with industrial hearing loss.

Two industrial hygiene organizations, the American Industrial Hygiene Association and the American Conference of Governmental Industrial Hygienists, have substantial involvements in noise related problems. The first named of these associations has an inter-industry noise subcommittee which directs its efforts toward industrial hearing loss, and is presently revising the Industrial Noise Manual published by the American Industrial Hygiene Association.

The American National Standards Institute is the national organization, representing industry, the individual consumer and the government, which meets demands for voluntary national standards. Through its committees on acoustics, bioacoustics, and shock and vibration, the Institute coordinates the work of standards development in the private sector in the areas of noise and noise related problems. The Institute has published approximately forty standards in acoustics and vibration which relate to noise problems.

Activities of professional and industrial organizations are also extended to testing procedures, certification, and rating of various noise producing products. For example, the American Society for Testing and Materials has proposed a standard method to test sound absorption and acoustical materials in reverberation rooms. Another example is the Air Conditioning and Refrigeration Institute which has developed a sound certification program and sound-rating procedures for outdoor air conditioning units.

Publications

The dissemination of relevant information on noise and noise related problems through the medium of publications of books, periodicals and technical reports, has been a major source of contribution toward the understanding of problems related to noise control. One of the several professional societies, the Acoustical Society of America, publishes monthly scientific research reports relating specifically to noise and related problems in the Journal of the Acoustical Society of America. Sound and Vibration, a controlled circulation publication to the professional community, publishes articles covering a wide spectrum of acoustic and vibration subjects. Noise Measurement, is a quarterly publication produced by an electronics instrument manufacturing and sound and electronics laboratory (General Radio Corporation). This company has also published a widely used book, Handbook of Noise Measurement. Recent books include Effects of Noise on Man, by Karl D. Kryter, Noise and Vibration Control by Leo L. Beranek, and Handbook of Noise Control by C. Harris.

CHAPTER 6

AN ASSESSMENT OF NOISE CONCERN IN OTHER NATIONS *

This section presents an overview of noise abatement and control problems and activities of foreign nations. It is given here in support of the premises that noise has attracted worldwide attention, that many nations have taken positive action and are supporting extensive noise abatement research and, finally, that all such work is nonpolitical and should be of universal benefit.

This material is presented in an integrated topical manner, rather than on a country-by-country basis, so that the reader may more easily compare international noise abatement and control problems and measures with those of the United States. The discussion on laws and regulations, however, is one exception to the integrated presentation, since it was necessary to review each country separately due to fundamental differences in the legal foundations and cultural backgrounds among nations.

* This chapter is based on material prepared by the staff EPA Office of Noise Abatement and Control and on data contained in EPA Technical Information Document NTID300.6, "An Assessment of Noise Concern in Other Nations," (EPA contract 68-01-0157, Informatics, Inc.). See Appendix A regarding procurement of this material, which contains bibliographic information.

SUMMARY OF IMPRESSIONS

In May of 1971, the U.N. Economic Commission for Europe sponsored a conference on environmental problems. The papers submitted at this conference indicate that noise is of serious concern in Europe and has been the object of specific attention for at least the past 10 years. Although the invitation to the conference suggested an outline for the subjects to be discussed and mentioned only transportation and building noise, 18 of the 26 countries represented specifically mentioned noise. Twelve of those countries treated noise as a major environmental topic along with water pollution, air pollution, and soil degradation.

Of the nations surveyed, it appears that Japan has some of the most severe pollution problems, including noise pollution, and is vigorously attacking them. Further, it can be concluded that European nations have become more noise conscious and have been more active in noise abatement than has the United States. There are, of course, a number of obvious reasons.

1. Since World War II, most European countries have been engaged in reconstruction and subsequent economic expansion. In England, construction noise has been intensive, with approximately 600,000 new residences being erected per year from 1966 to 1972. Similarly, aircraft flights there have increased at the rate of from 15 to 20 percent each year in recent years. In the European Common Market nations, the number of automobiles has been increasing about 11 percent each year.
2. European demographic characteristics and social traditions differ greatly from those of the U.S. Many European town dwellers own their own houses, and even farmers tend to live in densely populated towns. Further, proximity to one's neighbor and narrow, crowded streets are historical characteristics of European cities.

3. In most European governments there is a trend toward establishing unified ministries of the environment. However, most of these ministries are too new for their effectiveness to be measured. This is not to be interpreted, however, as meaning that these governments have not been active in pollution control, especially with respect to noise. Rather, the extensive activities of various ministries such as health, transport, and housing have led to major programs that required consolidation into single ministries.

The Scandinavian countries have been highly active in noise abatement and control. Recently, a technical body under the name of Scandinavian Building Council was established by the Nordic countries in order to exchange notes, to collect new ideas, to find common approaches, and to arrive at solutions in combating all aspects of environmental pollution. The Council's headquarters is located in Helsinki, with other departments in Stockholm. Lately, the Council has been notably preoccupied with traffic and aviation noise, resulting in recommendations that have been drafted for regulations prescribing minimum distances between buildings and different types of roads. Studies for providing safer and quieter road systems in new building developments are also conducted. The Council also plans to establish Scandinavian Standards and common regulations.

In England, the new Minister of Environment appears to have autonomy in his position; however, like his colleagues, he must plead his cases before the Prime Minister or before the full cabinet in instances, for example, in which conflicts might exist between environmental protection and industrial development. France's Ministry of Environment is barely 5 months old, and its scope is not yet well defined. However, it is noteworthy that jurisdiction for traffic and construction noise has been removed from local governments and assigned to the new Ministry.

In West Germany, Chancellor Brandt is developing a new environmental policy. It is already known, however, that his "sofort" priority program includes a new law on noise pollution. And it is expected that it will cover construction noise and emission/immission standards as well as a general monitoring program and a central clearinghouse for air and noise information. Structurally, Germany's Ministry of the Environment is an element of the Ministry of the Interior.

The Soviet Union and Eastern European countries do not seem to follow the same pattern of centralization of environmental affairs. While noise and abatement control has been an active issue, it has been pursued by such ministries as those of health and building technology. In the USSR, noise norms have the form of administrative laws and, in general, are not strictly enforced.

LEGISLATION AND REGULATIONS

Great Britain

The only Act of Parliament specifically designed to control noise is the "Act to make new provisions in respect of the control of noise and vibration with a view to their abatement" of November 28, 1960, which can be considered an extension of public health legislation. The first subsection of Section 1 of this noise abatement act states: "noise or vibration which is a nuisance shall be a statutory nuisance for the purposes of Part III of the Public Health Act, 1936, and the provisions of that Act shall have effect accordingly as if sub-sections (1) to (4) of this section were provisions of the said Part III." This part of the Public Health Act specifically states that action against "noise or vibration alleged to be a statutory nuisance can be instituted either by the local authority in which the nuisance is being committed or by any three or more persons, each of whom is an occupier of land or premises, who are affected by the nuisance." The stipulation limiting institution of proceedings to at least three aggrieved persons is intended to discourage unnecessary complaints within the statutory systems and does not restrict the right of individuals to take civil action. Before the passage of this act, noise control was vested in local authorities under the provisions set out in local acts and in bylaws instituted under the Local Government Act of 1933. It is estimated that before 1960 there were 400 authorities having noise control powers, although prosecutions may have numbered as little as 20.

Aircraft noise is specifically exempted from proceedings under the 1960 Act. Section 2 of the Act lays down detailed rules stating when and for what purposes loudspeakers may be used in streets and creates offenses punishable by small fines and enforceable by local authorities. The police themselves have various statutory powers to prosecute and may also prosecute under local bylaws in cases in which noise can be broadly described as resulting from disorderly behavior.

The only British statutory provisions, utilizing sound levels to directly decide whether a noise should be controlled are the Motor Vehicles (Construction and Use) Regulations of 1969. In addition, Section 60 of the Road Traffic Act of 1960 gives the Ministry of Transport extensive powers of regulation. Motor vehicle limits more strict than ECE requirements were issued for 1972. Domestic aircraft regulations were amended to consider aircraft noise subsequent to International Civil Aviation Organization Activity in 1969.

Switzerland

Switzerland does not have any federal legislation dealing exclusively with noise. When the Swiss Government deals with problems concerning noise, the Police Division of the Ministry of Justice and Police is consulted. The Federal Division of Police is presently responsible for coordinating all Federal anti-noise measures.

There are a number of administrative and legislative practices regarding aircraft and motor vehicle noise. They include mandatory vehicle certification, specifying maximum emissions for five different classes of motor vehicle. And motor vehicles are subject to inspection at intervals not to exceed three years. Public transportation is subject to special regulation that is enforced, essentially, by government/industry cooperation. On the local level, the Lausanne Anti-Noise Police Brigade is noteworthy. This organization is concerned with reducing noise from all sources: traffic, aircraft, construction sites, industry, and night clubs or bars. Similar brigades exist in other Swiss cities.

The Swiss campaign against noise is frequently viewed as a model. It has been effective in soliciting public and industrial cooperation.

France

Recently, France established a Ministry for the Environment; however, as of early 1971, no specific French law on noise had been enacted. Nevertheless, the legal tools for comprehensive noise control do exist and are enforced through various applicable ministries. For example:

- The Ministry of Equipment is responsible for laying down noise level standards for vehicles and for defining the conditions of sale of vehicles and new exhaust systems.
- The Ministry of Health is responsible—in particular through the agency of the Noise Commission—for assisting in the definition of desirable noise levels.
- The Ministry of the Interior and the Ministry of the Armed Forces are responsible, by means of the police force and gendarmerie, for the enforcement of approved legislation and regulations.

It is interesting to note that the French Anti-Noise League was declared to be "in the public interest" in 1963, and from that time its activities have been subsidized.

New motor vehicles must be certified, with limits of 76 dBA for scooters to 90 dBA for trucks over 3.5 tons, and the noise from agricultural tractors to be measured at a fixed distance. Motor vehicles may be stopped, and fines of up to 360 Francs can be imposed for violations. Numerous local ordinances exist that regulate traffic, especially truck traffic. Since March 1960, the operation of portable ratio receivers in the streets of Paris has been prohibited, and the use of rubber or plastic trash cans is mandatory, to reduce the noise associated with refuse collection.

Japan

In June of 1971, a new ministerial level agency for the environment was established. Within that organization, noise abatement and control falls under the purview of the Special Pollution Section and the Motor Vehicle Pollution Section. Japan is probably unique, with its national Law on Noise Abatement, drafted 25 May 1971. This law established national standards for maximum noise levels in the following zoning areas:

- Hospital and other quiet areas
- Residential areas
- Industrial and commercial areas.

The Japanese policy for implementing noise abatement measures includes some interesting features. For example, the Government is empowered to grant loans to local public institutions to cover the costs of special noise abatement activities. In addition, the law provides for tax incentives to those industries that have voluntarily modified their plants for quiet operations. Table 6-1 presents the major Japanese laws dealing with noise abatement and control.

Table 6-1

MAJOR JAPANESE NOISE LAWS

Classification	Law	Jurisdiction
1. Environmental standards	Basic pollution measure (Law 132, 1967)	Environmental Agency
2. Industrial	Noise abatement law (Law 98, 1968)	1. Environment Sanitation Division, Ministry of Health and Welfare. 2. Enterprise Bureau, Ministry of International Trade and Industry

Table 6-1 (cont.)

Classification	Law	Jurisdiction
		3. Forest Division, Agency for Forests and Fields. 4. Processing Food Division, Food Agency 5. Minister's Secretariat, Ministry of Transportation
3. Construction	Noise Abatement Law (Law 98, 1968)	1. Environment Sanitation Division, Ministry of Health and Welfare 2. Planning Bureau, Ministry of Construction
4. Aviation	Public or Private Airports and Vicinities (Law 110, 1966)	Aviation Bureau, Ministry of Transportation
5. Aviation (Military Bases)	Special Loss and Indemnity (Law 246, 1953) and Defense Force (Law 135, 1967)	1. Account Division, Agency Defense Equipment

Soviet Union

The Soviet Union may have the world's first comprehensive noise control legislation, dating from 1956. However, it is not embodied in one single law but, rather, is represented in a series of standards and norms that assume the role of administrative law. Sanitary Norm 785-69 covers industrial noise that is inside the factory emitted to the surrounding community. The maximum noise levels permitted by this norm inside Soviet work places is approximately 85 dBA; however, the norms for laboratories and offices are considerably lower.

In populated areas, the maximum noise an industry may legally emit into its neighborhood (measured just outside the buildings to be protected) is as specified:

Time	Approximate dBA
8 a.m. - 11 p.m.	55
11 p.m. - 8 a.m.	45

However, certain situations are allowed in which the noise levels may be increased by approximately 5 dBA.

The underlying principles of Soviet noise norms are the protection of man's central nervous system, the prevention of hearing loss or speech interference, and the concern for labor productivity. The Soviet norms appear to be a guide to equivalent laws of many Eastern European nations.

NOISE SOURCES

Community Noise

The noise to which workers are subjected in factories has been a matter of continuing concern in many countries. Only during the past 10 or 15 years, however, has significant attention been paid to noise exposure elsewhere. Although residents of rural areas and small towns are exposed to noise disturbances, it is often in the larger metropolitan centers that noise levels arouse social and civic awareness. Thus, it is not surprising that certain foreign cities have already become involved in practical noise research.

A typical approach to noise research usually begins with a city-wide survey aimed at assessing the extent of the local noise problem. Such a survey may be based on either or both of the two fundamental approaches; i.e., physical measurements of existing noise levels at a number of locations and sociological surveys of disturbance/annoyance reactions.

Some authorities consider Dortmund, Germany to be the leading city in this kind of noise research. Others group Dortmund with London and Tokyo. Each of these cities has conducted extensive surveys, and each is well known for one or more aspects of its noise research. Dortmund, for example, measured noise levels in over 1400 different places and developed an intricate noise map, with streets shown in different colors according to 5-dB noise level increments. Tokyo has taken a number of surveys, each concentrating on a different target, such as automobile noise, construction noise, industrial noise, noise levels at schools, and noise levels by zone. London chose to cover an area of 36 square miles with 540 measuring points systematically located 500 yards apart on a grid layout. These three cities are by no means the only ones that have made noise surveys.

Similar surveys have been made elsewhere, notably in Dusseldorf, Munich, Vienna, Berlin, Cologne, Toulouse, Paris, Athens, Madrid, Warsaw and Brno, as well as in several populated areas and towns in Romania and the Netherlands.

The findings of the various surveys tend to support each other, and thus, suggest that urban noise phenomena are much the same from city to city. For example, London, Tokyo, Dusseldorf, Madrid, and other cities all report that the average noise from heavy vehicles is higher than the noise from ordinary cars. The London report shows that the noise level next to a road increased by 4 dBA (from a base varying between 68 to 80 dBA) if the traffic flow increases from 1000 to 3000 vehicles per hour. Dusseldorf, though reporting in different measuring units, shows results of much the same magnitude. However, the Dusseldorf investigators carried this one step further, finding that a given increase in traffic density had less effect on the noise level 20 or 40 meters away than it did next to the roadway itself.

One of the most frequently cited results of the London survey indicates that over 80 percent of London's noise is caused by vehicular traffic. It should be pointed out, however, that this particular survey covered 36 square miles of the inner city, where vehicles were the most numerous noise sources. In the survey report, it was shown that the contribution of industrial and other noise emission grew as one proceeded toward the outlying areas. More specifically, traffic noise predominated in 84 percent of the locations chosen for the survey, while in the remaining 16 percent of the locations the predominant noise came from industrial plants, river boats, docks, railways, building operations, etc. While it is evidently true that surface traffic makes the largest contribution to urban noise, the fact that it is dominated by other noise sources in certain city locations is significant.

The relatively great impact of vehicular noise is supported by the sociological surveys made in several cities, but the results vary widely. Brno, Paris, and London offer typical examples. In Brno, 90 percent of the people interrogated ranked traffic noise as the most annoying, while 80 percent of the respondents in Paris ranked it in first place. In London, where the responses were classified according to location, the results showed 36 percent of the people at home, 20 percent of those outdoors, and 7 percent of those at work rated traffic noise as the most annoying. Interestingly enough, 39 percent of the Londoners at home gave higher priorities to home-generated noise from appliances, voices, television, pets, etc., while the rest complained about either aircraft or industry.

So far, researchers have been unable to find many meaningful correlations between technological and sociological noise surveys. Admittedly this can be attributed to the fact that the characteristics of a noise source as measured by an instrument are not necessarily consistent with the complaints about it by a human being. Moreover, neither sound level meters nor human ears can provide accurate identification of all the sounds that may have harmful effects. It becomes clear only that community noise is a cacophony of disturbances that require much research and analysis.

Air Traffic Noise

Virtually every country is concerned in some way with noise produced by air traffic. The disturbance caused by aircraft noise in residential areas around the world's major airports is generally regarded as a serious problem.

Protests from aroused citizens have prompted planning agencies in most countries to move cautiously in establishing new airports. London, for example, has spent several years debating the location of its third airport, and Tokyo its second. The problem has reached the stage where public reaction is influencing the development of future aircraft. Not the least of the impediments is the publicity given to the prospect of sonic boom carpets to be laid across the world during flights of supersonic transports.

Awareness of aviation noise problems has kept pace with both the increase in air traffic and the advancement of aircraft technology. According to the Airlines Research Bureau, for example, the volume of international traffic in Europe during the period of 1960 to 1969, exclusive of intercontinental flights not originating or terminating in Europe, increased from 10.4 to 24.9 million passengers. An even sharper rise was registered by freight and mail cargo. In view of increases in the power and size of jet aircraft during this same period, the expressions of alarm over aircraft noise are not surprising.

Typical of airport problems over this period of time is the experience of Heathrow Airport in London. Reacting to over 1200 complaints received in 1960, Heathrow authorities found that 23 percent of the daytime flights and 35 percent of the nighttime flights were exceeding the airport's own maximum permissible noise levels. After campaigning to bring noise levels to the established limits, airport authorities reduced noise levels to within 1 percent of standards for both day and night flights by 1963, and the number complaints dropped to 500. However, the increased traffic and the increase in the number of jet aircraft brought the number of complaints up to 2200 in 1969. Meanwhile, a survey of persons living in the two boroughs most seriously affected by Heathrow noise showed that inhabitants, who in 1965 or 1966 were able to tolerate the noise, had begun to resent it bitterly by as early as 1968.

Heathrow's concern for the reactions of residents is by no means unique. Almost every country considers it necessary to not only know the aircraft noise levels produced on the ground and in the vicinity of an airport but also to assess the noise disturbance in terms of public reaction. Consequently, the concept of the Perceived

Noise Level (PNdB), with various modifications and interpretations, is commonly accepted. This concept is reflected in the International Standards Organization procedure for the measurement and assessment of aircraft noise. Although most countries agree with the principles behind this procedure, some object to its methodology. Notable among these is South Africa, which has been working on the development of a measure that involves more factors and fewer measurements. South Africa was also among the countries to follow the recent trend toward the measurement of noise levels in dBA rather than in PNdB units, as originally specified in ISO recommendations.

One airport that has met reasonable success in the controlling noise is the Zürich Kloten Airport. More than five years ago, the government of the Canton Zurich established regulations to limit excessive noise in the airport vicinity. The regulations themselves are of less interest, however, than the techniques used to achieve compliance. The airport employs a permanent monitoring system involving strategically placed microphones connected by cables to a central evaluation unit, where A-weighted sound levels are continuously recorded. If a tripping level is exceeded, then the date, time, and duration of the event are printed out so that the offending pilot can be identified. The results of the monitoring activity are published in a bulletin distributed to all airlines every month. In this bulletin a rank order is given, showing the relative proportions of infringements for the various airlines. No airline likes to be at the top of the list, and no pilot likes to be cited too often. These factors alone have served to make the procedure effective; but they are reinforced on rare occasions by the practice of asking a pilot with an excessive number of citations to report to the traffic control office before each departure and receive a detailed briefing on the exact contents of the regulations. Even attempts to circumvent the system have provided unexpected benefits. For example, because knowledge of the system's details is common, some aircraft have been avoiding the known locations of monitoring microphones. Since these locations are at the outskirts of densely populated villages, the evasive actions of the pilots have proved to be advantageous.

In other countries the techniques for enforcement of airport noise standards tend to be more formal. Moreover, emphasis elsewhere seems to be placed on the establishment of acceptable criteria or on the selection of suitable sites. In common with nations from other continents, the rest of the European countries are interested in problems such as: noise certification, satisfactory methods for specifying noise levels, location of airports where land usage in their vicinity is reasonably compatible with the degree of noise disturbance likely to be experienced, and production or operation of aircraft to achieve noise abatement without sacrificing safety or economy.

A few countries have experimented with other approaches for protection from aircraft noise, both flyover disturbances and airport effects. In 1963, Tokyo tried a ban against jet flights between 11:00 p.m. and 6:00 a.m. In later years Japan, Norway, and Great Britain experimented with such physical measures as the construction of acoustic baffles and greenbelts, the installation of double windows, the use of sound insulation in the walls and ceilings of buildings, and the erection of concrete walls around schools. While all these measures were at least partially successful, circumstances often negated their effects. In some cases, for instance, the absence of air conditioning in such protected buildings prompted the occupants to open the windows in the summer.

The worldwide concern over aircraft noise comes at a time when the present generation of jet aircraft will probably be in use for at least another eight to 10 years. Accordingly, attention has been directed to retrofitting existing jet engines to make them quieter. Although the International Civil Aviation Organization sponsored a retrofit meeting in November 1971, little hope is held for general agreement on its recommendation, because the estimated cost per engine is beyond the means of many foreign nations. Air traffic noise thus promises to be a challenging problem for the decade of the seventies, a problem with technical, economic, and political overtones of considerable magnitude.

Surface Traffic Noise

Of all the irritant noise sources in both urban and rural settings, traffic noise has been isolated as the most significant. Many countries have undertaken sociological surveys that support this thesis. For example, Table 6-2 presents data gathered from a British survey in 1968.

Table 6-2

BRITISH TRAFFIC SURVEY

	Number of People Disturbed Per 100 Questioned		
Description of Noise	When at Home	When Outdoors	When at Work
Road traffic	36	20	7
Aircraft	9	4	1
Trains	5	1	-
Industry/construction work	7	3	10
Domestic/Light appliances	4	-	4
Neighbors' impact noise (knocking, walking, etc.)	6	-	-
Children	9	3	-
Adult voices	10	2	2
Radio/TV	7	1	1
Bells/alarms	3	1	1
Pets	3	-	-

The absolute percentages may vary from country to country, but the relative position of traffic noise versus that from other sources is constant. In Norway, a relatively thinly populated country, a poll of 1600 people yielded the date presented in Table 6-3.

Table 6-3

NORWEGIAN NOISE SURVEY

Type of Noise	Number of People Annoyed per 100 Questioned		
		Area	
	All Questioned	Urban	Rural
A. Noise from motor vehicles	17	20	11
B. Noise from aircraft	3	4	1
C. Noise from railroads	4	5	1
D. Noise from neighbors	5	6	3

A Swedish study shows that cultural differences are significant in assessing the social impact of traffic noise. This comparative study, with a sample population (matched in terms of age, social, and occupational status) of 200 in Stockholm and 166 in Ferrara, Italy, came up with a statistically significant difference—92 percent in Stockholm versus 63 percent in Ferrara spontaneously mentioned traffic noise, and 61 percent in Stockholm versus 43 percent in Ferrara were disturbed by traffic noise. The conclusion was drawn that results concerning annoyance reactions to traffic noise in one country cannot be directly extrapolated to another.

Road Traffic Noise Levels

In 1970 a report on urban traffic noise by the Organization for Economic Cooperation and Development the observation is made that effective enforcement of traffic noise regulations requires the availability of simple, reliable noise monitoring instruments. Experience attests to the ineffectiveness of legal enforcement of noise legislation without adequate equipment (or manpower). It implies that even though not all governments experience equal deficiencies, a universal need for improvement does exist. For research purposes, however, modern equipment satisfies all current requirements.

Between 1963 and 1965, in roadside surveys made in Great Britain traffic noise was isolated from all other sources. The measurements were made in a wide range of situations, to learn how to relate the variables of traffic flow and road gradient to noise levels. The procedures followed were those specified in British Standard 3425.

A useful method of displaying the time-varying nature of traffic noise is a statistical distribution. Figure 6-1 shows such distributions measured by Lamure and Auzou, in France, for light and heavy urban highway traffic. A straight line on the figure represents a Gaussian distribution. In this case, the heavy traffic situation is described well by such a distribution, while the distribution of the light traffic situation is skewed by the occasional noise peaks.

The data is essentially self-explanatory. It shows, for example, that in light traffic 80 dBA is exceeded 5 percent of the time, 70 dBA 20 percent of the time and that in heavy traffic 80 dBA is exceeded 60 percent of the time and 70 dBA 97 percent of the time. These noise levels far exceed those recommended by the Organization of Economic Cooperation and Development as acceptable.

A noise map plotted for Toulouse, France, showed that in the center of the city the noise level rarely falls below 80 to 90 dBA and sometimes even exceeds 100 dBA at peak periods.

Recordings made uninterrupted for 24-hour periods inside a number of buildings in Paris showed that inside a building particularly exposed to urban traffic noise,

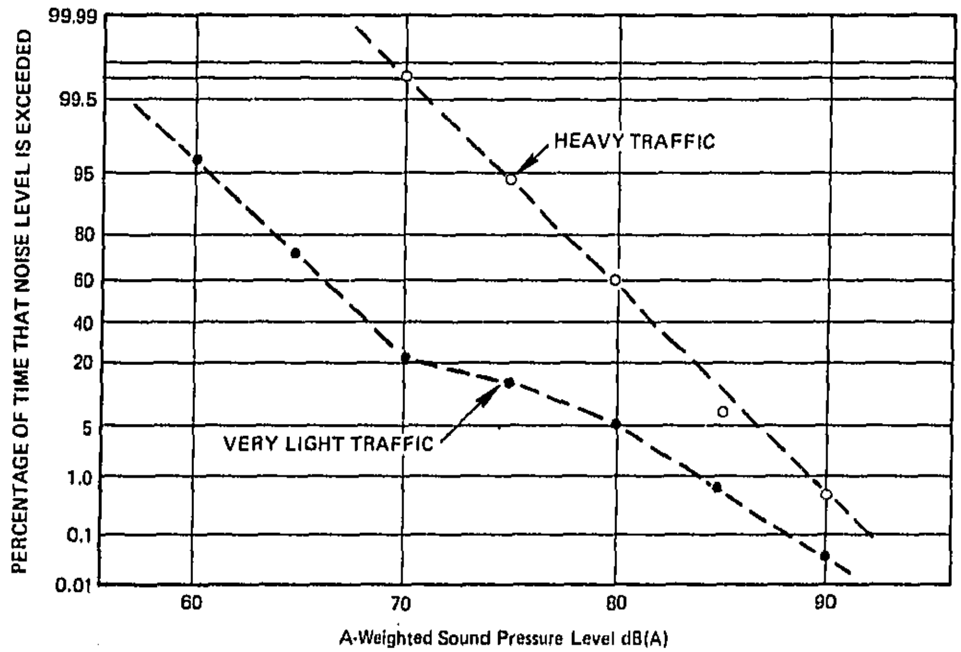

Figure 6-1. Typical Statistical Distributions of Urban Traffic Noise

the average total noise during the day (from 6:00 a.m. to 11:00 p.m.) varies between 50 and 60 dBA and that during the night (from 11:00 p.m. to 6:00 a.m.) is varied between 40 and 50 dBA, with frequent peaks of 60 dBA. During the day, the minimum noise never falls below 45 dBA and falls below 30 dBA only between 1:00 a.m. and 3:00 a.m. 5.

Control of Traffic Noise

Traffic noise abatement can be achieved by attacking either the source, the transmission path, the receiver (buildings), or any combination of these elements. There appears to be no consistency among the countries surveyed in their approach to the control of traffic noise. In Sweden as well as Great Britain, busses have been modified with special acoustic liners around the engines and exhausts. While an 8- to 10- dBA reduction is being claimed, the Organization for Economic Cooperation and Development cautions that such measures may be temporary unless relatively expensive maintenance procedures are observed.

Soviet experiments have shown positive results through dynamic balancing of the engine, gear box, wheels, and tires as well as through extensive use of soundproofing materials. A British study by the National Physics Laboratory achieved noise level reductions of 5 dBA for diesel engines and 9 dBA for gasoline engines by varying the compression ratios and timing patterns.

Regarding transmission path noise reduction, all countries surveyed agreed that depressed highways with either slanted or vertical walls offered best results. Similarly, noise shielding structures appear to be a popular approach, at least in Sweden, Great Britain, and the West German Republic. In a London noise study employing a protective barrier three meters from the edge of a road 30 meters wide, it was found that 30 meters from the screen the total noise reduction varied from 9 to 15 dBA for a 1.5-meter barrier, from 17 to 22 dBA for a 5-meter barrier, and 22 to 25 dBA for a 10-meter barrier. Noise reduction due solely to distance was about 9 dBA.

Many countries have introduced strips of grass and trees along highways. While such measures are aesthetically pleasing, Swiss and Scandinavian data show typical attentuation of 5 dBA per 100 meters for dense plantings of trees. The Swiss study states that such a measure may be worthwhile from a psychological point of view: when the source of the noise is not visible, it is less irritating.

Many large urban governments are redesigning entire sections of their cities to provide more pleasant environments that include reduced traffic noise levels outside and inside residences and other buildings. For example, an Amsterdam project calls for wide spaces, planted with grass and trees, between highways and residences. Only low nonresidential buildings are allowed along the highway.

Enforcement

Nearly all countries surveyed have explicit national or local legislation regulating noise emissions by motor vehicles. The Organization for Economic Cooperation and Development Urban Traffic Noise Survey of 1970 observes:

> "In order to be realistic these standards should reflect a compromise between social considerations, what the public is willing to pay, and what industry can manage to produce in the light of available technology. Some reductions in noise emission could be achieved in the fairly short run simply by adding acoustical absorbers and by detailed attention to silencers, air intakes and cooler fans. More significant noise reductions would, in many cases, require alterations in the design of the engine, and could therefore become effective only after a longer period. The important point is that standards should be set, and set on a sliding scale, so as to continue to reflect the current state of noise reduction technology."

A number of countries actively enforce noise emission standards by various methods. Denmark, for example, has compulsory noise inspection whenever cars over five years old are sold. In Switzerland, cities such as Lausanne, Zürich, Berne, engage regular police noise patrols empowered to fine the driver or to temporarily confiscate vehicles that have been altered to increase exhaust noise. Tokyo elicits public cooperation and consciousness regarding street noise by using illuminated signs that continually flash the noise level readings at busy intersections.

NOISE ENVIRONMENTS

The Residential Environment

Much has been said about the effects on residential areas of noise from aircraft, surface vehicles, industrial plants, and other external sources. However, a close review of foreign literature shows that other countries devote significant attention to the identification and control of disturbances that originate in and around residential buildings. Some of the annoyances already mentioned in connection with the London noise survey have been cited by representatives of other countries as well. Much of their discussion revolves around the transmission of sounds through poorly insulated walls and floors. These sounds include human voices, footsteps, radios, musical instruments, and many others generated either by neighbors or by members of the same household.

At least 15 major countries have insulation specifications for dwellings, especially for apartment buildings. A common characteristic of these countries is that apartment buildings predominate in a new residential construction. A typical example is Sweden, where, as early as 1961, 73 percent of all new dwellings were apartments. This country was one of the first to introduce insulation requirements that cover wall and floor insulation between living rooms and that set limits for noise produced by the turning on or off of faucets in bathrooms and kitchens.

In some countries, specifications are presented as requirements, while in others they are merely recommendations. Although most of the specifications center around International Standard Organization recommendations, particularly with respect to the measurement of airborne and impact sound transmissions, each country has introduced special features of its own. For example, in Poland as well as in other East European countries, all apartments must be separated longitudinally by double walls. Several countries recommend floating floors for control of impact noises and lead-based foundations for the attenuation of ground-transmitted vibrations. Most European countries specify insulation of water pipes from the structural members of buildings to avoid transmission of water hammer vibrations and faucet noise.

Not all domestic noise sources are directly related to insulation. Elevators, heating or air conditioning equipment, doorbells, household appliances, and other devices have been cited as offenders. Sweden and the USSR have conducted notable studies of such items, particularly of individual household appliances.

The Swedish Institute of Building Research has analyzed 66 noise sources such as vacuum cleaners, refrigerators, kitchen exhaust fans, freezers, heating fans, and hair driers. The highest noise levels in the Swedish study (70 to 80 dB at one meter) came from vacuum cleaners. A Soviet study of home appliances ranked an electric floor polisher as the noisiest, followed by a vacuum cleaner, a shaver, and a sewing machine. This study also included some appliances that had been designed specifically for quiet operation. Notable among these were a vacuum cleaner with the motor insulated from the housing, a centrifuge-type laundry extractor with a rubber pillow in the base, some noiseless melodic doorbells, and a washing machine that used high-pressure steam and had no moving parts.

An interesting viewpoint on household appliances was offered in the Hungarian monograph submitted for this year's environmental conference sponsored by the Economic Commission for Europe. The writer expressed the opinion that appliances made in Hungary had little value for export purposes because they were noisier than appliances manufactured in other countries. The Hungarian report introduces a rarely expressed evaluation of noise as an economic factor. In general, studies of domestic noise center around the same effects as do studies of other noises. Although home-generated noises are surpassed by disturbances from traffic and industry, they are by no means disregarded in other countries.

Public Institutions

Many countries have conducted special studies and surveys of public institutions. Most commonly studied have been schools and hospitals; but other institutions for which some foreign noise control efforts can be observed include museums, concert halls, libraries, and public administration buildings.

The USSR has developed a standard Vibronoise-I measurement laboratory for measuring noise and vibration in certain buildings for inspection and control purposes. Much of the equipment is portable, so field measurements can be made in schools, hospitals, health stations, juvenile institutions, etc. Over 350 Vibronoise-I units were produced and distributed between 1967 and 1970.

Studies conducted in Austria, Czechoslovakia, and Germany explore noise as a negative factor in the educational environment. These studies conclude that excessive noise not only distracts the attention of students but affects them physically and psychologically. Observations show that excess noise levels in classrooms produce fatigue, reduce concentration span, raise blood pressure, and sometimes cause neurosis. These observations concur with the maximum classroom level of 45 dBA recommended by Great Britain's Wilson Committee. A Swedish recommendation placed the maximum classroom level at 35 dBA.

Great Britain, Germany, Austria, Italy, Poland, Sweden, the USSR, and South Africa are among the countries in which studies have been undertaken to determine the noise levels in hospitals and to analyze the effects of noise on patients. Most of the surveys showed excessive noise levels ranging from 50 to 90 dBA within the rooms as compared to the recommended maximum levels of 55 dBA during the day and 25 dBA at night. All investigators agreed that noise levels considered tolerable for healthy individuals could be unbearable or damaging to hospital patients.

Effects of Industrial Noise on the Community

Although industrial noise receives some attention in general studies and surveys, much of the information about it is generated in special studies. Often, such studies are limited to isolated instances in single plants. For example, a cyclone extractor in Australia was studied after residents complained about it. As a result of this study, the unit was modified and shielded so that the emission was reduced to a level that was not objectionable. In another Australian case, the loud hissing noise of the oil burners in an industrial kiln was the subject of complaints and a subsequent investigation. A specially designed muffler system eliminated this problem.

The practice in London precludes the appearance in print of many reports on investigations of this nature. There, the control of industrial noise is the responsibility of the local boroughs, and investigations of complaints are made by the public health inspectors. In most cases the investigations consist of informal discussions with the offending firms.

A more extensive approach to industrial noise problems was taken by the Federal Republic of Germany in a study of noise in the metal industry. This study identified noise sources and measured their noise levels at various points in the surrounding communities. The worst sources identified included high speed blowers, drop hammers, and material handling equipment. In most instances, the residents had failed to register complaints, except when unusual events occurred.

Unlike the residents near fixed industrial plants, citizens exposed to temporary construction activities usually find the attendant disturbances objectionable. Consideration of this has caused some countries to shorten the work shifts for construction activities. Switzerland has developed a formula that determines the allowable work time on the basis of the average noise level of the operation.

In the Communist countries, allowance for industrial noise is often included in town planning. Plant screens, greenbelts, and distance standards are customarily employed.

SUMMARY

Most countries surveyed have viewed noise abatement and control as a major environmental issue for more than a decade. Research efforts have been and are being supported largely by national governments. On the basis of research results, a large number of countries have enacted comprehensive laws and regulations, and, in many instances, national laws are stricter than the corresponding International Standards Organization recommendations.

It is difficult to attribute these national concerns to a common basis, since there are varying levels of emphasis. For example, economic effects of noise have been frequently expressed, such as the impact of noise on labor productivity, the lack of foreign acceptability of domestic (noisy) industrial products, or the impact of a noisy community environment on a tourist-oriented economy. Similarly, the concern for social welfare brought about the enforcement of numerous specific regulations.

There are several international organizations that have promoted noise control to member nations. The World Health Organization has made a number of sweeping recommendations. Similarly, the Organization of Economic Cooperation and Development has pressed the issue of traffic noise, has issued a report, "Urban Traffic Noise" (Paris, 1971), and is presently sponsoring a comprehensive study on the environmental impact of the automobile, including air pollution and noise. The U. N. Economic Commission for Europe (ECE), issued in 1968, recommended "Maximum Limits of Sound Level – New Vehicles" (Rule No. 9, Uniform Provisions Concerning Approval of Noise – ECE Geneva; and the Council of European Communities (CEC) has issued a directive to the Common Market nations to provide for uniform noise limits for new vehicles. This rule is to become effective by the end of August 1972.

In general, all countries surveyed recognized the following sources as noise polluters (listed in order of impact):

1. Surface traffic
2. Aviation
3. Industry (as a community noise source)
4. Community activities.

Depending upon the political structure of each country, enforcement is guided nationally but implemented regionally. Many countries have been successful in their noise abatement efforts, but uniformity of approach is not evident.

Appendix A

SOURCE DOCUMENT INFORMATION

Appendix A

SOURCE DOCUMENT INFORMATION

The Technical Information Documents used as the basis for the preparation of this report are:

NTID300.1 - Noise From Construction Equipment and Operations, Building Equipment, and Home Appliances, prepared by Bolt, Beranek and Newman under EPA contract 68-04-0047.

NTID300.2 - Noise From Industrial Plants, prepared by L.S. Goodfriend Associates under contract EPA 68-04-0044.

NTID300.3 - Community Noise, prepared by Wyle Laboratories under EPA contract 68-04-0046.

NTID300.4 - Laws and Regulatory Schemes for Noise Abatement, prepared by the George Washington University under EPA contract 68-04-0032.

NTID300.5 - Effects of Noise on Wildlife and other Animals, prepared by Memphis State University under EPA contract 68-04-0024.

NTID300.6 - An Assessment of Noise Concern in Other Nations, prepared by Informatics, Inc. under EPA contract 68-01-0157.

NTID300.7 - Effects of Noise on People, prepared by the Central Institute for the Deaf under EPA contract 68-01-0500.

NTID300.8 - State and Municipal Non-Occupational Noise Abatement Programs, prepared by the staff of the EPA Office of Noise Abatement and Control.

NTID300.9 - Noise Programs of Professional/Industrial Organizations, Universities and Colleges, prepared by the staff of the EPA Office of Noise Abatement and Control.

NTID300.10 - Summary of Noise Programs in the Federal Government, prepared by the staff of the EPA Office of Noise Abatement and Control.

NTID300.11 - Social Impact of Noise, prepared by the National Bureau of Standards under interagency agreement with the Department of Commerce.

NTID300.12 - Effects of Sonic Boom and Other Impulsive Noise on Structures, prepared by the National Bureau of Standards under interagency agreement with the Department of Commerce.

NTID300.13 - Transportation Noise and Noise From Equipment Powered by Internal Combustion Engines, prepared by Wyle Laboratories under EPA contract 68-04-0046.

NTID300.14 - Economic Impact of Noise, prepared by the National Bureau of Standards under interagency agreement with the Department of Commerce.

NTID300.15 - Fundamentals of Noise: Measurement, Rating Schemes, and Standards, prepared by The National Bureau of Standards under interagency agreement with the Department of Commerce.

To obtain these documents contact the Environmental Protection Agency, Office of Noise Abatement and Control, Washington, D.C. 20460.

Also used in the preparation of this report was testimony obtained at public hearings held by the Office of Noise Abatement and Control under authority of the Noise

Pollution and Abatement Act of 1970 — Title IV to the Clean Air Amendments of 1970 (PL 91-604). The cities in which those hearings were held and their subjects covered are as follows:

Atlanta	Noise in Construction
Chicago	Manufacturing and Transportation Noise (Highway and Air)
Dallas	Urban Planning, Architectural Design; and Noise in the Home
San Francisco	Standards and Measurement Methods, Legislation and Enforcement Problems
Denver	Agriculture and Recreational use Noise
New York	Transportation (Rail and Other), Urban Noise Problems and Social Behavior
Boston	Physiological and Psychological Effects
Washington, D. C.	Technology and Economics of Noise Control; National Programs and their Relations With State and Local Programs.

The transcripts of these hearings may be obtained through the United States Government Printing Office, Superintendant of Documents, after announcement of their availability in the Federal Register.

Appendix B

PROPOSED BILL TO CONTROL THE GENERATION AND TRANSMISSION OF NOISE

ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D. C. 20460

Dear Mr. [President/Speaker]:

Enclosed is a draft of a proposed bill "to control the generation and transmission of noise detrimental to the human environment, and for other purposes."

The proposed legislation would expand and coordinate Federal efforts to control noise, which presents a growing threat to the health and welfare of the American people. Particularly in congested urban areas, the noise produced by the products of our advancing technology, and in the manufacture of those products, causes continual annoyance and in some cases serious physical harm. While the States and localities have the responsibility to deal with many aspects of noise, effective Federal action is essential with respect to major noise problems requiring national uniformity of treatment.

The proposed bill would achieve three primary functions. First, it would establish, in the Environmental Protection Agency, authority to coordinate existing Federal noise research and control programs, and authority to publish criteria and control-technology documents relating to noise. Second, it would supplement existing Federal authority to regulate the noise characteristics of articles that are major sources of noise, and authorize Federal noise labeling requirements for such articles. Third, it would direct all Federal agencies to administer their programs, consistent with existing authority, in such a manner as to minimize noise.

A detailed section-by-section analysis of the bill is enclosed. A similar letter is being sent to the [President of the Senate/Speaker of the House].

The bill is part of the President's environmental program as announced in his Environmental Message of February 8, 1971. It will be administered by the Environmental Protection Agency and was developed in coordination with the Council on Environmental Quality.

The Office of Management and Budget advises that enactment of this bill would be in accord with the program of the President.

Sincerely yours,

/s/ William D. Ruckelshaus

Honorable Spiro T. Agnew
President of the Senate
Washington, D.C. 20510

Honorable Carl B. Albert
Speaker of the House of Representatives
Washington, D.C. 20515

A BILL

To control the generation and transmission of noise detrimental to the human environment, and for other purposes.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That: This Act may be cited as the "Noise Control Act of 1971".

SECTION 2. FINDINGS AND POLICY

(a) The Congress finds --

(1) that inadequately controlled noise presents a growing danger to the health and welfare of the Nation's population, particularly in urban areas;

(2) that the major sources of noise include transportation vehicles and equipment, machinery, appliances, and other manufactured articles that move in commerce; and

(3) that, while primary responsibility for control of noise rests in many respects with the States and local governments, Federal action is essential to deal with major noise problems requiring national uniformity of treatment.

(b) The Congress declares that it is the policy of the United States to promote an environment for all Americans free from noise that jeopardizes their health or welfare. To that end, it is the purpose of this Act to establish a means for effective coordination of Federal research and activities in noise control, to supplement existing Federal authority for regulation of the noise characteristics of articles moving in commerce, and to authorize Federal noise labeling requirements for such articles. Nothing in this Act is intended to diminish the responsibilities of State and local governments to regulate other aspects of noise within their jurisdictions.

SECTION 3. DEFINITIONS

As used in this Act the term --

(a) "Administrator" means the Administrator of the Environmental Protection Agency;

(b) "person" means any private person or entity, any officer, department, agency, or instrumentality of any State or local unit of government, and, except with respect to the provisions of section

12(a), any officer, department, agency, or instrumentality of the Federal Government;

(c) "product" means any article or good manufactured for sale in, or introduction into, commerce, including but not limited to transportation vehicles and equipment, machinery, and appliances, provided, that it does not include (i) aircraft, aircraft engines, propellers, or appliances that are covered by Title VI of the Federal Aviation Act of 1958 (49 U.S.C. Secs. 1421-32), (ii) those military aircraft, weapons, or equipment that are designed for combat use; or (iii) those aircraft, rockets, or equipment that are designed for research or experimental or developmental work to be performed by the National Aeronautics and Space Administration, or other machinery or equipment designed for use in experimental work done by or for the Federal Government;

(d) "ultimate purchaser" means the first person who in good faith purchases a new product for purposes other than resale;

(e) "new product" means a product the equitable of legal title to which has never been transferred to an ultimate purchaser;

(f) "manufacturer" means any person engaged in the manufacturing or assembling of new products or who acts for, and is controlled by, any such person in connection with the distribution of such products;

(g) "commerce" means trade, traffic, commerce, transportation, or communication among the several States, or between a place in a State and any place outside thereof, or within the District of Columbia or a possession of the United States, or between points in the same State but through a point outside thereof.

SECTION 4. COORDINATION AND EVALUATION OF FEDERAL PROGRAMS

(a) The Administrator shall promote coordination of the programs of all Federal departments and agencies relating to noise research and noise control. Each Federal department or agency shall, upon request, furnish to the Administrator such information as he may reasonably require to determine the nature, scope, and results of the noise-research and noise-control

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programs of the department or agency.

(b) On the basis of regular consultation with appropriate Federal departments and agencies, the Administrator shall compile and publish, from time to time, a report on the status and progress of Federal activities relating to noise research and noise control. This report shall describe the noise programs of each Federal department or agency and assess the contributions of those programs to the Government's overall efforts to control noise.

SECTION 5. NOISE CRITERIA AND CONTROL TECHNOLOGY

(a) The Administrator shall, after consultation with appropriate Federal departments and agencies, develop and publish such criteria for noise as in his judgment may be requisite for the protection of the public health and welfare. Such criteria shall reflect the scientific knowledge most useful in indicating the kind and extent of all identifiable effects on the public health or welfare which may be expected from differing quantities and qualities of noise. The Administrator shall confer with the Secretaries of Health, Education, and Welfare, and of Labor to assure consistency between the criteria published under this subsection and the criteria and standards for occupational noise exposure produced under the Occupational Safety and Health Act of 1970.

(b) The Administrator shall, after publication of the initial criteria pursuant to subsection (a) of this section and after consultation with appropriate Federal departments and agencies, compile and publish a report or series of reports identifying major sources of noise and giving information on techniques for control of noise from such sources. This information shall include such data as are available on the technology, costs, and alternative methods of noise control.

(c) The Administrator shall from time to time review and, as appropriate, revise or supplement any criteria or information on control techniques published pursuant to this section.

(d) The publication or revision of any criteria or information on control techniques pursuant to this section shall be announced in the Federal Register, and copies shall be made available to the general public.

SECTION 6. NOISE-GENERATION STANDARDS

(a) If the Administrator, in a report published pursuant to section 5, identifies as a major source of noise any product or class of products of one or more of the following types:

(1) construction equipment,

(2) transportation equipment (including recreational vehicles and related equipment), or

(3) equipment powered by internal combustion engines,

he may, after consultation to the extent desirable with appropriate Federal departments and agencies, by regulation prescribe and amend standards limiting the noise-generation characteristics (including reasonable durability over the life of the product) of such product or class of products. The standards so prescribed shall be the standards that the Administrator determines, consistent with criteria published pursuant to section 5, to be requisite to protect the public health and welfare. In prescribing and amending such standards the Administrator shall consider whether any proposed standard is economically reasonable, technologically practicable, and appropriate for the particular products to which it will apply, and whether the particular products can more effectively be controlled through Federal regulation of interstate commerce or through State or local regulations. Provided, that no standards prescribed under this section shall apply to products manufactured on or before the effective date of such standards.

(b) The Administrator shall publish any standards proposed under subsection (a) in the Federal Register at least 60 days prior to the time when such standards will take effect. In addition to submissions of written views, any person who will be adversely affected by such proposed regulation may, within 45 days of the date of publication of the proposed regulation, or within such other time period as the Administrator may prescribe, file objections with the Administrator and request a public hearing. Requests for a public hearing made by a manufacturer of a product covered by the proposed standards shall be granted. Requests for a public hearing by other persons may be granted at the discretion of the Administrator. If a public hearing is held, final regulations will not be promulgated by the Administrator until after the conclusion of such hearing.

(c) Section 611 of the Federal Aviation Act of 1958 (49 U.S.C. Sec. 1431) is amended as follows:

(1) In subsection (a), after "with the Secretary of Transportation" insert "and subject to the approval of the Administrator of the Environmental Protection Agency".

(2) At the end of subsection (a), insert "Standards, rules, and regulations prescribed and amended under this section shall become effective only upon approval by the Administrator of the Environmental Protection Agency; provided, that, all standards, rules, and regulations prescribed pursuant to this section prior to the effective date of the Noise Control Act of 1971 shall remain in effect until amended or revoked by subsequent standards, rules, or regulations prescribed and approved pursuant to this section."

(3) After subsection (a), insert the following new subsections:

"(b) The Administrator of the Federal Aviation Administration shall not issue a type certificate under section 603 of this act for any aircraft, or for any aircraft engine, propeller, or appliance that affects significantly the noise or sonic boom characteristics of any aircraft, unless he shall have prescribed standards, rules, and regulations under this section that apply to such aircraft, aircraft engine, propeller, or appliance.

"(c) If at any time the Administrator of the Environmental Protection Agency has reason to believe that an existing standard, rule, or regulation under this section does not protect the public from aircraft noise or sonic boom to the maximum extent that is consistent with the consideration listed in subsection (d) of this section, he may request the Administrator of the Federal Aviation Administration to review and report to him on the advisability of revising such standard, rule, or regulation. Any such request shall be accompanied by a detailed statement of the information on which it is based."

(4) Subsections (b) and (c) are redesignated as (d) and (e).

(d) No State or subdivision thereof shall adopt or enforce, with respect to any product for which noise-generation standards have been prescribed by the Administrator under subsection (a) of this section, any standard limiting noise-generation characteristics different from the standards prescribed by the Administrator. Nothing in this section shall diminish or enhance the rights of any State or subdivision thereof otherwise to control, regulate, or restrict the use, operation, or movement of such products.

SECTION 7. LABELING

(a) The Administrator may by regulation designate products or classes thereof:

(1) that produce noise capable of adversely affecting the public health or welfare; or

(2) that are sold wholly or in part on the basis of their effectiveness in reducing noise.

(b) For each of such products or classes the Administrator may, after consultation to the extent desirable with appropriate Federal departments and agencies, by regulation require that a notice of the actual level of noise generation, or notice of the actual effectiveness in reducing noise, be affixed to the product and to the outside of its container at the time of its sale to the ultimate purchaser. He shall prescribe the form of the notice and the methods and units of measurement to be used for this purpose.

(c) Nothing in this section shall preclude or deny to any State or subdivision thereof the right to regulate product labeling in any way not in conflict with regulations promulgated by the Administrator under this section.

SECTION 8. PROHIBITED ACTS

(a) The following acts or the causing thereof are prohibited:

(1) in the case of a manufacturer of new products, the sale, the offering for sale, or the introduction or delivery for introduction into commerce of any product manufactured after the effective date of regulations promulgated under section 6(a) (respecting noise-generation characteristics) that are applicable

to such product, unless it is in conformity with such regulations (except as provided in subsection (b) of this section);

(2) in the case of an owner or operator of a product, the use in commerce of such product after the effective date of regulations promulgated under section 6(a) that are applicable to such product, unless it is in conformity with such regulations (except as provided in subsection (b) of this section);

(3) the removal or rendering inoperative by any person, other than for purposes of maintenence, repair, or replacement, of any device or element of design incorporated into any product in compliance with regulations promulgated under section 6(a), prior to its sale or delivery to the ultimate purchaser or during its term of use.

(4) in the case of a manufacturer of new products, the sale, the offering for sale, or the introduction or delivery for introduction into commerce of any product manufactured after the effective date of regulations promulgated under section 7 (respecting noise labeling) that are applicable to such product, unless it is in conformity with such regulations (except as provided in subsection (b) of this section);

(5) the removal by any person of any notice affixed to a product or container pursuant to regulations promulgated under section 7, prior to sale of the product to the ultimate purchaser;

(6) the importation into the United States by any person of any product in violation of regulations promulgated under section 13 that are applicable to such product; and

(7) the failure or refusal by any person to permit access to, or copying of, records or to make reports or provide information required under section 9.

(b)(1) The Administrator may exempt any product, or class thereof, from paragraphs (1), (2), (4), and (6) of subsection (a), upon such terms and conditions as he may find necessary to protect the public health or welfare, for the purpose of research, investigations, studies, demonstrations, or training, or for reasons of national security.

(2) A product intended solely for export, and so labeled or tagged on the outside of the container and on the product itself, shall not be subject to paragraph (1), (2), or (4) of subsection (a).

SECTION 9. RECORDS, REPORTS, AND INFORMATION

(a) Every manufacturer of a product for which applicable regulations have been promulgated under section 6(a) or section 7 shall establish and maintain such records, make such reports, and provide such information (which may include the availability of products coming off the assembly line for testing by the Administrator) as the Administrator may reasonably require to enable him to determine whether such manufacturer has acted or is acting in compliance with this Act and shall, upon request of an officer or employee duly designated by the Administrator, permit such officer or employee at reasonable times to have access to such information and to copy such records.

(b) All information obtained by the Administrator or his representatives pursuant to subsection (a) of this section, which information contains or relates to a trade secret or other matter referred to in section 1905 of title 18 of the United States Code, shall be considered confidential for the purpose of that section, except that such information may be disclosed to other Federal officers or employees, in whose possession it shall remain confidential, or when relevent in any proceeding under this Act.

(c) This section shall apply only to manufacturers in the United States.

SECTION 10. FEDERAL PROGRAMS

The Congress authorizes and directs that all agencies of the Federal Government shall, to the fullest extent consistent with existing authority, administer the programs within their control in such a manner as to further the policy declared in section 2(b).

SECTION 11. RESEARCH, TECHNICAL ASSISTANCE, AND PUBLIC INFORMATION

In furtherance of his responsibilities under this Act and to complement, as necessary, the noise-research programs of other Federal departments and agencies, the Administrator is authorized to:

(a) Conduct research, and finance

research by contract with other public and private bodies, on the effects, measurement, and control of noise, including but not limited to:

(1) Investigation of the psychological and physiological effects of noise on humans and the effects of noise on domestic animals, wildlife, and property, and determination of acceptable levels of noise on the basis of such effects;

(2) Development of improved methods and standards for measurement and monitoring of noise, in cooperation with the National Bureau of Standards, Department of Commerce; and

(3) Determination of the most effective and practicable means of controlling noise generation, transmission, and reception;

(b) Provide technical assistance to State and local governments to facilitate their development and enforcement of ambient noise standards, including but not limited to:

(1) Advice on training of noise-control personnel and on selection and operation of noise-abatement equipment; and

(2) Preparation of model State or local legislation for noise control; and

(c) Disseminate to the public information on the effects of noise, acceptable noise levels, and techniques for noise measurement and control.

SECTION 12. ENFORCEMENT

(a)(1) Any person who violates section 8(a) of this Act shall be subject to a civil penalty of not more than $25,000 for each violation, which may be assessed by the Administrator or by a court in any action authorized by subsection (b) or (c) of this section.

(2) In any proceeding by the Administrator to assess a civil penalty under this subsection, no penalty shall be assessed until the person charged shall have been given notice and an opportunity for a hearing on such charge. In determining the amount of the penalty, or the amount agreed upon in compromise, the Administrator shall consider the gravity of the violation and the demonstrated good faith of the person charged in attempting to achieve rapid compliance after notification by the Administrator of a violation. Upon

failure of the offending party to pay any penalty assessed, the Administrator may request the Attorney General to commence an action in the appropriate district court for appropriate relief.

(3) For the purpose of this subsection, the commission of any act prohibited by paragraph (1), (2), (3), (4), (5), or (6) of section 8(a) shall constitute a separate violation for each day or product involved.

(b) The district courts of the United States shall have jurisdiction of actions brought by and in the name of the United States to restrain violations of this Act or to enforce civil penalties authorized by this Act. Any civil action authorized to be brought by the United States under this Act shall be referred to the Attorney General for appropriate action.

(c) By agreement with any State, with or without reimbursement, the Administrator may authorize law enforcement officers or other personnel of such State to enforce the prohibitions of section 8(a) by bringing actions in the appropriate State courts. When authorized by State law, the courts of such State may entertain actions brought by such officers or personnel to restrain violations of this Act or to enforce civil penalties authorized by this Act. In any action under this subsection, any civil penalty imposed shall be payable one-half to the State and one-half to the United States Treasury.

SECTION 13. IMPORTS

(a) Products offered for importation shall be subject to the same general standards and labeling requirements that are applied to like domestic products. The Administrator shall by regulation prescribe the procedures by which this will be accomplished with a minimum detrimental effect on domestic and international trade.

(b) The Secretary of the Treasury shall, in consultation with the Administrator, issue regulations to carry out the provisions of this Act with respect to products offered for importation.

SECTION 14. APPROPRIATIONS

There are authorized to be appropriated to carry out this Act for Fiscal Year 1972 and for each fiscal year thereafter such sums as are necessary.

SECTION 15. REPORT OF NOISE STUDY

Section 402(a) of the Clean Air Act is amended by deleting everything before "a full and complete investigation" and inserting in lieu thereof "The Administrator shall carry out".

SECTION-BY-SECTION ANALYSIS

The title of the proposed act is designated as "The Noise Control Act of 1971."

Section 2 contains a statement of congressional findings and policy. Subsection 2(a) states findings that noise, particularly in urban areas, presents a growing danger to the public health and welfare; that the major sources of noise include a variety of manufactured articles that move in commerce; and that the Federal Government bears a responsibility to deal with major noise problems requiring national uniformity of treatment. Subsection 2(b) declares a Federal policy to promote an environment for all Americans free from noise that jeopardizes their health or welfare. This subsection further states that the purpose of the proposed act is to establish a means for effective coordination of Federal noise programs, to supplement existing Federal authority for regulation of the noise characteristics of articles moving in commerce, and to authorize Federal noise labeling requirements for such articles. The Act is not intended to relieve States and localities of their responsibilities to control other aspects of noise within their jurisdictions.

Section 3 defines certain terms used in the proposal. Subsection 3(a) defines the official primarily responsible for implementing the legislation as the Administrator of the Environmental Protection Agency (EPA). Subsection 3(b) defines "person" in such a way that all Federal, State, or local governmental organizations, employees, and agents, along with private persons or entities, are included within the enforcement provisions of section 12. However, Federal organizations, employees, and agents are excepted from the definition of "person" insofar as subsection 12(a), providing for civil penalties, is concerned. Thus, Federal organizations, employees, and agents must comply with the prohibitions of section 8, but they are not liable for or subject to the civil penalties authorized in subsection 12(a).

Subsection 3(c) defines "product" to include any article or good manufactured for sale in, or introduction into, commerce with three general exclusions. "Product" does not include aircraft or aircraft components that are covered by Title VI of the Federal Aviation Act of 1958. The noise characteristics of these aircraft and aircraft components are already subject to regulation under that Act, which will continue in effect subject to the amendments made by section 6 of the proposed legislation, discussed below.

"Product" also excludes any article that, although otherwise within the broad definition, is designed for military combat use. National security requires that the responsible authorities be free to determine to what extent noise control objectives must be subordinated to military necessities in the use of such articles. Therefore, they are excluded from the definition of "product" to exempt them entirely from the standard-setting and labeling provisions of sections 6 and 7 without regard to the exercise by the Administrator of his power under section 8(b)(1), discussed below, to grant specific exemptions for national security reasons. The policy of the proposed legislation will, however, dictate that all feasible steps be taken to improve the noise characteristics of even these articles. "Product" also excludes equipment designed for use in experimental work done by or for the National Aeronautics and Space Administration or other agencies of the Federal Government.

Subsection 3(d) defines "ultimate purchaser" to be the first person who purchases a new product for a use other than resale. This excludes both those intermediaries who may handle the product before sale to the first user, and subsequent users who may obtain the product second-hand. Subsection 3(e) defines "new product" to mean a product the title to which has not yet been transferred to an ultimate purchaser.

Subsection 3(f) defines "manufacturer" to include any person who manufactures or assembles new products or who acts on behalf of such a person in the distribution of new products. "Commerce" is defined in subsection 3(g) to include all forms of interchange involving two or more States, or a State and a place outside thereof or the District of Columbia or a possession of the United States.

Section 4 entrusts to the Administrator of EPA the primary responsibility for promoting coordination of Federal programs relating to noise. To assist him in exercising this responsibility, subsection 4(a) directs each other Federal agency to furnish him with any information he may reasonably request about the agency's noise programs. Subsection 4(b) directs the Administrator, on the basis of consultation with appropriate Federal agencies, to publish a periodic report covering the noise-related activities of all Federal agencies. It is intended that this report will provide a means for assessing the overall progress of Federal noise control efforts.

Section 5 gives the Administrator of EPA responsibility to develop and publish basic documents on noise and its control. Subsection 5(a) directs him to develop criteria for noise, taking into account up-to-date scientific knowledge on noise effects. These criteria should make clear what quantities and qualities of noise are consistent with protection of the public health and welfare under differing circumstances. The Administrator is directed to seek consistency between these criteria and the criteria and standards for occupational noise exposure produced by the Secretaries of Health, Education, and Welfare and Labor under the Occupational Safety and Health Act of 1970.

Subsection 5(b) directs the Administrator, after initial publication of criteria under subsection 5(a), to publish one or more reports identifying major sources of noise and discussing techniques for controlling noise from such sources. It is not intended that any single report published under subsection 5(b) must cover all or most major noise sources. Rather, as information becomes available, the Administrator may publish individual reports identifying one or more major sources and outlining the noise control technology applicable to each identified source. Subsection 5(c) directs the Administrator to review and, when appropriate, revise both the criteria and the control technology documents published under section 5, to ensure that these reflect changes in available knowledge. Subsection 5(d) requires announcement of each publication or revision of criteria or control technology documents in the Federal Register and release of copies to the public. This provision is intended to ensure adequate public knowledge of the content of these publications.

Subsection 6(a) authorizes the Administrator of EPA to prescribe noise standards for construction equipment, transportation equipment, and equipment powered by internal combustion engines that he has identified as a major source of noise and for which he has discussed control technology in a report published pursuant to section 5. When the Administrator determines to impose standards, subsection 6(a) requires that they be set at the level required, in light of the published criteria, to protect health and welfare, taking into account the feasibility of such a level of control and the appropriateness of Federal regulation. Standards under subsection 6(a) shall not apply to products manufactured on or before the effective date of the standards. Subsection 6(b) alters the procedures under the Administrative Procedure Act by granting a manufacturer the right to a public hearing on proposed standards that would cover his products.

Subsection 6(c) amends section 611 of the Federal Aviation Act, which authorizes regulation of the noise characteristics of civil aircraft and aircraft components. Subsection 6(c) provides that standards, rules, and regulations prescribed by the Federal Aviation Administration under section 611 must be approved by the Administrator of EPA, and that such standards, rules, and regulations become effective only upon such approval. However, subsection 6(c) contains a saving clause which allows all standards, rules, and regulations prescribed under section 611 prior to the effective date of the proposed legislation to continue in effect until superseded by new standards, rules, or regulations prescribed in accordance with the proposed legislation.

Subsection 6(c) further provides that after the effective date of the proposed act the Federal Aviation Administrator shall not issue a type certificate for any aircraft unless he has already prescribed standards, rules, and regulations governing the noise characteristics of that aircraft. This requirement also applies to any aircraft engine, propeller, or appliance that affects significantly the noise characteristics of any aircraft in which it is to be used. This provision will ensure that in the future the noise characteristics of any new aircraft or aircraft component will be ascertained and controlled prior to its introduction into air commerce or air transportation.

Subsection 6(c) further provides that if the Administrator of EPA has reason to believe that an existing standard, rule, or regulation prescribed under 611 of the Federal Aviation Act inadequately protects the public from noise, he may request the Federal Aviation Administrator to review the standard, rule, or regulation and report to him on the advisability of revising it. Any such request must be accompanied by a detailed statement of the reasons therefor. The Administrator of EPA may invoke this provision with respect to a standard, rule, or regulation prescribed before or after the effective date of the proposed act.

Subsection 6(d) provides that when the Administrator of EPA has prescribed standards for any product under subsection 6(a), no State or subdivision thereof shall adopt or enforce noise standards for that product different from the standards set by him. Nothing in section 6 preempts any existing powers of the States or localities to set noise standards for products for which the Administrator has not yet set standards under the proposed act, to set State standards identical to standards set by the Administrator for the same product, or to regulate the use, operation, or movement of products.

Section 7 authorizes Federal noise labeling requirements for products in commerce. Subsection 7(a) authorizes the Administrator of EPA to designate classes of products that either produce noise capable of adversely affecting the public health or welfare, or are sold at least in part on the basis of their effectiveness in reducing noise. These products need not be limited to those for which noise standards have been set under section 6 or which have been discussed in a control technology document under section 5. Subsection 7(b) authorizes the Administrator to prescribe a noise-generation or noise-reduction labeling requirement for any product designated under subsection 7(a). To assure that such notices are informative and useful in facilitating choices by buyers in the marketplace, the Administrator is directed to prescribe the form of the notice and the methods and units of measurement used in its preparation. Subsection 7(c) leaves intact any existing powers of the States to regulate product labeling, except that such regulation may not conflict with regulations promulgated by the Administrator under section 7.

Subsection 8(a) prohibits a number of acts in violation of the proposed legislation. Paragraph 8(a)(1) forbids any manufacturer to sell a product manufactured after the effective date of noise-generation standards prescribed under subsection 6(a) that apply to the product, unless the product conforms with such standards. Paragraph 8(a)(2) forbids any person who owns or operates a product to use it in commerce after the effective date of noise-generation standards prescribed under subsection 6(a) that apply to it, unless the product conforms with such standards. Paragraph 8(a)(3) forbids any person to remove or render inoperative, other than for maintenance, repair, or replacement, any device or element of design incorporated into a product to make the product comply with noise-generation standards prescribed under subsection 6(a). This prescription applies both prior to sale of the product to the ultimate purchaser and during its term of use.

Paragraph 8(a)(4) forbids any manufacturer to sell a product manufactured after the effective date of labeling regulations promulgated under section 7 that apply to the product, unless the product conforms to such regulations. Paragraph 8(a)(5) forbids any person, prior to sale of a product to the ultimate purchaser, to remove a notice affixed to the product or its container pursuant to regulations promulgated under section 7. Paragraph 8(a)(6) forbids the importation into the United States of any products in violation of regulations under section 13, discussed below, relating to imports. Paragraph 8(a)(7) forbids any person to fail to comply with the provisions of section 9, discussed below, respecting access to required records and reports.

Subsection 8(b) creates two exceptions to the prohibitions in paragraphs 8(a)(1), (2), (4), and (6). First, the Administrator is authorized to exempt any new product from those prohibitions, upon such terms and conditions as he may find necessary to protect the public health or welfare, for the purpose of research, investigations, studies, demonstrations, or training, or for reasons of national security. Second, subsection 8(b) provides that a product produced solely for export, and visibly labeled or tagged to that effect, is exempted from the prohibitions of paragraphs 8(a)(1), (2) and (4).

Section 9 requires every manufacturer of a product covered by noise regulation or labeling regulations under subsection 6(a) or section 7 to maintain such records, make such reports, and provide such information as the Administrator may reasonably require to enable him to determine whether the manufacturer has acted or is acting in compliance with the proposed act. This may include the availability of products coming off the assembly line for testing by the Administrator. The manufacturer shall, on request, permit a representative of the Administrator to view and copy such records. Any information obtained by the Administrator or his representatives pursuant to section 9, if it contains or relates to a matter referred to as confidential in section 1905 of title 18 of the United States Code, shall be protected from disclosure as provided in that section, except that it may be disclosed to other Federal employees or when relevant in any proceeding under the proposed act. Disclosure to other Federal employees or in a proceeding under the proposed act will not terminate the confidential status of the information.

Section 10 authorizes and directs all Federal agencies to administer the programs within their control in such a manner as to further the policy of the proposed Act, to the fullest extent consistent with the agencies' existing authority.

Section 11 authorizes the Administrator of EPA, in furtherance of his responsibilities under the proposed act, to conduct and assist noise research, to provide technical assistance to State and local governments, and to disseminate to the public information on noise. The enumeration in section 11 of particular activities within these categories is not intended to exclude other activities but only to stress the importance of those enumerated. However, it is not intended that the activities of the Administrator under section 11 will

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duplicate activities carried on in other agencies.

Section 12 provides for enforcement of the prohibitions in subsection 8(a) of the proposed act. Subsection 12(a) establishes a civil penalty of not more than $25,000 for each violation of subsection 8(a), and provides for imposition of this fine either by the Administrator or by a court in a proceeding authorized by subsection 12(b) or (c), discussed below. Subsection 12(a) further provides that in any administrative proceeding for imposition of such a civil penalty by the Administrator the person charged must be given notice and an opportunity for a hearing, and the Administrator must, in determining the penalty or the amount accepted in compromise, consider the gravity of the violation and the efforts of the person charged to achieve rapid compliance after notice of the violation. If the offending party fails to pay any penalty assessed, the Administrator may request the Attorney General to sue in the appropriate district court for appropriate relief. For the purpose of imposing cumulative penalties, the commission of any act prohibited by paragraph 8(a)(1), (2), (3), (4), (5), or (6) will be a separate violation for each day or product involved. For example, sale of 10 identical products in violation of noise-generation or labeling regulations would constitute 10 violations, punishable by a maximum cumulative fine of $250,000.

Subsection 12(b) gives jurisdiction to the Federal district courts to entertain actions brought by and in the name of the United States to restrain violations of the proposed act or to enforce civil penalties authorized by it. This provision will allow the Administrator of EPA, by recommending that the Attorney General bring suit, to seek equitable relief or judicial imposition of a civil penalty, or both, as an alternative to the administratively imposed fine also authorized by section 12.

Section 12(c) enables the Administrator to enlist the aid of State or local governments in the enforcement of the proposed act. While neither the executive nor the judicial bodies of any State will be required to participate, they may do so where this is authorized by State law and also by the Administrator of EPA in an agreement with the appropriate State authorities.

Under this provision the Administrator may authorize State personnel to sue in State court both to restrain violations and to impose civil penalties; he may not authorize State personnel to impose fines administratively. Any civil penalty imposed under the proposed act by a State court in a suit under subsection 12(c) will be payable one-half to the appropriate State authorities and one-half to the United States Treasury.

Section 13 directs the Administrator and the Secretary of the Treasury to issue regulations to apply to imports the same general standards and labeling requirements that are applied to like domestic products.

Section 14 authorizes the appropriation for Fiscal Year 1972 and for each fiscal year thereafter such sums as are necessary to carry out the proposed act.

Section 15 amends the Clean Air Act by deleting the requirement that there by an Office of Noise Abatement and Control in the Environmental Protection Agency.

Appendix C

PUBLIC HEARINGS ON NOISE -- TITLE IV PL 91-604

Noise in Construction
Atlanta, Ga., July 8-9, 1971

PANEL:

Dr. Alvin F. Meyer, Jr., Office of Noise Abatement and Control, EPA, Washington, D.C.
Dr. Erich Bender, Bolt, Beranek & Newman
Dr. D. Lyons, Clemson University
Mr. R.A. Baron, Citizens for a Quieter City
Mr. Gerald P. McCarthy, Governor's Council on the Environment, State of Virginia
Dr. Daniel A. Okun, University of North Carolina

ATTENDEES:

K.S. Kronoveter, National Institute for Occupational Safety & Health
George Allgood, FAA (Atlanta Airport)
James Rickard, FAA
Lutz Kohnagel, Engineer
Dr. Alvin F. Meyer, Jr.
Alice Suter, National Association of Hearing and Speech Agencies
Earl Ellwood, United States Gypsum Company
Frank H. Walk, Professional Engineer, Walk, Haydel & Associates, Inc., New Orleans, Louisiana
George Diehl, Ingersoll-Rand Research, Inc.
Captain David H. Riley, Training Division, Atlanta Police Department
Edwin Jackson, Executive Vice President, Delta P Incorporated
Roger D. Wellington, Staff Engineer, Testing and Development, Detroit Diesel Allison Division, General Motors Corporation
Charles L. Skinner, Managing Director, Georgia Motor Trucking Association, Inc.
John Palazzi, The Associated General Contractors of America
Lyle G. Munson, Director of Engineering, Colt Industries, Quincy Compressor Division
R.F. Ringham, Vice President, Engineering, Chassis Test Construction Equipment Division, Internal Harvester Company
J.R. Prosek, Chief Engineer, Chassis Test Construction Equipment Division, International Harvester Company
Jack Hasten, Manager, Products Control Department, Caterpillar Tractor Company
Lester Bergsten, Staff Research Engineer, Caterpillar Tractor Company
J.B. Codlin, Manager, Special Engineering Assignments, Construction Machinery Division, Allis-Chalmers Corporation
William Hansell, Director of Environmental Health, Georgia Public Health Department

ATTENDEES (Cont'd.):

R.L. Smelley, Southeast Regional Director, N.O.I.S.E.
Mrs. Wirt Jones, Sierra Club
George H. Grindley, Audiologist, Administrator of Doctors Memorial Hospital Hearing and Speech Center, Atlanta, Georgia, on behalf of S.A.V.E.
Thomas Muehlenbeck, City Manager, College Park, Georgia
William J. Doughorty, North Georgia Chapter, American Institute of Architects
J.M. Benson, College Park, Georgia
James Rickard, Air Traffic Division, Southern Region, Federal Aviation Administration
Glenn E. Bennett, Executive Director, Atlanta Region Metropolitan Planning Commission
Mrs. Adele G. Northrup, Morningside-Lenox Park Community, Atlanta, Georgia
John Glenn, Citizens for Clean Air
Peter Chanin and George Lipton, LCL Corporation, Atlanta, Georgia
L.E. Abernathy, Atlanta Area Association of Senior Citizens Clubs
Ruby Ballard Zumbrook, Decatur Civic Association
W.E. Joyner, Decatur Civic Association
Stephanie Coffin, Great Speckled Bird, Newspaper
Maura Enright, Crisis Center, Atlanta, Georgia
Mrs. Charles Holman, Private Citizen
Edwin Eckles, Mingledorff's, Inc.
Corwin Robertson, Carrier Air Conditioning
William Hansell, Georgia Public Health Department Director
Wilson Smith, City of Atlanta Department of Planning
B.J. Dasher, Georgia Institute of Technology
W.E. Blount, Georgia Power Company
Dan Shepherd, Shepherd Construction Company

Manufacturing and Transportation Noise
Chicago, Ill., July 28-29, 1971

PANEL:

Dr. Alvin F. Meyer, Jr., Director, Office of Noise Abatement and Control, Environmental Protection Agency, Washington, D.C.
Dr. Mel Whitcomb, Executive Director, Committee on Hearing, Bioacoustics, and Biodynamics, National Research Council-National Academy of Sciences, Washington, D.C.
Professor Sheldon J. Plager, University of Illinois, School of Law, Champaign-Urbana, Illinois
Mr. Henry Martin, Manager, Resource Development, Society of Automotive Engineers, New York City, New York
Mr. Lloyd Hinton, Executive Director, Metropolitan Aircraft Noise Abatement Council, Minneapolis, Minn.
Professor John Kerrebrock, Professor of Aerospace, Massachusetts Institute of Technology, Cambridge, Mass.

ATTENDEES:

Hon. Roman Pucinski, Member of Congress, 11th District, Illinois
Dr. Edward Herman
Commissioner Herbert W. Poston, Department of Environmental Control, Chicago, Ill.
Mr. Franklin Kolk, Vice President, American Airlines, New York City, New York
Mr. William Becker, Vice President, Air Transport Association of America, Washington, D.C.
Mr. A.M. McPike, McDonnell-Douglas Corp., Long Beach, Calif.
Mr. John Cornell, General Electric Co., Lockland, Ohio
Mr. J.J. Corbett, U.S. Airport Operators Council International, Washington, D.C.
Congressman Abner Mikva, 2nd Congressional District of Illinois
Captain Richard Heller, Airline Pilots Association, Chicago, Illinois
Mr. Lewis Goodfriend, Goodfriend-Ostergaard Associates, Cedar Knolls, New Jersey
Mr. Harter Rupert, Federal Highway Administration, Washington, D.C.
Mr. William Carey, Executive Director, Highway Research Board, National Research Council, Washington, D.C.
Dr. Ernest Starkman, Vice President for Engineering, General Motors Corp., Warren, Mich.

ATTENDEES (Cont'd.)

John Damian, Ford Motor Co., Detroit, Mich.
Ted Shreves, Ford Motor Co., Detroit, Mich.
Mr. Lee Hench, Chrysler Corp., Detroit, Mich.
Richard Kolb, Heavy Truck Manufacturer's Association, Washington, D.C.
Mr. Roger Ringham, International Harvester, Chicago, Illinois
Mr. Jack Hasten, Caterpillar Tractor, Inc., Peoria, Ill.
Mr. Joseph Kigin, Rubber Manufacturer's Association, Washington, D.C.
S.J. Lippmann, Rubber Manufacturer's Association, Washington, D.C.
Mr. Sheldon Samuels, AFL-CIO, Washington, D.C.
Laura Fermi, American Association of University Women
Jo Ann Horowitz, American Association of University Women
Omar Marcus
Ted Decca
Richard Blomberg
Warren Edwards
John Kerrigan
Wendell P. Berwick
Dr. Richard Marcus
Noah Roberts
Al Romeo, Jr.
Alfred Etter
John D. Harper
Herbert G. Poertner
Henry Karplus
Samuel Peskin
Carl Carlson
Richard Young
George J. Franks
William Singer
Fred H. Tabak
John Watts
Cleveland Walcutt
Glenna Alevizos
Janice Del Calzo
John Desmond
John Varble, Representative, National Organization to Insure a Sound-Controlled Environment
Herman Spahr
George Dayiantis
Elizabeth Lewis

Urban Planning and Noise; Architectural Design and Noise;
Noise in the Home
Dallas, Texas, August 18-19, 1971

PANEL:

Dr. Alvin F. Meyer, Jr., Director, Office of Noise Abatement and Control, Environmental Protection Agency, Washington, D.C.
Theodore Berland, President, Citizens Against Noise (Author: The Fight for Quiet), Chicago, Illinois
Professor Leon Cole, Department of Urban Planning, University of Texas, Austin, Texas
Dr. Aram Glorig, Director, Callier Hearing and Speech Institute, Dallas, Texas
Dr. Robert Newman, Bolt, Beranek, and Newman, Cambridge, Mass.
Dr. W. Dixon Ward, Hearing Research Institute, University of Minnesota, Minneapolis, Minnesota
Dr. Jack Westman, Department of Psychiatry, University of Wisconsin, Madison, Wisconsin

ATTENDEES:

Wes Wise, Mayor, Dallas, Texas
Mr. Edward C. Fritz, Air Quality Coalition of North Texas, Dallas, Texas
Dr. Hal Watson, Jr., Southern Methodist University, Dallas, Texas
Mrs. Roger C. Fletcher, Arlington Conservation Council, Arlington, Texas
Mrs. Franklyn Wright, Conservationist, Dallas, Texas
Mrs. Robert Sapp, American Association of University Women, Dallas, Tex.
Mrs. Richardson, Private Citizen, Dallas, Texas
Dr. Robert Finch, University of Houston, Houston, Texas
Mr. J.W. Joiner, Joiner, Pelton, and Rose, Inc., Dallas, Texas
Mr. J.A. Shirley, Private Citizen, Dallas, Texas
Mr. Rod Rylander, Texoma Outdoor Club, Sherman, Texas
Mrs. Sharon Stewart, Citizens' Survival Committee, Lake Jackson, Texas
Mr. Tom Maddocks, Chairman, North Texas Group of the Lone Star Chapter, Sierra Club, Dallas, Texas
Mr. Dan DeGrassi, Conservationist, Dallas, Texas
Mr. Joe Allen, Texas House of Representatives, Baytown, Texas
Mr. Bob Johnston, Environmental Action Center, Dallas, Texas
Cecil Sparks, Southwest Research Institute, San Antonio, Texas
Bart Spano, Polysonics, Inc., Washington, D.C.

ATTENDEES (Cont'd.):

Charles Parrott, Director, Redevelopment Authority, La Crosse, Wisconsin
Bailus Walker, Department of Environmental Services, Cleveland, Ohio
Robert Wegner, American Institute of Planners, Arlington, Texas
Gene Schrickel, American Society of Landscape Architects, Arlington, Texas
John Burdis, Environistics Division, Instrument Systems Corp., Jerico, New York
David McCandless, McCandless Associates, Visiting Professor of Architecture, University of Texas, Austin, Texas
Dr. Elmer Hixon, Department of Electrical Engineering, University of Texas, Austin, Texas
Herbert Phillips, Association of Home Appliance Manufacturers, Chicago, Ill.
John Dorn, Frigidaire Division, General Motors Corp., Dayton, Ohio
J.E. Duff, Hoover Corp. Research Laboratory, North Canton, Ohio
E.B. Thompson, W.G. Martin, III, Home Ventilating Institute, Chicago, Ill.
Arthur Meling, Scott Bayless, Air Conditioning and Refrigeration Institute, Arlington, Virginia

Standards, Measurement Methods, Legislation and Enforcement Problems
San Francisco, Calif., September 27-29, 1971

PANEL:

Dr. Alvin F. Meyer, Jr., Director, Office of Noise Abatement and Control, Environmental Protection Agency, Washington, D.C.
Robert Alexander Baron, Citizens For A Quieter City, New York, N.Y.
Dr. Charles Dietrich, Bolt, Beranek & Newman, Cambridge, Mass.
James L. Hildebrand (Editor: Noise Pollution and the Law), Tokyo, Japan
Prof. Sheldon Plager, Univ. of Illinois Law School, Urbana, Illinois
Henry Martin, American Society of Automotive Engineers, New York, N.Y.

ATTENDEES:

Ellen Stern Harris, Council for Planning & Conservation, Los Angeles, Calif.
Robert Watkins, California Division of Highways, Sacramento, Calif.
Glendon Craig, Inspector, California State Highway Patrol, Sacremento, Calif.
Raymond Lucia, Motorcycle Industry Council, Washington, D.C.
Stephen Mayne, Dinkelspeil, Stefel, Levitt, Weiss, & Donovan, San Francisco, Calif.
James Taylor, Research Development Associates, Los Angeles, Calif.
John Parnell, Environmental Acoustics, Palos Verdes, Calif.
Thomas Young, Executive Director, Engine Manufacturer's Association, Chicago, Ill.
Jonathan Howe, Legal Council, Engine Manufacturer's Association
Arthur Snyder, City Council, Los Angeles, Calif.
Louis Beliczky, AFL-CIO, Akron, Ohio
Erin Fenton, Automotive Parts and Accessories Association, Gardena, Calif.
H.T. Larmore, Construction Industry Manufacturer's Association, Milwaukee, Wisconsin
John J. Bucholtz, Plaster Information Center, San Jose, Calif.
G.F. Hohn and Associate, American National Standards Institute, New York, N.Y.
Bruce Jett, Acoustical Sciences Instrumentation Data Systems, Arlington, Va.
Carol Tanner, Hydrospace Research, San Diego, Calif.
William Burtis, Dr. Marjorie Evans, California Society of Professional Engineers, Los Altos Hills, Calif.
Roger Ringham, International Harvester, Inc., Chicago, Ill.
Richard Staadt, Truck Division, International Harvester, Inc., Chicago, Ill.
Dr. George Steinbruegge, University of Nebraska, Lincoln, Neb.
Ralph Hillquist, General Motors, Detroit, Mich.

ATTENDEES (Cont'd.):

Ralph Van Demark, Motor and Equipment Manufacturer's Association, New York, N.Y.
Seymour Lippmann, Rubber Manufacturer's Association, Washington, D.C.
Arthur Meling, Air Conditioning and Refrigeration Institute, Arlington, Va.
G.B. Ribnick, Institute of Heating and Air Conditioning Industries, Los Angeles, Calif.
Pat Russell, City Council, Los Angeles, Calif.
Dr. Hayes, President, Save Our Valley, Santa Clara, Calif.
Nicholas Yost, Deputy Attorney General, California, Sacramento, Calif.
Albert Cooper, California Highway Patrol, Sacramento, Calif.
Randall L. Hurlburt, City of Inglewood, California
Dale Hoge, Director of Standards in the R & D Department Automotive Parts and Accessories Association
William Scott, Chairman, Vehicle Sound Level Committee, Society of Automotive Engineers
Bobby J. Greer, Computer Sciences Corporation
Meyer S. Bogost, Environmental Engineer, Hawaii State Office of Environmental Quality Control
Richard Dyer, State of California Business and Transportation Agency, Department of Aeronautics
Inspector Glendon Craig, California Highway Patrol, Sacramento, Calif.
Bob Smith (representing himself)
John Sutter, Oakland City Council and Bay Anti-Noise Group
Donald A. Belt, Audiologist
Gary Compton, Northern California Auto Dismantlers Association, et al
David S. Lawyer, Walnut Creek, Calif.
Steven R. Skale, San Mateo, Calif.
Bradley Collins, Seattle, Wash.
Douglas T. Corbin, Richmond, Calif.
Donald W. Baldra, Walnut Creek, Calif.
T. D. Harriman, Fairfax, Calif.
Joseph J. Hillner, Walnut Creek, Calif.
Peter B. Jansen, Berkeley, Calif.
Mrs. Mitchell Madison, Los Altos, Calif.
Joseph Heizer, San Francisco, Calif.
W. C. Reynolds, Stanford, Calif.
Antionette Riley, Redwood City, Calif.
David Parker
Mrs. Dennis G. Drake, San Rafael, Calif.
Joseph E. Cornish, Redwood City, Calif.
John L. Burton, California State Assemblyman, San Francisco, Calif.
Milan Dostal, City Councilman, Newport Beach, Calif.
Dobie Jenkins, Northern California Field Representative for U. S. Senator Alan Cranston of California
Wes Uhlman, Mayor, City of Seattle, Wash.
Diane Feinstein, President, San Francisco Board of Supervisors
Warren Boggess, Supervisor, Contra Costa County, Representing Regional Airport Systems Study of the Association of Bay Area Governments

ATTENDEES (Cont'd.):

Richard Nagel, City Councilman, El Segundo, California, Representing the League of California Cities
Alba Bly, City Councilwoman, Palmdale, Calif.
A. M. Man, Barrio Planners, Los Angeles, Calif.
Mrs. Thomas Souza, Walnut Creek, Calif.
Donald Miller, Los Altos Noise Abatement Committee
Pat Russell, Councilwoman, Los Angeles, Calif.
James K. Carr, Director of Airports, City and County of San Francisco
Thomas L. Geers, Chairman, Portola Valley Noise Abatement Committee, Coordinator of the Peninsula Noise Abatement League
Kenneth Scheidig, Assistant City Attorney, Walnut Creek, Calif.
Michael Berger, Attorney for Fadem & Tanner, Los Angeles, Calif.
Ione Maxwell, Point Richmond, Calif.
Dr. C. Michael Hogan, Environmental Systems Laboratory, Sunnyvale, Calif.
Dor Hesselgrave, Palo Alto, Calif.
Ann Fibish, San Francisco, Calif.
Charles Christman, San Francisco, Calif.
Robert Shaw, Sunnyvale, Calif.
Raymond Carrington, Vacaville, Calif.
Mark Tarses, Berkeley, Calif.
Lloyd Krause, Stanford Research Institute
Jay Beckerman
Ronald Pelosi, Supervisor, San Francisco, Calif.
Jim Knott, President, San Francisco Tomorrow
Storm Goranson, Oakland, Calif.
Col. John Reagan, Foster City, Calif.
Dr. R. W. Procunier, Stanford Committee for Environmental Information
Michael Moriarty, Oakland, Calif.
Mrs. Fallie Davison, Airport Cities Action Committee, Playa Del Rey, Calif.
Loretta Fontechio, North Runway Residents, Los Angeles, Calif.
Janice Cruikshank, Watchful Eye Women's Council for Community Preservation, Los Angeles, Calif.
Marian Rubin, San Francisco, Calif.

Agricultural and Recreational Noise
Denver, Colo., Sept. 30-Oct. 1, 1971

PANEL:

Alvin F. Meyer, Jr., Director, Office of Noise Abatement and Control, Environmental Protection Agency, Washington, D.C.
Dr. Clyde Berry, University of Iowa, Iowa City, Iowa
James Botsford, Bethlehem Steel Corp., Bethlehem, Penn.
Dr. John Fletcher, Memphis State University, Memphis, Tenn.
Boyd Norton, Friends of the Earth, Denver, Colorado
Sheldon Plager, University of Illinois Law School, Urbana, Illinois
Richard Strunk, Bolt, Beranek & Newman, Chicago, Ill.

ATTENDEES:

John A. Green, Regional Administrator, Environmental Protection Agency, Rocky Mountain-Prairie Region, Denver, Colo.
Dr. Steven Williams, Planned Boulder Commission, Boulder, Colo.
Prof. Olwin Olpin, University of Utah, Salt Lake City, Utah
Hal Weber, Colorado Dept. Public Health, Denver, Colo.
Jim Monaghan, CSU Environmental Corps, Fort Collins, Colo.
John Green, Boulder, Colo.
Bob Michener, Denver, Colo.
Dr. James Wright & Representatives, Balarat Center for Environmental Studies, Denver, Colo.
Donald Ahrenholtz, Colorado Farm Bureau, Denver, Colo.
Tom Logan, Bureau of Reclamation, Denver, Colo.
Robert Million, Environmental Control Group -- Technical Service Co., Denver, Colo.
Howard McGregor, Engineering Dynamics, Denver, Colo.
Nicholas Pohlit, National Environmental Health Association, Denver, Colo.
Ralph Hill, Colorado Wildlife Federation, Denver, Colo.
Bernie Goetze, Wildlife Conservation Office, Colorado Division Game, Fish, & Parks, Denver, Colo.
Mrs. W.H. McAnally, Lakewood, Colo.
Al Hine and Representatives, Colorado Motorcycle Dealers Association, Denver, Colo.
Bernie Bovee, Denver Colo.
Tom Martin, Noise Control Officer, Boulder, Colo.
Dr. Donald Billings, Director, Astro-Physics, University of Colorado, Boulder, Colo.

ATTENDEES (Cont'd.):

Dr. Robert Chanaud, Civil Engineering, University of Colorado, Boulder, Colo.
John Cooper, Rocky Mountain Cycle Shop, Boulder, Colo.
Donald V. Glenn, Boulder, Colo.
Cecil Sparks, Southwest Research Institute, San Antonio, Tex.
Leo Lechtenberg, Briggs-Stratton Co., Milwaukee, Wis.
Jack Williford, Colorado State University, Fort Collins, Colo.
Roger Fooger, University of Illinois, Urbana, Ill.
Dr. Glen Peterson, Memphis State University, Memphis, Tenn.
Anthony Wayne Smith, National Parks and Conservation Association, Washington, D.C.
Robin Harrison, Sierra Club, San Dimas, Calif.
David Beach, Boating Industry Association, Chicago, Ill.
Dick Lincoln, Outboard Marine Corp., Milwaukee, Wis.
Hans Von Barby, National Wildlife Federation, Evergreen, Colo.
John Nesbitt, International Snowmobile Industry Association, Minneapolis, Minn.
Robert Turner, Audubon Society, Boulder, Colo.
Newton Sacks, Deere and Co., Moline, Ill.
R.W. Randt, Farm and Industrial Equipment Institute, Chicago, Ill.
Arnold Skarjune, White Farm Equipment Co., Hopkins, Minn.
Roger Ringham, International Harvester, Chicago, Ill.
R.T. Bennett, Farm Equipment Division, International Harvester
Dr. Ed Simpson, University of Nebraska, Lincoln, Neb.
Professor David Cook, University of Nebraska, Lincoln, Neb.
Dr. William Gatley, Society of Professional Engineers, University of Missouri Rolla, Mo.
Dr. William Splinter, University of Nebraska, Lincoln, Neb.
Dr. Irwin Deshayes, University of Nebraska, Lincoln, Neb.

Transportation, Urban Noise and Social Behavior
New York, N.Y., October 21-22, 1971

PANEL:

Dr. Alvin F. Meyer, Jr., Director, Office of Noise Abatement and Control, Environmental Protection Agency
John Burdis, Environistics, Inc., Jericho, New York
Cyril Harris, Columbia University
Albert Rosenthal, Columbia University School of Law
Lloyd Hinton, Metropolitan Aircraft, Sound Abatement Council
George Wilson, Wilson, Ihrig Acoustical Consultants
Dr. Phyllis Gildston, Chairman, Subcommittee on Noise, New York Scientists' for Public Information

ATTENDEES:

Robert Rickles, Commissioner, New York City Department of Air Resources, New York City Environmental Protection Administration
William Bentley, New York State Department of Environmental Conservation
Honorable William F. Ryan, U.S. House of Representatives
Miss Anne MacNaughton, New York State Department of Highways
Richard Rosenthal, Lincoln Square Community Council
Mrs. Betty Little, Coordinator, Citizens for Conservation of Bernard's Township, N.J.
Councilman Theodore Weiss, New York City Council
Arlene Weltman, Consumer Action Now
Paul Housberg, Environmental Control Class, Roslyn High School
Thomas E. Carroll, Asst. Administrator for Planning and Management, Environmental Protection Agency
Mr. Stanley Welgman, Brooklyn School of Pharmacy
Edward T. Hall, Northwestern University
Robert Alex Baron, Citizens for a Quieter City, New York, N.Y.
Abraham Cohen, Environistics Division, Instrument Systems Data Corp.
Dr. Ernest Zelnick, Noise Pollution Consultants, Inc.
William Harris, Association of American Railroads, Washington, D.C.
Kenneth Knight, Chairman, Institute for Rapid Transit Noise Control, Washington, D.C.
George Wilson, Wilson, Ihrig & Associates, Berkeley, Calif.
Anthony Paolillo, Engineer, New York City Transit Authority, Division of Noise and Vibration Control
Honorable John W. Wydler, U.S. House of Representatives
Francis Purcell, Presiding Supervisor, Town of Hempstead, New York
Honorable Norman F. Lent, U.S. House of Representatives

ATTENDEES (Cont'd.):

Herbert McCollum, Hearing Conservation Center, Lancaster, Penn.
Robert Cusumano, Chief of Air Pollution Control, Nassau County Health Department
Honorable Lester L. Wolff, U.S. House of Representatives
Ernest Litschauer, Town of Greenwich, Northwest Greenwich Association
Lewis Rotendo, Conney Hill Associates, Armonck, New York
Clifford Deeds, Town Village Aircraft, Safety and Noise Abatement Commission, Lawrence, New York
Richard Carlson, President, CRASH (Citizens Reaction Against Sudden Holocausts), Halbrook, N.Y.
Robert Check, President, Metro-Suburban Air-Noise Association, Inc., Inwood, N.J.
William Webster, New York State Department of Environmental Conservation
Jack Marshall, Port of New York Authority
Arthur Podwall, M.D., Director, Syossett Hearing and Speech Center, Syossett, New York
James Rogers, Jet Sonics, Inc., Hauppage, New York
Clifford Bragdon, Associate Professor of City Planning, Georgia Institute of Technology, Atlanta, Ga.
Fred Roberts, Sierra Club, Princeton, New Jersey
David London, Citizen

Physiological and Psychological Effects
Boston, Mass., October 27-28, 1971

PANEL:

Dr. Alvin Meyer, Jr., Director, Office of Noise Abatement and Control, EPA, Washington, D.C.
Dr. James Botsford, Senior Noise Control Engineer, Bethlehem Steel Corporation, Bethlehem, Pa.
Dr. Donald Elderedge, Central Institute of the Deaf, Washington, D.C.
Dr. Sanford Fidell, Bolt, Beranek & Newman, Cambridge, Mass.
Dr. Henning vonGierke, Aerospace Medical Laboratory, Wright-Patterson Air Force Base, Dayton, Ohio
Dr. Milton Whitcomb, National Academy of Science, Washington, D.C.

ATTENDEES:

Fred Salvucci, Representative, Mayor's Office, Boston, Mass.
Guy D. Rosmarin, Assistant Transportation Secretary, Boston, Mass.
The Honorable Ralph E. Sirianni, Jr., Massachusetts State Representative, Boston, Mass.
Statement of The Honorable Edward M. Kennedy, U. S. Senator, State of Massachusetts, Washington, D. C.
Dr. Robert J. Cunitz, Psychologist, National Bureau of Standards, Gaithersburg, Md.
T. Jack Kelley, Commission Member, City of Pittsfield Noise Control Commission, Pittsfield, Mass.
Mr. David Standley, Executive Director, City of Boston Air Pollution Control Commission
Dr. Aram Glorig, Collier Hearing and Speech Institute, Dallas, Tex.
Dr. Bruce Welsh, Friends Medical Science Research Institute, Baltimore, Md.
Mr. Tom Callahan, Assistant to the Executive Director, Massachusetts Port Authority
Monsignor Mimie Pitaro, State Senator, East Boston
Mr. Charles Schmid, Private Citizen discussing noise on Cape Cod
Mr. Desmond McCarthy, representing Sierra Club and Friends of the Earth
Mr. Jerry Falbo, Massachusetts Air Pollution Noise Abatement Committee (MAPNAC)
Mr. Allen Morgan, Executive Secretary, Massachusetts Audubon Society
Mr. John Reagan, Chairman, Faculty Senate, Barnes Junior High School, East Boston
Dr. John Dougherty, School of Public Health, Harvard University, Cambridge, Mass.
Dr. Jerome Carr, Environmental Specialist, Pollution Control Division, Lowell Technological Institute Research Foundation, Lowell, Mass.

ATTENDEES (Cont'd.):

Dr. Arthur Sackler, M.D., and Dr. Stanley Waltman, M.D., Laboratory for Therapeutic Research, Brooklyn College of Pharmacy, Long Island University, Brooklyn, N.Y.
Dr. Michael Baron, Massachusetts Institute of Technology
Dr. Edwin Newman, Psychological Lab, Harvard University
Dr. Robert Grinell, Institute of Psychiatry and Human Behavior, University of Maryland, Baltimore, Maryland
Dr. W. Dixon Ward, Hearing Research Laboratory, University of Minnesota, Minneapolis, Minn.
Dr. Glen Jones, Bolt, Beranek & Newman, Cambridge, Mass.
Dr. Paul Borsky, Department of Environmental Hygiene, Columbia University, New York, N.Y.
Stanley Weltman, Ph.D.
Dr. John Dougherty
Michael S. Baram, Ph.D.

Technology and Economics of Noise Control; National Programs and the Relations with State and Local Programs
Washington, D.C., November 9-12, 1971

PANEL:

Dr. Alvin F. Meyer, Jr., Director, Office of Noise Abatement and Control
John Johnson, Acoustical Society of America, State College, Pennsylvania
Theodore Berland, President, Citizens Against Noise (Author: The Fight for Quiet), Chicago, Ill.
Leo Beranek, Bolt, Beranek & Newman, Cambridge, Mass.
Henry Martin, Society of Automotive Engineers, New York, N.Y.
Wes Wise, Mayor, Dallas, Tex.
Ken Eldred, Wyle Labs, Los Angeles, Calif.
Charles Dietrich, Bolt, Beranek & Newman, Cambridge, Mass.

ATTENDEES:

Prof. Richard Bolt, Acoustical Society of America
Dr. Keith Lumsden, Dept. of Business Administration, Stanford University
Emerson Rhyner, California State Dept. of Public Works, Sacramento, Calif.
Dr. C. Kenneth Orski, Head, Division of Urban Affairs Environmental Directorate, OECD, Paris
Terry Trumbull, Institute of Public Administration, Washington, D.C.
Robert Smith, Council of Economic Priorities, New York, N.Y.
Ray Leonard, U.S. Forest Service, Syracuse, New York
C.A. Wold, Corporative Noise Control Consultant, Boise Cascade Corp., Boise, Idaho
Dorn McGrath, American Institute of Planners
Dan Hanson and Ray Crowe, American Society of Road Builders, Washington, D.C.
Representative of the Homebuilders of America, Washington, D.C.
Representative from the International Association for Pollution Control
Allan Surosky, General Testing Labs, Arlington, Va.
Roger Ringham, International Harvester, Chicago, Ill.
David Wulfhorst, Cummins Engine, Co., Columbus, Indiana
Franklyn Kreml, Automobile Manufacturers Association, Washington, D.C.
Representative of the Transportation Association of America, Washington, D.C.

ATTENDEES (Cont'd.):

Jerbis Kester, Pratt and Whitney Aircraft, Hartford, Conn.
Representative of Boeing Aircraft, Washington, D.C.
G.F. Dilabio, Northrop Aircraft, Los Angeles, Calif.
Franklin Kolk, American Airlines, New York, N.Y.
Dr. Louis Mayo, George Washington University, Washington, D.C.
Thomas Young and Jonathan Howe, Engine Manufacturers of America, Chicago, Ill.
John Lentz, Washington Metropolitan Council of Governors, Washington, D.C.
Representative of the Conference of States, Washington, D.C.
Wes Gilbertson, Conference of State Sanitary Engineers, Harrisburg, Pa.
John Moore, Bureau of Noise Pollution Control, Illinois State EPA
Don Scheisswohl and David Scott, Florida State Department of Air & Water Pollution Control, Tallahassee, Florida
Representative of the Texas State Dept. of Health
Dwight Metzler, New York State Dept. of Environmental Conservation, Albany, N.Y.
Representative of the Conference of Mayors, Washington, D.C.
Robert Benin, New York City Environmental Protection Administration, New York, N.Y.
Representative of Los Angeles Mayor's Council on Environmental Management
Mrs. Betty Little, Citizens for Conservation of Bernard's Township, Basking Ridge, N.J.
Robert Cusamano, Nassau County Bureau of Air Pollution, Nassau County, Long Island, New York
Joseph Kigin, Rubber Manufacturers Association, Washington, D.C.
N. Larmore, Construction Industry Manufacturers Association, Chicago, Ill.
George Washnis, Center for Governmental Studies, Washington, D.C.
Herschel Griffin, Dean of the University of Pittsburgh School of Public Health
Mrs. Ann Sutton, Burgundy Hill Farm School, Alexandria, Va.
John Winder, President, Metropolitan Washington Air Quality Coalition, Washington, D.C.
George Coling, Executive Director, Ecology Center Communications Council, Washington, D.C.

GLOSSARY

The following explanations of terms are provided to assist the reader in understanding terms commonly encountered in the literature of "noise pollution" as well as terms commonly employed in this report.

ABSORPTION — Absorption is a property of materials that reduces the amount of sound energy reflected. Thus, the introduction of an "absorbent" into the surfaces of a room will reduce the sound pressure level in that room by virtue of the fact that sound energy striking the room surfaces will not be totally reflected. It should be mentioned that this is an entirely different process from that of transmission loss through a material, which determines how much sound gets into the room via the walls, ceiling, and floor. The effect of absorption merely reduces the resultant sound level in the room produced by energy which has already entered the room.

ABSORPTION COEFFICIENT — The sound-absorbing ability of a surface is given in terms of a sound-absorption coefficient. This coefficient is defined as the fraction of incident sound energy absorbed or otherwise not reflected by the surface. Unless otherwise specified, a diffuse sound field is assumed. The values of sound-absorption coefficient usually range from about 0.01 for marble slate to about 1.0 for long absorbing wedges such as are used in anechoic chambers.

ACCELEROMETER (ACCELERATION PICKUP) — An electroacoustic transducer that responds to the acceleration of the surface to which the transducer is attached, and delivers essentially equivalent electric waves.

ACOUSTICAL POWER — See sound power.

ACOUSTICS — (1) The science of sound, including the generation, transmission, and effects of sound waves, both audible and inaudible. (2) The acoustics of an auditorium or of a room, the totality of those physical qualities (such as size, shape, amount of sound absorption, and amount of noise) which determine the audibility and perception of speech and music.

AIRBORNE SOUND — Sound that reaches the point of interest by propagation through air.

AMBIENT NOISE LEVEL — The ambient noise level, for purposes of this report, follows the usage of the word "ambient" throughout the environmental sciences (except acoustics). That is, the ambient noise level is that level which exists at any instant, regardless of source.

ANALYSIS — The analysis of a noise generally refers to the composition of the noise into various frequency bands, such as octaves, third-octaves, etc.

ANECHOIC ROOM — An anechoic room is one whose boundaries have been designed (with acoustically absorbent materials) to absorb nearly all the sound incident on its boundaries, thereby affording a test room essentially free from reflected sound.

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

AUDIO FREQUENCY — The frequency of oscillation of an audible sine-wave of sound; any frequency between 20 and 20,000 hertz. See also frequency.

AURAL — Of or pertaining to the ear or hearing.

AUDIOGRAM — A graph showing hearing loss as a function of frequency.

AUDIOMETER — An instrument for measuring hearing sensitivity or hearing loss.

A-WEIGHTED SOUND LEVEL — The ear does not respond equally to sounds of all frequencies, but is less efficient at low and high frequencies than it is at medium or speech range frequencies. Thus, to obtain a single number representing the sound level of a noise containing a wide range of frequencies in a manner representative of the ear's response, it is necessary to reduce, or weight, the effects of the low and high frequencies with respect to the medium frequencies. The resultant sound level is said to be A-weighted, and the units are dB. A popular method of indicating the units, dBA, is frequently used in this report. The A-weighted sound level is also called the noise level. Sound level meters have an A-weighting network for measuring A-weighted sound level.

BACKGROUND NOISE — The total of all noise in a system or situation, independent of the presence of the desired signal. In acoustical measurements, strictly speaking, the term "background noise" means electrical noise in the measurement system. However, in popular usage the term "background noise" is also used with the same meaning as "residual noise."

BAFFLE — A baffle is a shielding structure or series of partitions used to increase the effective length of the external transmission path between two points in an acoustic system. For example, baffles may be used in sound traps (as in air conditioning ducts) or in automotive mufflers to decrease the sound transmitted while affording a path for air flow.

BAND CENTER FREQUENCY – The designated (geometric) mean frequency of a band of noise or other signal. For example, 1000 Hz is the band center frequency for the octave band that extends from 707 Hz to 1414 Hz, or for the third-octave band that extends from 891 Hz to 1123 Hz.

BAND PRESSURE (OR POWER) LEVEL – The pressure (or power) level for the sound contained within a specified frequency band. The band may be specified either by its lower and upper cut-off frequencies, or by its geometric center frequency. The width of the band is often indicated by a prefatory modifier; e.g., octave band, third-octave band, 10-Hz band.

COMMUNITY NOISE EQUIVALENT LEVEL – Community Noise Equivalent Level (CNEL) is a scale which takes account of all the A-weighted acoustic energy received at a point, from all noise events causing noise levels above some prescribed value. Weighting factors are included which place greater importance upon noise events occurring during the evening hours (7:00 p.m. to 10:00 p.m.) and even greater importance upon noise events at night (10:00 p.m. to 6:00 a.m.).

COMPOSITE NOISE RATING – Composite noise rating (CNR) is a scale which takes account of the totality of all aircraft operations at an airport in quantifying the total aircraft noise environment. It was the earliest method for evaluating compatible land use around airports and is still in wide use by the Department of Defense in predicting noise environments around military airfields.

Basically, to calculate a CNR value one begins with a measure of the maximum noise magnitude from each aircraft flyby and adds weighting factors which sum the cumulative effect of all flights. The scale used to describe individual noise events is perceived noise level (in PNdB), the term accounting for number of flights is $10 \log_{10} N$ (where N is the number of flight operations), and each night operation counts as much as 10 daytime operations. Very approximately, the noise exposure level at a point expressed in the CNR scale will be numerically 35-37 dB <u>higher</u> than if expressed in the CNEL scale.

CONTINUOUS SOUND SPECTRUM – A continuous sound spectrum is comprised of components which are continuously distributed over a frequency region.

C-WEIGHTED SOUND LEVEL (dBC) – A quantity, in decibels, read from a standard sound-level meter that is switched to the weighting network labeled "C". The C-weighting network weights the frequencies between 70 Hz and 4000 Hz uniformly, but below and above these limits frequencies are slightly discriminated against. Generally, C-weighted measurements are essentially the same as overall sound-pressure levels, which require no discrimination at any frequency.

CYCLES PER SECOND – See frequency.

DAMAGE-RISK CRITERIA (HEARING-CONSERVATION CRITERIA) – Recommended maximum noise levels that for a given pattern of exposure times should, if not exceeded, minimize the risk of damage to the ears of persons exposed to the noise.

DAMPING — The dissipation of energy with time or distance. The term is generally applied to the attenuation of sound in a structure owing to the internal sound-dissipative properties of the structure or owing to the addition of sound-dissipative materials.

DECIBEL — The decibel (abbreviated "dB") is a measure, on a logarithmic scale, of the magnitude of a particular quantity (such as sound pressure, sound power, intensity, etc.) with respect to a standard reference value.

DIFFUSE SOUND FIELD — The presence of many reflected waves (echoes) in a room (or auditorium) having a very small amount of sound absorption, arising from repeated reflections of sound in various directions.

DIRECTIVITY INDEX — In a given direction from a sound source, the difference in decibels between (a) the sound-pressure level produced by the source in that direction, and (b) the space-average sound-pressure level of that source, measured at the same distance.

DUCT LINING OR WRAPPING — Usually a sheet of porous material placed on the inner or outer wall(s) of a duct to introduce sound attenuation and heat insulation. It is often used in air conditioning systems. Linings are more effective in attenuating sound that travels inside along the length of a duct, while wrappings are more effective in preventing sound from being radiated from the duct sidewalls into surrounding spaces.

EFFECTIVE PERCEIVED NOISE LEVEL (EPNL) — A physical measure designed to estimate the effective "noisiness" of a single noise event, usually an aircraft flyover; it is derived from instantaneous Perceived Noise Level (PNL) values by applying corrections for pure tones and for the duration of the noise.

ELECTROACOUSTICS — The science and technology of transforming sound waves into currents in electrical circuits (and vice versa), by means of microphones, loudspeakers, and electronic amplifiers and filters.

FAR FIELD — Consider any sound source in free space. At a sufficient distance from the source, the sound pressure level obeys the inverse-square law, and the sound particle velocity is in phase with the sound pressure. This region is called the far field of the sound source. Regions closer to the source, where these two conditions do not hold, constitute the near field. Now consider a sound source within an enclosure. It is also sometimes possible to satisfy the far-field conditions over a limited region between the near field and the reverberant field, if the absorption within the enclosure is not too small so that the near field and the reverberant field merge.

FILTER — A device that transmits certain frequency components of the signal (sound or electrical) incident upon it, and rejects other frequency components of the incident signal.

FREE SOUND FIELD (FREE FIELD) — A sound field in which the effects of obstacles or boundaries on sound propagated in that field are negligible.

FREQUENCY — The number of oscillations per second (a) of a sine-wave of sound, and (b) of a vibrating solid object; now expressed in hertz (abbreviation Hz), formerly in cycles per second (abbreviation cps).

HEARING DISABILITY — An actual or presumed inability, due to hearing impairment, to remain employed at full wages.

HEARING HANDICAP — The disadvantage imposed by a hearing impairment sufficient to affect one's efficiency in the situation of everyday living.

HEARING IMPAIRMENT — A deviation or change for the worse in either hearing structure or function, usually outside the normal range; see hearing loss.

HEARING LOSS — At a specified frequency, an amount, in decibels, by which the threshold of audibility for that ear exceeds a certain specified audiometric threshold, that is to say, the amount by which a person's hearing is worse than some selected norm. The norm may be the threshold established at some earlier time for that ear, or the average threshold for some large population, or the threshold selected by some standards body for audiometric measurements.

HEARING LOSS FOR SPEECH — The difference in decibels between the speech levels at which the "average normal" ear and a defective ear, respectively, reach the same intelligibility, often arbitrarily set at 50%.

HERTZ — See frequency.

IMPACT — (1) An impact is a single collision of one mass in motion with a second mass which may be either in motion or at rest. (2) Impact is a word used to express the extent or severity of an environmental problem; e.g., the number of persons exposed to a given noise environment.

IMPACT INSULATION CLASS (IIC) — A single-figure rating which is intended to permit the comparison of the impact sound insulating merits of floor-ceiling assemblies in terms of a reference contour.

IMPACT SOUND — The sound arising from the impact of a solid object on an interior surface (wall, floor, or ceiling) of a building. Typical sources are footsteps, dropped objects, etc.

INVERSE-SQUARE LAW — The inverse-square law describes that acoustic situation where the mean-square sound pressure changes in inverse proportion to the square of the distance from the source. Under this condition the sound-pressure level decreases 6 decibels with each doubling of distance from the source. See also spherical divergence.

ISOLATION — See vibration isolator.

LEVEL — The level of an acoustical quantity (e.g., sound power), in decibels, is 10 times the logarithm (base 10) of the ratio of the quantity to a reference quantity of the same physical kind.

LINE SPECTRUM — The spectrum of a sound whose components occur at a number of discrete frequencies.

LOUDNESS — Loudness is the intensive attribute of an auditory sensation, in terms of which sounds may be ordered on a scale extending from soft to loud. Loudness depends primarily upon the sound pressure of the stimulus, but is also depends upon the frequency and wave form of the stimulus.

LOUDNESS LEVEL — The loudness level of a sound, in phons, is numerically equal to the median sound pressure level, in decibels, relative to 0.0002 microbar, of a free progressive wave of frequency 1000 Hz presented to listeners facing the source, which in a number of trials is judged by the listeners to be equally loud.

MACH NUMBER — The ratio of a speed of a moving element to the speed of sound in the surrounding medium.

MASKING — The action of bringing one sound (audible when heard alone) to inaudibility or to unintelligibility by the introduction of another, usually louder, sound. See masking noise.

MASKING NOISE — A noise which is intense enough to render inaudible or unintellibible another sound which is simultaneously present.

MICROPHONE — An electroacoustic transducer that responds to sound waves and delivers essentially equivalent electric waves.

NEAR FIELD — See far field.

NOISE — Any sound which is undesirable because it interferes with speech and hearing, or is intense enough to damage hearing, or is otherwise annoying.

NOISE CRITERION (NC) CURVES — Any of several versions (SC, NC, NCA, PNC) of criteria used for rating the acceptability of continuous indoor noise levels, such as produced by air-handling systems.

NOISE EXPOSURE FORECAST — Noise exposure forecast (NEF) is a scale (analogous to CNEL and CNR) which has been used by the federal government in land use planning guides for use in connection with airports.

In the NEF scale, the basic measure of magnitude for individual noise events is the effective perceived noise level (EPNL), in units of EPNdB. This magnitude measure includes the effect of duration per event. The terms accounting for number of flights and for weighting by time period are the same as in the CNR scale. Very approximately, the noise exposure level at a point expressed in the NEF scale will be numerically about 33 dB lower than if expressed in the CNEL scale.

NOISE INSULATION — See sound insulation.

NOISE ISOLATION CLASS (NIC) — A single number rating derived in a prescribed manner from the measured values of noise reduction. It provides an evaluation of the sound isolation between two enclosed spaces that are acoustically connected by one or more paths.

NOISE LEVEL — See sound level.

NOISE AND NUMBER INDEX (NNI) — A measure based on Perceived Noise Level, and with weighting factors added to account for the number of noise events, and used (in some European countries) for rating the noise environment near airports.

NOISE POLLUTION LEVEL (L_{NP} or NPL) — A measure of the total community noise, postulated to be applicable to both traffic noise and aircraft noise. It is computed from the "energy average" of the noise level and the standard deviation of the time-varying noise level.

NOISE REDUCTION (NR) — The noise reduction between two areas or rooms is the numerical difference, in decibels, of the average sound pressure levels in those areas or rooms. A measurement of "noise reduction" combines the effect of the transmission loss performance of structures separating the two areas or rooms, plus the effect of acoustic absorption present in the receiving room.

NOISE REDUCTION COEFFICIENT (NRC) — A measure of the acoustical absorption performance of a material, calculated by the averaging its sound absorption coefficients at 250, 500, 1000, and 2000 Hz, expressed to the nearest integral multiple of 0.05.

NOYS — A unit used in the calculation of perceived noise level.

OCTAVE — An octave is the interval between two sounds having a basic frequency ratio of two. For example, there are 8 octaves on the keyboard of a standard piano.

OCTAVE BAND — All of the components, in a sound spectrum, whose frequencies are between two sine wave components separated by an octave.

OCTAVE-BAND SOUND PRESSURE LEVEL — The integrated sound pressure level of only those sine-wave components in a specified octave band, for a noise or sound having a wide spectrum.

OSCILLATION — The variation with time, alternately increasing and decreasing, (a) of some feature of an audible sound, such as the sound pressure, or (b) of some feature of a vibrating solid object, such as the displacement of its surface.

PEAK SOUND PRESSURE — The maximum instantaneous sound pressure (a) for a transient or impulsive sound of short duration, or (b) in a specified time interval for a sound of long duration.

PERCEIVED NOISE LEVEL (PNL) — A quantity expressed in decibels that provides a subjective assessment of the perceived "noisiness" of aircraft noise. The units of Perceived Noise Level are Perceived Noise Decibels, PNdB.

PHASE — For a particular value of the independent variable, the fractional part of a period through which the independent variable has advanced, measured from an arbitrary reference.

PHON — The unit of measurement for loudness level.

PITCH — A listener's perception of the frequency of a pure tone; the higher the frequency, the higher the pitch.

PRESBYCUSIS — The decline in hearing acuity that normally occurs as a person grows older.

PURE TONE — A sound wave whose waveform is that of a sine-wave.

RANDOM INCIDENCE — If an object is in a diffuse sound field, the sound waves that comprise the sound field are said to strike the object from all angles of incidence at random.

RANDOM NOISE — An oscillation whose instantaneous magnitude is not specified for any given instant of time. It can be described in a statistical sense by probability distribution functions giving the fraction of the total time that the magnitude of the noise lies within a specified range.

RESIDUAL NOISE LEVEL — For purposes of this report, the term "residual noise" has been adopted to mean the noise which exists at a point as a result of the combination of many distant sources, individually indistinguishable. In statistical terms, it is the level which exists 90 percent of the time. (Acousticians should note it means the same level to which they have customarily applied the term "ambient.")

RESONANCE — The relatively large effects produced, e.g., amplitude of vibration, when repetitive sound pressure or force is in approximate synchronism with a free (unforced) vibration of a component or a system.

RETROFIT — The retroactive modification of an existing building or machine. In current usage, the most common application of the word "retrofit" is to the question of modification of existing jet aircraft engines for noise abatement purposes.

REVERBERATION — The persistence of sound in an enclosed space, as a result of multiple reflections, after the sound source has stopped.

REVERBERATION ROOM — A room having a long reverberation time, especially designed to make the sound field inside it as diffuse (homogeneous) as possible.

REVERBERATION TIME (RT) — The reverberation time of a room is the time taken for the sound pressure level (or sound intensity) to decrease to one-millionth (60 dB) of its steady state value when the source of sound energy is suddenly interrupted. It is a measure of the persistence of an impulsive sound in a room and of the amount of acoustical absorption present inside the room.

ROOT-MEAN-SQUARE (RMS) — The root-mean-square value of a quantity that is varying as a function of time is obtained by squaring the function at each instant, obtaining the average of the squared values over the interval of interest, and taking the square root of this average.

SINE-WAVE — A sound wave, audible as a pure tone, in which the sound pressure is a sinusoidal function of time; sound pressure ~ sine of (2π x frequency x time).

SONE — The unit of measurement for loudness.

SONIC BOOM — The pressure transient produced at an observing point by a vehicle that is moving past (or over) it faster than the speed of sound.

SOUND — See acoustics (1).

SOUND INSULATION — (1) The use of structures and materials designed to reduce the transmission of sound from one room or area to another or from the exterior to the interior of a building. (2) The degree by which sound transmission is reduced by means of sound insulating structures and materials.

SOUND LEVEL (NOISE LEVEL) — The weighted sound pressure level obtained by use of a sound level meter having a standard frequency-filter for attenuating part of the sound spectrum.

SOUND LEVEL METER — An instrument, comprising a microphone, an amplifier, an output meter, and frequency-weighting networks, that is used for the measurement of noise and sound levels in a specified manner.

SOUND POWER — Of a source of sound, the total amount of acoustical energy radiated into the atmospheric air per unit time.

SOUND POWER LEVEL — The level of sound power, averaged over a period of time, the reference being 10^{-12} watts.

SOUND PRESSURE — (1) The minute fluctuations in atmospheric pressure which accompany the passage of a sound wave; the pressure fluctuations on the tympanic membrane are transmitted to the inner ear and give rise to the sensation of audible sound. (2) For a steady sound, the value of the sound pressure averaged over a period of time. (3) Sound pressure is usually measured (a) in dynes per square centimeter (dyn/cm^2), or (b) in newtons per square meter (N/m^2). $1\ N/m^2 = 10\ dyn/cm^2 \approx 10^{-5}$ times the atmospheric pressure.

SOUND PRESSURE LEVEL — The level of sound pressure; squared and averaged over a period of time, the reference being the square of 2×10^{-5} newtons per square meter.

SOUND TRANSMISSION CLASS (STC) — The preferred single figure rating system designed to give an estimate of the sound insulation properties of a partition or a rank ordering of a series of partitions. It is intended for use primarily when speech and office noise constitute the principal noise problem.

SOUND TRANSMISSION COEFFICIENT — The fraction of incident sound energy transmitted through a structural configuration.

SOUND TRANSMISSION LOSS (TRANSMISSION LOSS) (TL) — A measure of sound insulation provided by a structural configuration. Expressed in decibels, it is 10 times the logarithm to the base 10 of the reciprocal of the sound transmission coefficient of the configuration.

SPECTRUM — Of a sound wave, the description of its resolution into components, each of different frequency and (usually) different amplitude and phase.

SPEECH-INTERFERENCE LEVEL (SIL) — A calculated quantity providing a guide to the interfering effect of a noise on reception of speech communication. The speech-interference level is the arithmetic average of the octave-band sound-pressure levels of the interfering noise in the most important part of the speech frequency range. The levels in the three octave-frequency bands centered at 500, 1000, and 2000 Hz are commonly averaged to determine the speech-interference level. Numerically, the magnitudes of aircraft sounds in the Speech-Interference Level scale are approximately 18 to 22 dB less than the same sounds in the Perceived Noise Level scale in PNdB, depending on the spectrum of the sound.

SPEED (VELOCITY) OF SOUND IN AIR — The speed of sound in air is 344 m/sec or 1128 ft/sec at 78°F.

SPHERICAL DIVERGENCE — Spherical divergence is the condition of propagation of spherical waves that relates to the regular decrease in intensity of a spherical sound wave at progressively greater distances from the source. Under this condition the sound-pressure level decreases 6 decibels with each doubling of distance from the source.

SPHERICAL WAVE — A sound wave in which the surfaces of constant phase are concentric spheres. A small (point) source radiating into an open space produces a free sound field of spherical waves.

STANDING WAVE — A periodic sound wave having a fixed distribution in space, the result of interference of traveling sound waves of the same frequency and kind. Such sound waves are characterized by the existence of nodes, or partial nodes, and antinodes that are fixed in space.

STEADY-STATE SOUNDS — Sounds whose average characteristics remain constant in time. Examples of steady-state sounds are a stationary siren, an air-conditioning unit, and an aircraft running up on the ground.

STRUCTUREBORNE SOUND — Sound that reaches the point of interest, over at least part of its path, by vibrations of a solid structure.

THIRD-OCTAVE BAND — A frequency band whose cut-off frequencies have a ratio of 2 to the one-third power, which is approximately 1.26. The cut-off frequencies of 891 Hz and 1123 Hz define a third-octave band in common use. See also band center frequency.

THRESHOLD OF AUDIBILITY (THRESHOLD OF DETECTABILITY) — For a specified signal, the minimum sound-pressure level of the signal that is capable of evoking an auditory sensation in a specified fraction of the trials.

THRESHOLD SHIFT — An increase in a hearing threshold level that results from exposure to noise.

TRAFFIC NOISE INDEX (TNI) — A measure of the noise environment created by vehicular traffic on highways; it is computed from measured values of the noise levels exceeded 10 percent and 90 percent of the time.

TRANSDUCER — A device capable of being actuated by waves from one or more transmission systems or media and supplying related waves to one or more other transmission systems or media. Examples are microphones, accelerometers, and loudspeakers.

TRANSIENT SOUNDS — Sounds whose average properties do not remain constant in time. Examples are an aircraft flyover, a passing truck, a sonic boom.

TRANSMISSION LOSS (TL) — See sound transmission loss.

VIBRATION ISOLATOR — A resilient support for machinery and other equipment that might be a source of vibration, designed to reduce the amount of vibration transmitted to the building structure.

WAVEFORM — A presentation of some feature of a sound wave, e.g., the sound pressure, as a graph showing the moment-by-moment variation of sound pressure with time.

WAVEFRONT — The front surface of a sound wave on its way through the atmosphere.

WAVELENGTH — For a periodic wave (such as sound in air), the perpendicular distance between analogous points on any two successive waves. The wavelength of sound in air or in water is inversely proportional to the frequency of the sound. Thus the lower the frequency, the longer the wavelength.