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Procedure for Assessing Impact on Public Health and Welfare Due to Noise Emitted By Household and Consumer Products

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U.S. DEPARTMENT OF COMMERCE, Philip M. Klutznick, ***Secretary***

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NATIONAL BUREAU OF STANDARDS, Ernest Ambler, ***Director***

ABSTRACT

This report documents the development of a conceptual model, and a computer program for its implementation, for assessing the aggregate impact of noise from household and consumer products on the health and welfare of the national population. The computer program requires input data on population, time utilization, dwelling type, noise isolation in dwellings, product noise emission, and product utilization. From the input data, the "weighted population," corresponding to each of a number of different noise descriptors, is computed. The report describes the assumptions involved in the model, reviews available input data, and documents the computer program.

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EXECUTIVE SUMMARY

The objective of the present study was the development of a conceptual model and a practical procedure for assessing the aggregate impact of noise from household and consumer products on the health and welfare of the national population. A secondary objective of this study was to determine the availability of data on household and consumer products, for use in application of the impact assessment model, and identification of essential gaps in current information.

The assessment of the impact of noise exposure on the population requires consideration of the intensity, or severity, of the effect and consideration of the extent, or number of people affected. Thus, to assess the total impact of noise it is necessary to determine:

- individual noise exposures,
- response criteria -- cause-effect relationships in which a given noise exposure is expressed in terms of its effects,
- the number of people who experience various levels of noise exposure,
- a procedure for combining the properties of intensity and extent.

Because of the large amount of input data required, the complexity of the calculation procedures, and the number of computations required, a computer program was developed to assess the population impact due to noise from household products. The concepts underlying this computer model, the criteria used to assess impacts, the required input data, and the use of the model are discussed in the body of the report. The computer program itself is contained in Appendix C.

A large number of noisy products are used in and around the home. Thus, it was important to classify consumer products into a limited and manageable number of categories. Since the manner, place, and time of use are dependent upon the function performed by the product, products were grouped according to their function. The proposed categorization allows various products to be treated as groups.

The main objective in obtaining noise emission data for consumer products is to provide information needed for predicting, quantitatively and accurately, the effects of the noise on people. For noise sources that emit steady-state noise over their operating cycle, the average noise emission over the period of operation suffices. For those sources with several modes of operation, each with its own characteristics, the noise emission must be averaged over all modes of operation. The computer program requires information on the octave-band spectrum shape for each product class and the probability distributions for the noise emission from the products within a class.

Few noise emission data for consumer products are available. Those data which are available are frequently unreliable, chiefly due to the lack of well-defined and uniform measurement procedures. A similar situation exists with respect to market saturation data and usage patterns needed to derive estimates of the population exposed to the noise from consumer products.

In order to assess the noise exposure resulting from a given product at each potential listener location, it is necessary, in addition to having noise emission data for the source, to obtain information on the degree of noise isolation between the source and each listener location. Accordingly, the computer model requires data on the noise isolation, as a function of frequency, between rooms within a given dwelling, between rooms in one dwelling and rooms in a neighboring dwelling, and between rooms and the location(s) of an outdoor source. In addition, data are needed on the total sound absorption in the room where a listener is located as well as data regarding the location of the listener relative to a source located in the same room.

Once information has been compiled on the noise emission characteristics and market saturation of a consumer product and the sound levels have been predicted at the listener location(s), it is necessary to have further information in order to predict the population impact of that product. First, it is necessary to know what the population groupings are and how many persons in each group are potentially exposed to consumer product noise. Second, data on the time utilization for each group need to be obtained. Finally, product utilization information must be obtained for each consumer product. Using all these data, estimates can be made of the population exposed to each consumer product and how long that population is exposed at various levels. Accordingly, the computer program requires data on time and product utilization. The time utilization data currently available do not cover all of the potentially exposed population groups. The categories of activities considered are so broad that it is difficult to establish in sufficient detail the amount of exposure to appliance noise sustained by each population grouping.

Assuming that input data described above could be obtained, the computer program calculates the "Weighted Population," which is the summation of the results of multiplying a weighting factor (as a function of noise exposure, for each response of concern) by the population subjected to that exposure. Twenty different weighting factors are available for use in computing population impact for hearing loss, general adverse response, speech interference, and sleep interference.

In addition to the Weighted Population, another quantity computed, useful in comparing the relative impact of one noise exposure to another, is the Noise Impact Index. This is the Weighted Population divided by the number of people potentially exposed to the noise from each class of products.

1. INTRODUCTION

Through the Noise Control Act of 1972 (PL92-574), Congress established a national policy "to promote an environment for all Americans free from noise that jeopardizes their health and welfare." This policy has been reaffirmed through the Quiet Communities Act of 1978 (PL95-609). In pursuit of that policy, Congress stated in Section 2 of the Act that "while the primary responsibility for the control of noise rests with state and local governments, Federal action is essential to deal with major noise sources in commerce, control of which requires national uniformity of treatment."

As part of this essential Federal action, Section 5(b) of the Noise Control Act requires the Administrator of the Environmental Protection Agency to publish, after consultation with appropriate Federal agencies a report or series of reports "identifying products (or classes of products) which in his judgment are major sources of noise." Section 6 of the Act requires that the Administrator of EPA publish proposed regulations for each product identified as a major source of noise and "for which in his judgment noise standards are feasible and are requisite to protect the public health and welfare."

In addition, Section 8 of the Act directs the Administrator of EPA "to designate any product or class thereof which emits noise capable of adversely affecting the public health or welfare and to require that notice be given to the prospective user of the level of noise the product emits" through a labeling action.

The Noise Control Act requires EPA to develop uniform procedures for assessing the public health and welfare impact of noise from various products. The main objective of the present study was the development of a conceptual model and a practical procedure for assessing the impact of noise from household and consumer products on the health and welfare of the national population. A secondary objective of the study was to ascertain the availability of data on household and consumer products for use as input to an impact assessment model, and to identify gaps in that information.

As pointed out in previous EPA documents [1-5]*, assessment of the population impact due to noise exposure requires consideration of the intensity, or severity, of the effect and consideration of the extent, or number of people affected. Therefore, to assess the total impact of noise, it is necessary to determine:

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* Figures in brackets indicate the literature references in Section 7 of this report.

- individual noise exposures,

- response criteria -- cause-effect relationships in which a given noise exposure is expressed in terms of its effects,

- the number of people experiencing various levels of noise exposure,

- a procedure for combining the properties of intensity and extent.

In order to estimate individual exposures, it is necessary to have data on the noise emission for each class of product, the length of time each product is operated, the noise isolation between the location of the product and the location(s) of the listeners, and the length of time listeners spend in various locations. Criteria are needed that relate each effect of concern to the noise exposure which produces that effect. Data are needed on the number of people in each category of "population at risk." Finally, a procedure is needed to combine all of these data into a single measure of the total population impact. These data and criteria requirements are discussed in the sections that follow.

2. CONSUMER PRODUCT NOISE EMISSION

2.1. PRODUCTS INCLUDED AND EXCLUDED

Much attention has been focused on the impact of noise from sources such as aircraft, vehicular traffic, and construction activities. In the past, little attention has been given to noise sources encountered in and around the home. The present study focuses only on household appliances and consumer products (referred to hereafter as "consumer products"). These include typical built-in interior equiment such as heating and cooling systems, dishwashers, and garbage disposers. Also included are portable appliances, such as electric shavers, food blenders, hair dryers, vacuum cleaners, shop tools, and lawn-care equipment.

Consumer products whose sound level is under the control of the operator -- radios, television sets, and stereo systems -- are not included in the present study. Plumbing systems and built-in mechanical equipment, such as elevators and trash chutes, also are not included because they normally are not purchased directly by people for use in their own homes.

Also excluded are those consumer products which are used either very infrequently, or by very few people, and products that produce noise levels that can be considered to be below the levels of immediate concern with respect to public health or welfare. Included among such products are rotisseries, refrigerators, freezers, and hot water heaters. The decision to exclude these products from consideration was arbitrary and does not imply that under no condition can they be noisy. The assessment model could be used with these products provided that appropriate input data were available.

2.2. PRODUCT CLASSIFICATION

Because of the large number of noisy products used in and around the home, it was important to classify consumer products into a limited and manageable number of categories. Since the manner, place, and time of use depend on the function performed by the product, products were grouped according to their function. For example, products that are used for food preparation, disposal, or storage, and may operate for varying amounts of time, are most frequently used in the kitchen by the person in the family who is responsible for food preparation. Products designed for personal hygiene and grooming are normally used in the bathroom or bedroom by various members of the family but usually only for brief amounts of time.

This rationale led to a practical, although arbitrary, classification scheme that specifies nine classes of products, each of which is subdivided (when appropriate) according to the specific function associated with a given product. Table 1 summarizes the classification format used and separately lists those products emitting noise that (1) potentially could or (2) probably could not adversely affect public health and welfare.* These latter products have been excluded from further consideration in this report.

The proposed categorization allows various products to be treated as groups for selection of noise measurement procedures. For example, appliances used in the kitchen normally affect the user most, although they can be heard elsewhere, but to a lesser degree, by people located in either adjacent rooms or adjacent dwellings. The important parameters affecting the exposure of the user are the sound power radiated, the directivity pattern of an appliance, and, to a lesser extent, the acoustical properties of the room. For counter-top appliances such as blenders, coffee grinders, and mixers, the noise exposure may be sensitive to the presence of nearby walls and corners. These should be considered when measurement procedures are developed. For built-in kitchen appliances, the noise emission will be influenced by the counter top and cabinet construction and the manner in which the appliance is installed. In this latter case, these factors also may affect greatly the noise received along structure-borne paths. Such products may require different measurement procedures to account for this factor. As another example, appliances used for grooming and personal hygiene are often used in proximity to the ear, thus requiring different measurement procedures from those used for other classes of products.

2.3 REQUIRED NOISE EMISSION DATA

The chief application of noise emission data for consumer products is to provide information needed to predict, quantitatively and with a satisfactory degree of accuracy, the effects of the noise on people. The accumulated evidence of research on human response to sound indicates that the intensity of a sound, as a function of time and frequency, is the basic indicator of probable human response. For this reason, specification of the noise emission data from consumer products is desired in terms that permit computation of the average sound pressure level, over the period of operation of the product, at various listener locations.

Two basic approaches can be used to characterize the noise emission from a source. The average sound pressure level at some reference distance from the source can be determined or the sound power level and the directivity pattern of the source can be measured.

Since the human ear is not equally sensitive to sound of different frequencies, the spectrum shape for each class of products is required. Since the range of sound levels for any given class of product can be large, the distribution of 1/3-octave-band and A-weighted levels over the population of products contained within a class is also required.

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* In order to avoid interfering with the continuity of the text, tables and figures are located at the end of each Section.

2.4 AVAILABLE NOISE EMISSION DATA

Published noise emission data on consumer products are scarce. Those which are available do not lend themselves to the kind of analyses required to provide a basis for comparisons among products. This stems mainly from a lack of adequate definition and general acceptance of measurement methods for most products. As a result most published data were obtained by measurement procedures that either are not fully reported or not documented at all.

Measurement procedures that are reported in the literature vary considerably, even for the same product. In many instances, each researcher devised his own test procedure. Sometimes a controlled environment, such as an anechoic or reverberation chamber was used; other tests were performed in situ or outdoors. Terms such as "acoustically average kitchen" might be all the information given to specify the environment. Operating conditions might be described as "normal" or "simulated." For hand-held appliances, some were resiliently suspended; others were not. A counter top may be specified as part of the test for mounted appliances or for appliances which rest on a counter top under actual use conditions, but this was not always the case. Often it was impossible to know whether the data reported for a product were obtained in situ or in the laboratory, whether mounting conditions were actual or simulated, and whether or not precautions were taken to control the influences of structure-borne interactions. In addition, some products were measured in their noisiest modes of operation, while others were measured in all operating modes and the average of all modes reported. All of these factors combine to make the published physical data very difficult to interpret, and intercomparisons virtually impossible.

To further complicate the situation, since there are no standard measurement methods for most products, data are not reported in a standardized way. Some authors report their data in terms of 1/3-octave-band levels while others report octave-band data, narrow-band data, A-weighted levels, C-weighted levels, sones, N-ratings, or some other metric. To illustrate the variability in the available data, Table 2 summarizes the type of physical data reported by various authors for a variety of consumer products.

In a few instances either data are reported in terms of sound power levels, or a measurement distance accompanies a reported sound pressure level. In cases such as these, it is possible to convert the reported data to levels at a single reference distance. To provide some insight into the range of data associated with consumer products, whenever possible the range of A-weighted levels and the average A-weighted level at a distance of 1 meter were computed (assuming spherical spreading). These data are reported in Table 3. Note that the tabulated values in Table 3 are illustrative only and should not be construed as representative of the noise emission of actual consumer products. This disclaimer is made for two reasons. First is the weakness associated with the basic data from which they were derived. Second, products found in homes throughout the United States are of different ages and brands and are in various states of wear (all factors affecting noise emission). These products were not sampled, and thus the levels reported would not necessarily be representative of actual conditions found in the home.

2.5 MEASUREMENT PROCEDURES

Most of the published physical data on consumer products were obtained by diverse measurement procedures. This diversity is due to the lack of well-accepted and standardized measurement procedures. At least two exceptions are worth noting -- fans and lawn mowers. Data for these products usually have been acquired by methods prescribed in voluntary standards.

Emission data on fans often have been obtained in accordance with either the measurement methodology recommended by the American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE) [6] or by that of the Air Moving and Conditioning Association [7]. Both procedures call for measurement of the sound power level for eight octave-bands in a reverberation room calibrated using a reference sound source. The ASHRAE procedure further specifies that 1/3-octave-band data must be obtained to estimate whether pure tones may be present for a given product.

In the case of lawn mowers, measurement data usually were obtained by a procedure developed by the Society of Automotive Engineers [8]. This procedure calls for measurements to be made outdoors over artificial turf.

The general lack of standard measurement methods for household products causes acute problems. Although this matter is receiving attention, particularly at the international level, considerable disagreement remains concerning how to measure the noise emission of each product, what constitutes a suitable test environment and how to report the data. In order to obtain the essential data base required by EPA, suitable measurement standards must be available.

Although it is not the purpose of the present section to address all the problems involved in the development of measurement procedures, an illustrative example of questions that emerge may be useful.

One of the key problems is that of defining and choosing the acoustical quantity to be measured: sound pressure at one or more selected locations, total sound power, or sound power and directivity. Furthermore, should this quantity be expressed in terms of a weighted level, such as an A-weighted sound pressure level or an A-weighted sound power level?

Some acousticians strongly prefer noise ratings expressed in terms of sound power rather than sound pressure. Since sound power is almost always computed from measured sound pressures it is difficult to argue that sound power is inherently superior to sound pressure. However, the proponents of sound power argue that the sound pressure values observed from a given source depend strongly upon the point at which the measurement is made, and can depend upon the environment in which both the source and the measuring microphone are located. Sound power level is a measure of the total sound power radiated by the source in all directions and directivity is a measure of the spatial intensity distribution. Sound power and directivity are basic characteristics of the noise source and hence need not be specified in terms of any particular measurement distance, except that measurements ought to be made in the far field. Sound power depends less on the environment in which the source is located than does sound pressure. However, both the radiated sound power and the directivity are influenced by nearby reflecting surfaces, such as floors and walls. In enclosed spaces, the sound power usually is less affected by the environment than is the sound pressure observed at distances far enough from the source to be in the reverberant field.

As was mentioned above, sound power usually must be computed from sound pressure measurements. This is accomplished simply and accurately in two limiting cases: (1) in a free field beyond the near field, and (2) in a reverberant (diffuse) sound field. In such fields the sound power can be calculated from the mean-square sound pressure, averaged over an appropriate surface enclosing the source (free field) or averaged over the volume of the room (reverberant field). Close approximations to free-field conditions can be achieved in anechoic chambers, hemianechoic chambers (i.e., free field over a reflecting plane), or outdoors. Approximately diffuse sound fields can be obtained in large, hard-walled reverberation chambers. To determine the directivity of the source, an essentially free-field environment must be used.

Sound power proponents further argue that whenever acoustical data are expressed in terms of sound power, one should be able to assume that the data correspond to the far field around the source, and the the sound power is based either on measurements at a sufficient number of angular positions to sample the field adequately in all directions or by adequately sampling a reverberant field. If on the other hand, acoustical data are expressed in terms of sound pressure, these data must be accompanied with sufficient information regarding the measurement location and test environment to enable one to infer the extent to which the data may be used to predict sound pressure at other locations and in other locations and in other environments.

Proponents of sound pressure level argue that one disadvantage of sound power is that the human ear does not respond directly to sound power but rather to sound pressure. Thus, in cases where human response is of concern, they believe that sound power may not be the most suitable measure. So long as the sound pressure levels reported are accompanied with sufficient information regarding the measurement location and test environment, the data can be useful in predicting sound pressure levels at other locations and/or other environments.

Recently, the relationship between source emission and sound pressure levels has been challenged by Schultz [9] who suggests that some of the underlying assumptions of theoretical acoustics are "valid only under certain limited conditions." These conditions may not necessarily be present for many noise sources found in dwellings since even "at distances far from the source, real rooms do not behave like the classical reverberant rooms of theoretical acoustics, but more like lined ducts."

The most important criterion in terms of consumer product noise emission is relating the data to human response. If the operator of the product stays at a particular location the sound pressure at the position of his head may be the most useful quantity to measure. If the operator moves around and/or if the concern is with potential bystanders that move about the noise source, a spatial average of sound pressure levels over the total region of interest may be the most appropriate quantity. In cases where several products operate at the same time it may be necessary to know the sound pressure level at the ear of the operator for a particular product plus the sound power contributed by the other products in order to ascertain the total noise level at the operator position.

As can be seen by the above discussion the problem of choosing which quantity to measure is a difficult one to resolve. In general, sound pressure level at the location of a listener is required to assess the effect of noise from a product. How this quantity is obtained is less clear. Sound pressure level is appropriate if the listener location is well defined, the transmission to the listener does not differ much in various situations, and if the data can be obtained and are reported in sufficient detail to be easily extrapolated to other locations. Sound power, on the other hand, may be more appropriate if information is needed to predict sound pressure in a variety of environments which significantly affect the resultant sound pressure.

In addition to the problem of what is to be measured, many other choices must be made when developing standard measurement procedures. These include the choice of the measurement environment (e.g., anechoic, hemianechoic, reverberant, and in situ conditions), how the measurements are to be made, where the product is located, how it is to be installed and operated, how much precision is required, and how the data are to be reported. Obviously, answers to such questions are not independent; for example, sound pressure level measurements for a given device are obtained by measuring at a specified distance from the source in essentially free-field conditions. For sound power determinations, in an acoustically controlled environment, the source is usually located near the center of the room for anechoic measurements, near the center of the floor for hemi-anechoic measurements, for reverberant measurements the source could be located at various locations. For devices normally mounted on or against a wall, products should be tested in their use configuration.

The noise level produced by a specific device depends not only on the sound radiating characteristics of the product itself but also on the way the appliance is operated and/or installed and the specific environment in which it is used. In setting noise limits for such devices through noise emission or labeling standards, test procedures and measurement methods should include such items as loading, operating speeds, installation requirements, and the location and specification of needed auxiliary equipment.

Thus it can be seen that standard measurement methods should specify at least the following:

1. the quantity to be measured

2. the environment in which the measurements are to be made

3. the mode of installation and operation of the source, which includes the following information:

    - the device under test should be located in its use configuration or, alternatively, the choice of a location should be governed by the test environment and the quantity to be measured; e.g., the source should be located near the center of the room for anechoic measurements of sound power,

    - the device under test should be mounted under conditions similar to those recommended for normal installation. Care should be taken to ensure that adequate isolation is provided to minimize extraneous airborne noise due to vibration excitation,

    - the operational modes under which tests are to be carried out,

    - the extent of loading and the manner of application of the load to the source under test, these should be similar to actual use conditions wherever possible.

4. the actual measurement procedures should include:

    - the location of all microphones,

    - the position of the source with respect to the test environment,

    - the number of observations, and the averaging time, necessary for each sound level measurement,

    - criteria which determine whether the use of diffusers is indicated in reverberation room measurements,

    - procedures for determining background noise,

    - techniques and procedures for characterizing the adequacy of the test environment,

    - instrumentation and facility calibration requirements and procedures.

5. the information to be recorded should include:

- o the size, dimensions, design characteristics, and noise performance claims for the source under test,
- o the location, mounting, and/or installation details of the source,
- o the operational and loading characteristics of the source during the test,
- o a description of the acoustic environment, including test facility, background noise levels, and environmental conditions,
- o identification of instrumentation used,
- o documentation of unavoidable deviations from the prescribed test procedures,
- o a maintenance and calibration record to indicate the current calibration status of all instrumentation (calibration methods and periodicity, accuracy, and traceability of the calibration devices need to be detailed),
- o all significant data collected during the test,
- o documentation of calculation procedures used in transforming the raw data into its final form,
- o an indication of the accuracy and precision of the data.

2.6 MARKET SATURATION DATA

In order to derive estimates of the national population exposed to the noise from consumer products, it is desirable to have market saturation data -- information as to how many households possess one or more of each product class. Table 4 lists all of the household products included in this study, indicates whether or not saturation data were found, and if so, shows the percentage of wired households containing each product. Practically, what this means is that, of all the wired households in the United States, X% of the households contain at least one of the product of interest. The data do not account for households which may have more than one particular product (such as electric razors, vacuum cleaners, etc.). Moreover, there is probably no practical way to get this information from existing data. Saturation data are available for only about 25% of the products included in this study.

Even though three different references have been cited in Table 4 as primary sources of data, References 11 and 12 both used Reference 10 as their primary primary source. The U. S. Census Bureau also uses statistics from Merchandising magazine in compiling the product data tables for the Statistical

Abstract of the United States. The statistical and marketing reports of Merchandising magazine are considered reliable, accordingly, their saturation data have been used to make estimates of potential consumer exposure to household appliance and product noise.

There are major problems, however, with using market saturation data. First, for many appliances there are no data readily available. In fact, there are more noise-producing appliances for which there are little or no data than there are appliances for which data are available. In order to determine the actual impact of household appliances and consumer products, hard data will be required in the future.

Second, for a product such as an electric shaver there is little problem in deciding whether it can be categorized as a home appliance. It is not always this clear-cut. Appliances such as a vacuum cleaner or a room air conditioner seem to qualify as home appliances (and probably are, predominantly); however, these are also used and have an impact in numerous situations outside of the home. There appears to be no way to identify and quantify these situations from the data currently available. For example, office and public buildings have to be cleaned, and there are numerous vacuum cleaners used for this purpose. In older public buildings with no central air conditioning, window air conditioning units are often used. When categorizing lawn care and home shop products, the situation is worse. Who can tell, for example, whether a circular saw has been purchased for home use, or for use at a construction site? Thus, in order to assess the impact of such products, even if complete saturation data were to exist, there would still be a need to determine how and where these products are used.

2.7 INFORMATION GAPS

Large information gaps exist in the available noise emission data, product measurement procedures, and market saturation data. In connection with the noise emission data, it must first be stated that quantitative data do not exist for all of the products considered. Moreover, for those products for which data are available, these data are weak because, in general, no standardized measurements methods were utilized. In addition, there is no way to assess whether or not, for any product, reported data represent the product class. Finally, where data are found in the literature they appear in a variety of metrics, thus making comparisons among data difficult, if not impossible.

Market saturation data are problematic also. First, there is no way of determining for each household and each particular appliance how many of these are owned. It can only be known that if a household is included among those owning an appliance, it contains at least one such appliance. Even if a household contains an appliance, it cannot be said with any certainty that the product is actually used. Product usage is merely assumed. Second, for most household products, there are no readily available saturation data.

Table 1. Classification of consumer products that emit noise which may adversely affect public health and welfare.

Potentially Hazardous		Potentially Less Hazardous[a]
	FOOD PREPARATION, DISPOSAL AND STORAGE	
	a. Mixing, Straining, Crushing	
Blender/liquidizer Electric mixer Coffee grinder Ice crusher		Juicer Electric ice cream freezer Electric meat grinder
	b. Cutting, Slicing	
Electric knife Slicer Knife sharpener		
	c. Opening	
Electric can opener		
	d. Cooking	
		Rotisserie
	e. Clean Up/Disposal	
Garbage disposer Dishwasher Trash compactor		
	f. Storage	
		Refrigerator/freezer
	PERSONAL HYGIENE AND GROOMING	
Oral hygiene device Hair dryer/blower Electric razor Electric hair clipper		Electric shoe polisher
	CLIMATE AND ENVIRONMENTAL CONTROL	
Exhaust fan, range hood Heating and air conditioning (central) Air conditioner (room)		Sump pump Vaporizer Gas water heater

[a] Inclusion of products in this column does not imply that under no conditions can they be noisy.

Humidifier
Dehumidifier
Electric portable and window fan
Electronic air cleaner
Space heater

INDOOR MAINTENANCE

Vacuum cleaner
Rug cleaner/floor waxer
Floor scrubber

CRAFTS, HOBBIES, AND NON-WORKSHOP TOOLS

Sewing machine
Electric typewriter
Movie/slide projector
Electric scissors
Calculator
Antenna rotor

LAUNDRY EQUIPMENT

Washing machine
Clothes dryer

LAWN AND GARDEN CARE AND MAINTENANCE

Lawn mower (gas, electric, riding)
Edger/trimmer/grass shears
Chain saw
Incinerator
Lawn thatcher
Weed eater
Leaf blower
Leaf sweeper/mulcher/shredder
Rotor tiller
Snow blower
Hedge trimmer
Garden tractor
Pool filter
Aerator
Insect fogger
Power washer
Electronic bug killer

HOME WORKSHOP TOOLS

a. Cutting

Power shears
Sabre saw
Pneumatic power chisel
Circular saw
Abrasive cut-off machine
Radial arm saw
Table saw
Power hacksaw
Electric engraving pen

Scroll saw
Band saw
Reciprocating saw
Motorized mitre box

b. Shaping

Router
Lathe
Shaper

c. Drilling

Drill press
Portable electric drill
Impact drill
Pneumatic air drill

d. Driving

Nail gun
Electric staple gun
Pneumatic chipping hammer
Electric screwdriver
Roto hammer

e. Sanding/Planing

Belt sander
Pneumatic sander
Vibration sander
Sander/polisher
Disc sander
Planer/jointer
Sand blaster

f. Sharpening

Grinder
Saw blade sharpener
Drill bit sharpener

g. Fastening

Impact wrench
Molder
Spot welder
Arc welder

h. Unfastening

Flameless heat gun

i. Pumping

Liquid pump
Vacuum pump

j. Power Generating

Air compressor
Power generator
Motor

k. Cleaning

Shop vacuum
Chipper cleaner
Spark plug cleaner

l. Finishing

Paint sprayer
Spray gun

Table 2. List of references and types of physical data available on consumer products.

Appliance	Type of Spectral Information: 1/3-Octave-Band Levels	Octave-Band Levels	A-Weighted Sound Level	Other Descriptors	Number of Products Tested
1. Food Preparation, Disposal, Storage					
A. Mixing, Straining, Crushing					
Blender	1	8,33	1,2,14		18
Liquidizer	12				4
Electric mixer	1,12	8,19,33	2,14,17	19 (sones)	23
Coffee grinder			1,2,14		3
B. Cutting, Slicing					
Electric knife	1	33	1		4
Knife sharpener			1,14		2
C. Opening					
Can opener	1	33	1		4
D. Clean Up/Disposal					
Garbage disposer	1,11,12	19,33,34	1,2,14,34	19 (sones)	17
Dishwasher	12	1,10,19,33	1,2,14	11 (narrow band)	12
				19 (sones)	12
Trash compactor		33			1
2. Personal Hygiene and Grooming					
Oral hygiene devices	1,12		1		4
Hair dryer	1,12	8	1,2,14		10
Electric shaver	1,12	8,9,17,19	1,14	19 (sones)	16
Electric hair clipper			1		1
3. Climate and Environmental Control					
Exhaust fans	1	1,19	1,14,34	19 (sones)	17
Heating and air conditioning (central)	21	1,19,34,31	1,34		16
Heating and air conditioning (room)	1	10,24,29	1,2,6,14,16	19 (sones)	14
Humidifier	1		1		5
Dehumidifier	1		1		3
Electric fan	1,30,12	19,20,26,28	1,14	19 (sones)	36
Heater (room)	36	1,9,17	1	17 (N rating)	16
4. Indoor Maintenance					
Vacuum cleaner	1	9,17,19,33	1,2,14,16	11 (narrow band) 17 (N rating) 19 (sones) 13 (C-wt.)	27
Rug cleaner/floor waxer			2		1

Appliance		Type of Spectral Information: 1/3-Octave-Band Levels	Octave-Band Levels	A-Weighted Sound Level	Other Descriptors	Number of Products Tested
5.	Crafts, Hobbies, and Non-Workshop Tools					
	Sewing machine	1	33	1,14		5
	Electric typewriter			2		1
6.	Laundry Equipment					
	Washing machine	1,12	19	1,2,14	19 (sones)	16
	Clothes dryer	1,12	9,17,19,33	1,2,14	19 (sones)	15
7.	Lawn/Garden Care and Maintenance					
	Lawn mower			1,2,3,4,16		8
	Edger/trimmer/grass shears	1				1
	Chain saw			2,6		
	Leaf sweeper/mulcher/shreader			2		15
	Hedge trimmer			1		1
8.	Home Workshop Tools					
	A. Cutting					
	Sabre saw	1		2,14		10
	Circular saw	18	7,15	2,5,14		11
	Radial arm saw	1		14		2
	Table saw	1				3
	Band saw	1		2		3
	B. Shaping					
	Router	1		2		10
	Lathe	1		2,14		5
	Shaper			2		5
	C. Drilling					
	Drill press	1		2		3
	Portable electric drill	1		1,2,14,23		
	D. Sanding/Planing					
	Belt sander	1		2,14		10
	Vibration sander			1		1
	Disc sander			14		1
	Sander/polisher			2,14		2
	E. Sharpening					
	Grinder	1		1,16		5
	F. Pumping	22	1,22	1,16		9
	G. Power Generating					
	Air compressor		1	1,2		4
	Motor	32	1	1		3
9.	Miscellaneous					
	Small equipment cooling fan		25,27		27(NR, SIL)	12

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Table 3. Range, mean, and standard deviation of the A-weighted sound levels (at 1 meter from the source) for certain household products.

Appliances	Range of A-Weighted Levels (re 20 μPa) (dB)	Number of Products Tested	Mean A-Weighted Level (re 20 μPa) (dB)	Standard Deviation of Levels (dB)
1. FOOD PREPARATION, DISPOSAL, AND STORAGE				
a. Mixing, Straining, Crushing				
Blender	62-91	15	75	8
Liquidizer	61-89	4	75	12
Electric mixer	45-75	17	64	8
b. Cutting, Slicing				
Electric knife	64-74	3	70	6
c. Opening				
Electric can opener	64-80	3	70	7
d. Clean up/Disposal				
Garbage disposer	59-70	8	67	4
Dishwasher	66-74	4	69	3
2. PERSONAL HYGIENE AND GROOMING				
Hair dryer/blower	47-61	6	55	6
Electric razor	44-71	12	58	8
3. CLIMATE AND ENVIRONMENTAL CONTROL				
Exhaust fan	46-63	4	58	8
Central heat	32-51	5	47	10
Room air conditioner	59-66	3	64	4
Humidifier	41-64	3	52	12
Electric fan	45-66	12	54	7
Heater	41-53	10	47	4
4. INDOOR MAINTENANCE				
Vacuum cleaner				
Rug cleaner/floor	64-85	12	73	6
waxer [a/]	65-67	--	--	--
5. CRAFTS, HOBBIES, NON-WORKSHOP TOOLS				
Sewing machine	66-72	3	69	3
Electric typewriter[a/]	65-74	--	--	--

Appliances	Range of A-Weighted Levels (re 20 μPa) (dB)	Number of Products Tested	Mean A-Weighted Level (re 20 μPa) (dB)	Standard Deviation of Levels (dB)
6. LAUNDRY EQUIPMENT				
Washing Machine	55-75			
Clothes dryer	52-68	7	59	6
7. LAWN AND GARDEN CARE AND MAINTENANCE				
Powered lawn mowers	80-106	-	-	-
8. HOME WORKSHOP TOOLS				
a. Cutting				
Sabre saw	84-90	2	87	4
Circular saw	89-102	2	96	9
Table saw	72-91	3	79	11
b. Shaping				
Router	80-87	2	84	5
Lathe	72-73	2	73	1
Shapers[a]	85-90	5	88	3
c. Drilling				
Drill press	78-86	2	83	6
Portable electric drill	77-86	3	82	5
d. Sanding/Planing				
Belt sander	85-88	2	87	2
Sander/polisher[a]	80-82	-	--	--
Disc sander[b]	93	-	--	--
e. Sharpening				
Grinder	84-91	3	91	7
f. Pumping	73-93	-	--	--
g. Power Generating Motors	79-102	-	--	--

[a] Measurements made at the operator's ear.

[b] No measurement distance given.

Table 4. Saturation data currently available on household consumer products.

Product	Saturation Data Available	Percentage of Wired Homes with
FOOD PREPARATION/DISPOSAL		
Blender	Yes [11]	45
Electric mixer	Yes [11]	
Coffee grinder	No	
Ice crusher	No	
Electric knife	Yes [11]	41
Slicer	No	
Can opener/knife sharpener	Yes [11]	55
Garbage disposer	Yes [11]	39
Dishwasher	Yes [11]	38
Trash compactor	Yes [11]	2
PERSONAL HYGIENE/GROOMING		
Oral hygiene device	Yes [11]	14
Hair dryer/blower	Yes [11]	47
Electric razor	Yes [12]	40
Electric hair clipper	No	
CLIMATE/ENVIRONMENTAL CONTROL		
Exhaust fan, range hood	No	
Central heat/air conditioning	No	
Room air conditioner	Yes [11]	53
Humidifier	Yes [12]	7
Dehumidifier	Yes [12]	7
Electric fan	No	
Electronic air cleaner	No	
Heater	No	
Space heater	No	
INDOOR MAINTENANCE		
Vacuum cleaner	Yes [11]	99
Rug cleaner/floor waxer	No	
Floor scrubber	No	
CRAFTS, HOBBIES, NON-WORKSHOP TOOLS		
Sewing machine	Yes [12]	50
Electric typewriter	No	
LAUNDRY EQUIPMENT		
Washing machine	Yes [11]	70
Clothes dryer	Yes [11]	58
LAWN AND GARDEN CARE AND MAINTENANCE		
Powered lawn mower	Yes [12]	59
Edger/trimmer/grass shears	Yes [12]	8
Chain saw	Yes [13]	3
Incinerator	No	
Lawn thatcher	No	
Weed eater	No	
Leaf blower	No	
Leaf sweeper/mulcher/shredder	No	
Rotor tiller	No	

Table 4. (cont.)

Snow blower	No		
Hedge trimmer	No		
Garden tractor	No		
HOME WORKSHOP TOOLS	Yes	[12]	20
Power shears	No		
Sabre saw	No		
Pneumatic power chisel	No		
Circular saw	No		
Abrasive cut-off machine	No		
Radial arm saw	No		
Table saw	No		
Power hacksaw	No		
Scroll saw	No		
Band saw	No		
Reciprocating saw	No		
Motorized mitre box	No		
Router	No		
Lathe	No		
Shaper	No		
Drill press	No		
Portable electric drill	No		
Impact drill	No		
Pneumatic air drill	No		
Nail gun	No		
Electric staple gun	No		
Pneumatic chipping hammer	No		
Belt sander	No		
Pneumatic sander	No		
Vibration sander	No		
Sander/polisher	No		
Disc sander	No		
Planer/jointer	No		
Sand blaster	No		
Grinder	No		
Saw blade sharpener	No		
Drill bit sharpener	No		
Impact wrench	No		
Molder	No		
Air compressor	No		
Power generator	No		
Motor	No		
Shop vacuum	No		
Chipper cleaner	No		
Paint sprayer	No		
Spray gun	No		

3. NOISE ISOLATION

In addition to having noise emission data on the source in order to assess the noise exposure at each potential listener location, it is necessary to obtain information on the degree of noise isolation between the source and each listener location. The methods used to predict or estimate the noise exposure for various listener locations are described in the following section.

3.1. PREDICTION OF SOUND LEVELS AT LISTENER LOCATIONS

The spatially-averaged mean-square sound pressure in a room is, within the limitations of certain simplifying assumptions, proportional to the total sound power entering the room and inversely proportional to the total sound absorption in the room. In a typical dwelling this acoustic power can be generated by sources: (1) within a room, (2) elsewhere in the building, or (3) exterior to the building. Therefore, to predict sound levels at potential listener locations, each of these three conditions must be examined.

When a source is located in the same room as a listener the sound energy from the source is largely confined by the boundaries of the room. If there were no absorption by walls and other objects the sound energy density in the room theoretically would increase indefinitely so long as the source were operated. However, since some energy gets absorbed by surfaces such as walls, carpets, draperies, etc., the sound pressure in the room builds up only to the point where as much energy (per unit time) gets absorbed by these boundaries as is being supplied by the source (per unit time). The more absorption there is in a room, the lower the build-up.

In the region close to the source and for a source away from reflecting walls or floors, the sound behaves as it would outdoors. This occurs when the boundaries of a room are far enough from the source so that they do not influence the local sound behavior. In such (direct-field) cases the sound pressure level for a listener located near the source depends upon the power output of the source, the directivity of the source, and the distance of the observer from the acoustic center of the source (it decreases at a rate of 6 dB per doubling of distance for an idealized source).

In the reverberant field the sound pressure level is no longer determined by the direct field; rather it is determined by the sound power emitted by the source and the amount of absorptive material in the room. In the reverberant field, the sound pressure level is more or less the same everywhere and can be computed using the following equation:

$$\overline{SPL_s} = PWL - 10 \log A + 6, \qquad (3.1)$$

where $\overline{SPL_s}$ = space-averaged sound pressure level, re 20 μPa, in dB,

A = total absorption in the room, in m^2, and

PWL = sound power level of the source, re 1 pW, in dB.

In the case where a noise source is located in one room and the listener is in another room, the sound pressure level in the listener room is given by:

$$\overline{SPL_R} = \overline{SPL_S} - NR \quad , \qquad (3.2)$$

where $\overline{SPL_R}$ = space-averaged sound pressure level in the receiving room (i.e., room where listener is located), re 20 μPa, in dB,

$\overline{SPL_S}$ = space-averaged sound pressure level in the source room, re 20 μPa, in dB,

NR = noise reduction, or noise isolation, between the two rooms for each specified frequency band, in dB.

In many instances the actual noise reduction between two rooms is unknown and must be computed from transmission loss data, usually obtained from laboratory measurements performed according to a procedure standardized by the American Society for Testing and Materials [13]. The transmission loss of a material is defined by the following relationship:

$$TL = 10 \log \frac{1}{\tau} \qquad (3.3)$$

where TL = transmission loss of the partition in a specified frequency band, in dB,

τ = sound transmission coefficient of the wall in the same frequency band (fraction of the incident power that is transmitted through the wall).

To estimate the noise reduction from a knowledge of the transmission loss tEe following equation is used:

$$NR = TL - 10 \log \frac{S}{A} \quad . \qquad (3.4)$$

where NR = noise reduction in a specified frequency band, in dB

TL = transmission loss of the particular partition in the same frequency band, in dB,

S = surface area of the wall, in m^2,

A = total absorption in the receiving room in the same frequency band, in m^2.

When a partition is composed of several elements, such as wall, windows doors and cracks, each element provides a parallel pathway through which sound can be transmitted. The overall transmission loss of such an assembly may be computed from a knowledge of the TL associated with each element and its area. This computation is carried out in terms of the transmission coefficient, τ, of each element, which itself is obtained according to the following equation:

$$\tau_i = 10^{-TL_i/10} , \qquad (3.5)$$

where τ_i = transmission coefficient in a specified frequency band for the i-th element,

TL_i = corresponding transmission loss.

Once the transmission coefficient of each element has been computed, the transmission coefficient of the whole assembly, τ_o, can be computed using the following expression:

$$\tau_o = \frac{\tau_1 S_1 + \tau_2 S_2 + \tau_3 S_3 + \ldots\ldots\ldots \tau_n S_n}{S_1 + S_2 + S_3 + \ldots\ldots\ldots\ldots\ldots S_n} , \qquad (3.6)$$

where τ_1 = transmission coefficient of the first element,

S_1 = surface area of the first element, in m^2,

τ_2 = transmission coefficient of the second element,

S_2 = surface area of the second element, in m^2,

and so forth.

Having determined the transmission coefficient of the whole assembly, the transmission loss (TL_o) of the whole assembly is computed according to the following:

$$TL_o = 10 \log \frac{1}{\tau_o} , \qquad (3.7)$$

where τ_o = transmission coefficient of the whole assembly.

The principles involved in computing the sound pressure level in a listening room resulting from a source located outdoors are basically similar. However, in the absence of significant excess attenuation (i.e., for a source close by), the sound pressure level from an exterior point source is assumed to fall off by 6 decibels per doubling of the distance from the source until the sound wave impinges upon the exterior wall. The average sound pressure level in a room having an exterior wall on which sound is incident is given by:

$$\overline{SPL}_R = PWL - 20 \log r - LR - 8 \quad , \qquad (3.8)$$

where SPL_R and PWL are as above,

r = distance from outside source to the center of receiving room, m,

and

LR = level reduction due to structure, in dB.

The level reduction, in a specified frequency band, is the decrease in sound pressure level due to the building shell. Note that the level reduction is a function of the direction from which the incident wave impinges upon the partition. The maximum transmission loss occurs for a normally incident sound wave and decreases significantly as the sound approaches grazing incidence.

3.2. CHARACTERISTICS OF TYPICAL DWELLINGS

As mentioned previously, the sound pressure level to which a listener is exposed when indoors may arise from a source located in the same room or from a source located either in another room or outdoors. In the latter two cases it is useful to have a general idea of typical construction styles in the United States. From this information, the noise isolation between rooms located within a dwelling, between dwellings within a multifamily building, or outdoor-to-indoor noise isolation may be estimated.

Figures 1 through 4 show floor plans of four different types of dwellings -- a single family residence, a townhouse, a low-rise apartment unit, and a high-rise apartment unit. These floor plans originally appeared in studies carried out by Hittman Associates [14,15] for the Department of Housing and Urban Development to determine residential energy consumption patterns in the Baltimore/Washington area.

Because of the wide variety of combinations of style, size, and construction materials that occurs in actual buildings, it was necessary in that study to reduce various residential types into a finite number of general plans which are purported to represent "typical" design for each type of dwelling. In performing this reduction, the data base used by Hittman Associates was supplemented by data obtained from the U. S. Census Bureau, trade associations, and industrial sources. Additional information was derived from a survey of building and development companies in the Baltimore-Washington area, as well as field observation of completed dwellings and dwellings under construction throughout the study area [14,15].

The floor plans presented in the Hittman studies may or may not be "representative" of "typical" current architectural trends throughout the United States. Moreover, "typical" design does not imply that any one of the plans presented therein would be found in an actual dwelling but, rather, that actual dwelling units would be variations of the general characteristics shown in the floor plans.

There are numerous reports (e.g., see [16-18]) in the literature that provide data on the sound transmission loss of walls, floor-ceiling assemblies, and windows. However, these data must be used with great caution in attempting to infer the noise reduction between rooms and the level reduction due to the exterior shell of a dwelling. Very few data are available on noise or level reduction, including the effects of openings and common construction practices. In the sample calculations of Appendix D, fictitious but not unreasonable values were assumed for the noise reductions between spaces.

3.3. INFORMATION GAPS AND RESEARCH REQUIREMENTS

The procedures described in Section 3.1 for determining the sound pressure level at listener locations from noise emission data are based upon "classical" theory presented in textbooks. Recently Schultz [9] has questioned the applicability of the assumptions inherent in classical theory and has stated that in fact "most kinds of equipment that will be considered for labelling are large enough that within the direct field they are point sources, the attenuation with distance is more like 3 dB than 6 dB per distance doubled. Moreover, at distances far from the source, real rooms do not behave like the classical reverberant rooms of theoretical acoustics, but more like lined ducts." These observations suggest that there is a need to determine the acoustic behavior of real and furnished rooms, of the types found in dwellings. It would appear that conventional room acoustics theory may not be adequate for determining the sound pressure level at a listener's ear.

Another research need is the validation of the assumption that most dwellings within the United States fall within one of the "typical" floor plans shown above since these floor plans may be representative only of middle class dwellings along the eastern seaboard. Finally, reliable data must be obtained on noise isolation within and between dwellings and on level reduction from outside to inside a dwelling. Such data are needed for representative dwellings selected in different climates throughout the country.

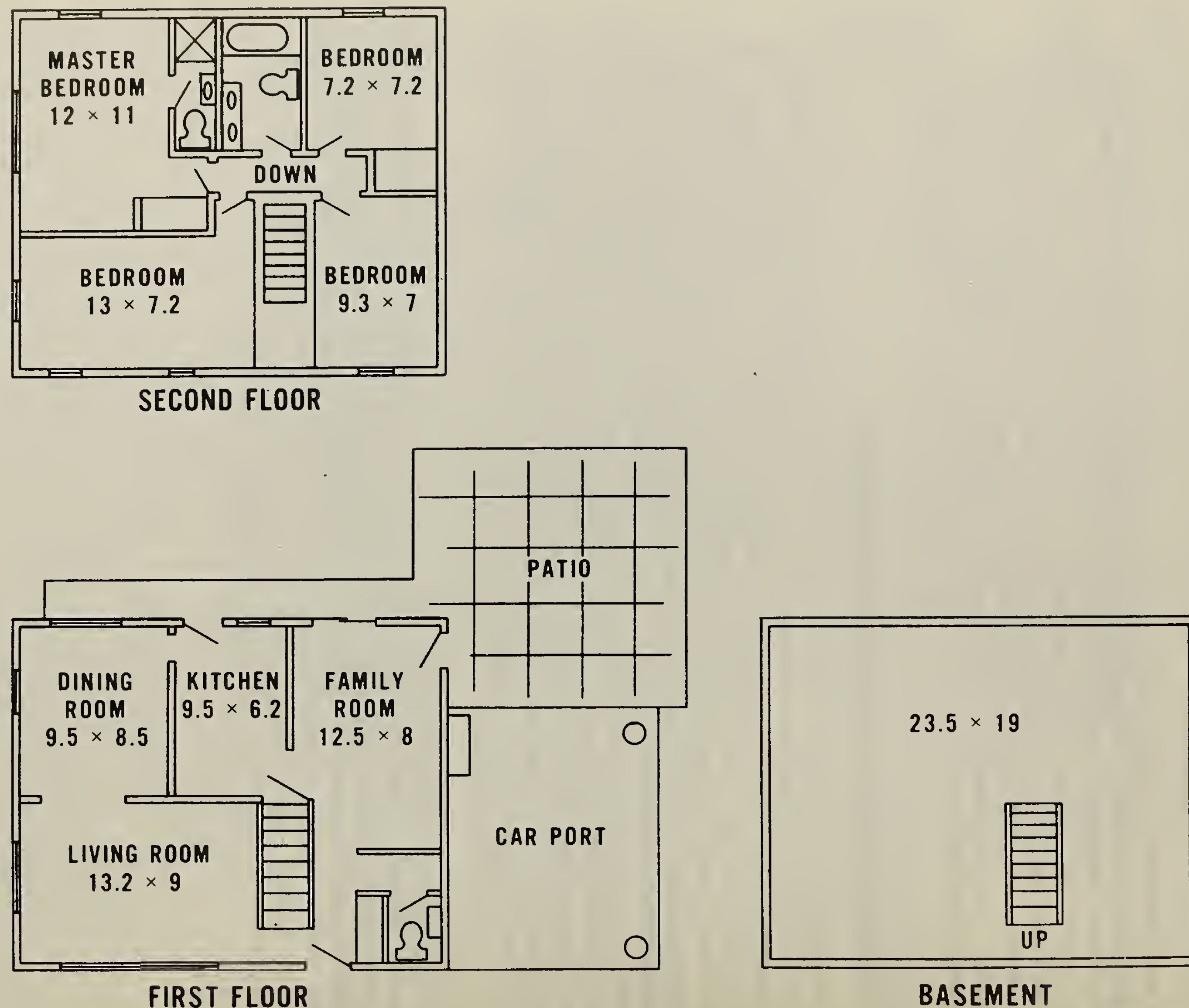

Figure 1. Floor plan of characteristic single family home [15].

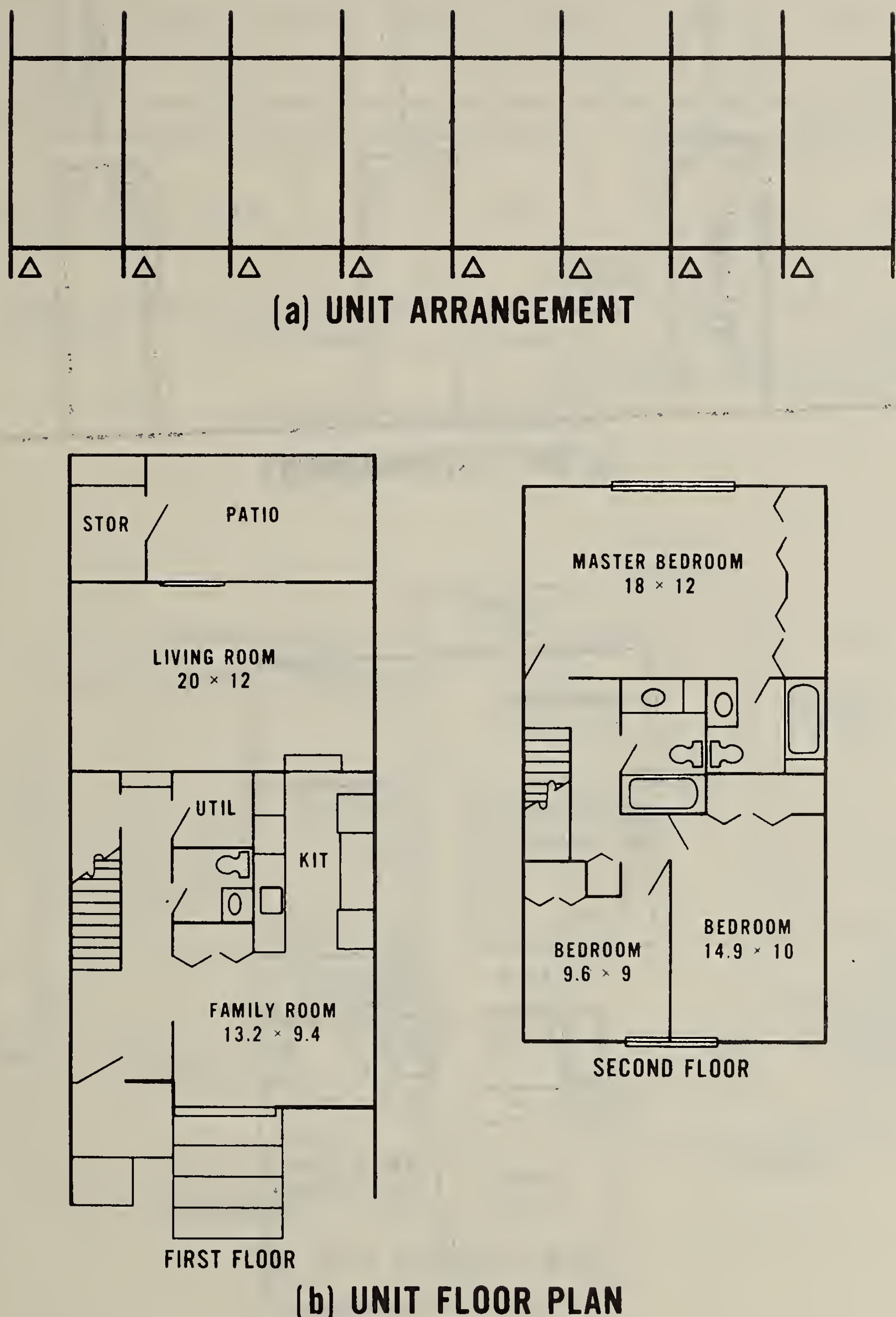

Figure 2. Floor plan of characteristic townhouse [16].

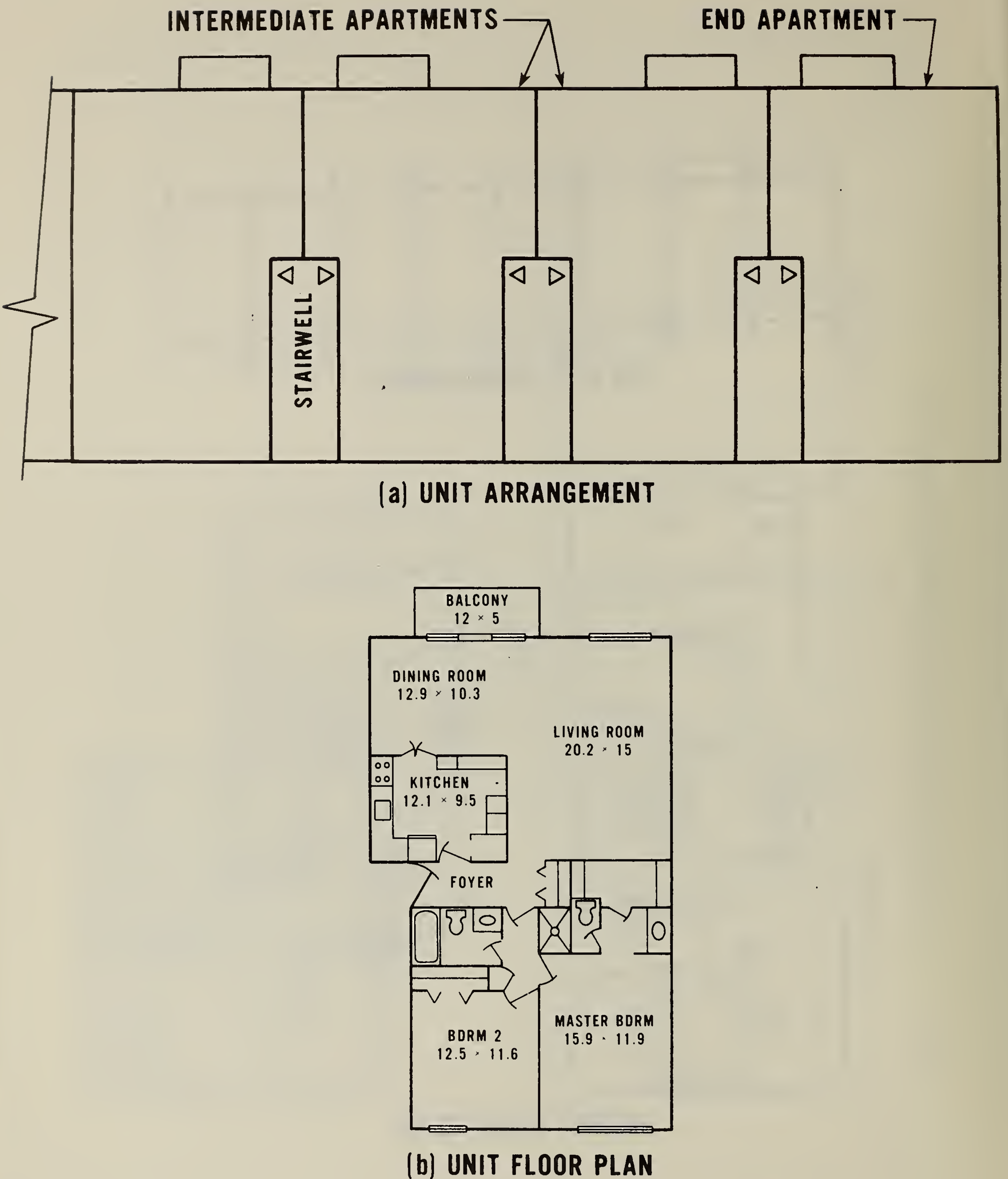

Figure 3. Floor plan of characteristic low-rise apartment [16].

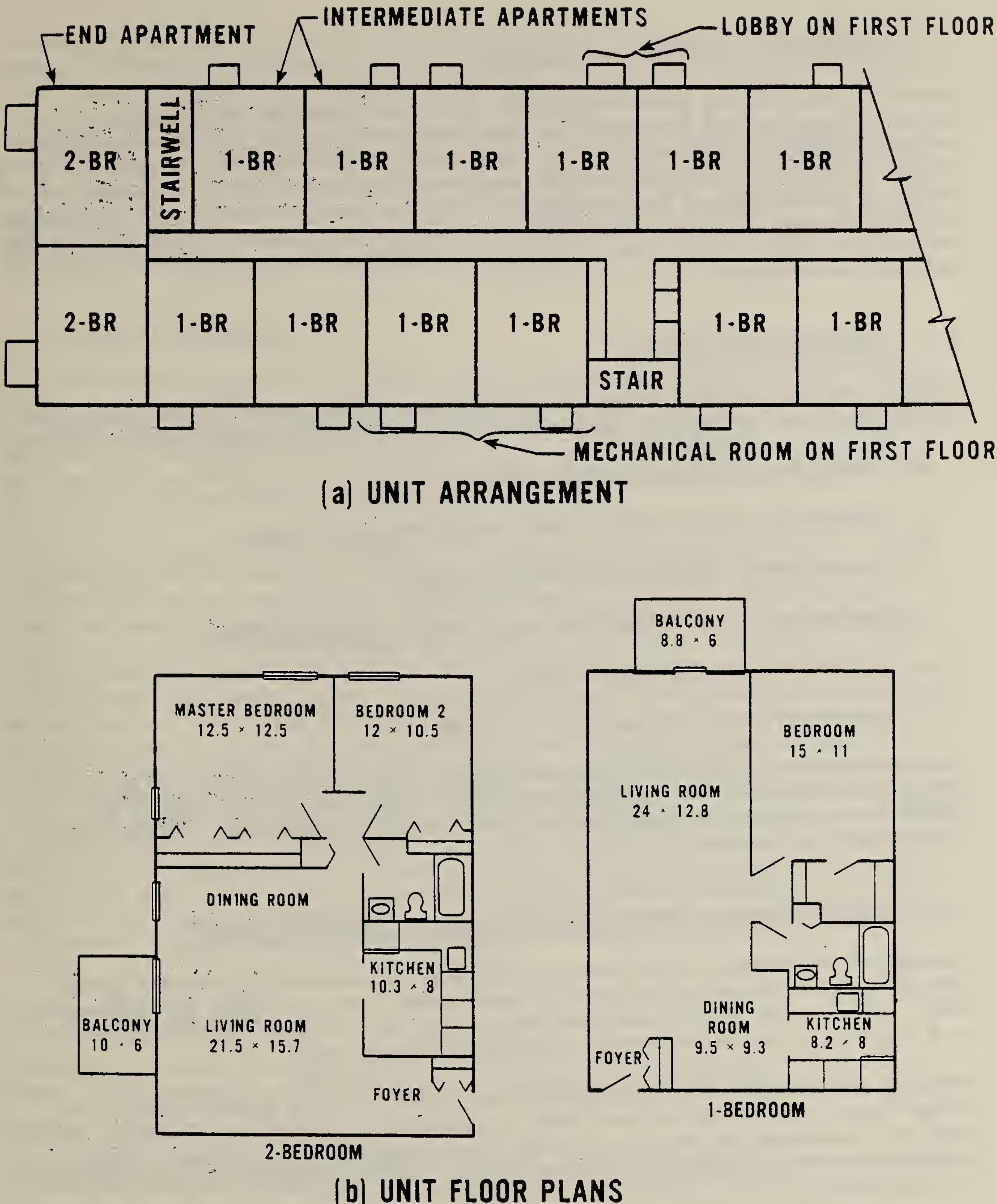

Figure 4. Floor plan of characteristic high-rise apartment [16].

4. DESCRIPTION OF EXPOSED POPULATIONS

Once information has been compiled on the noise emission characteristics and market saturation of a consumer product and sound levels have been predicted at the listener location(s), it is necessary to have further information in order to predict the impact of the product on the population. Exposure patterns of sub-groups of the population, for each product class, and the number of people potentially in each sub-group must be determined. This section discusses the type of available information on population groupings and product utilization patterns.

4.1. POPULATION SUB-GROUPS

For the purpose of this study, the population of the United States was classified into six categories based upon time utilization. These categories are:

- adult male employed outside the home,
- unemployed adult male or adult male working at home,
- adult female employed outside the home,
- unemployed adult female or adult female working at home,
- school-age or day care child,
- preschool child at home.

These particular groups were chosen because, in terms of time utilization, they each show their own distinct patterns. (The model could easily be modified to utilize other groupings than these and other time periods than those described below.)

4.2. TIME UTILIZATION OF POTENTIALLY EXPOSED POPULATION GROUPS

A detailed break-down of the time utilization of potentially exposed population groups, in terms of consumer product usage, was not found in the literature. This is not merely our conclusion, but that reached by other authors in a report to the Environmental Protection Agency [12].

There is information in the literature as to how certain groups of persons divide their time among certain broad categories of activities (some of these data are presented in Tables 5-7 along with references as to their origin). Based on the data contained in these tables, certain behavioral patterns may be inferred.

A limited amount of data was found in the literature for some groups of people which show either when people are at home and during what hours (see Fig. 5 [19]) or for how many hours/day they are at home (see Table 8 [20]). This information was used to examine time utilization patterns for some population groups. However, the data do not cover all of the potentially exposed population groups in sufficient detail for the purposes of this study.*

Another type of time utilization datum which may aid in making inferences about persons, other than the primary operator, who are exposed to household product noise, is the distribution of time for household obligations for certain categories of people as a function of their social contacts. The distribution for four different groups of adults is shown in Table 9, where the results of different surveys [19] are summarized.

4.3 PRODUCT UTILIZATION

The information available on product utilization is, at best, scarce. Table 10 gives a list of the household products under consideration in this study, and identifies those for which usage information is available. The primary exposure for each appliance is given in Table 11. This table was, for the most part, obtained from a study conducted by Bolt Beranek and Newman in 1976 for the U. S. Environmental Protection Agency [12].

The major problem in developing data on exposure time is the scarity of usage information and the fact that which is available is usually incomplete. For example, one study states that a vacuum cleaner is used an average of 2-3 times per week in the home [20]. However, no data were found on the average amount of time the vacuum cleaner is operated when in use. Likewise, for a clothes washer, several sources [21,22] state that 8-10 loads/week/home is the average number of loads washed. The average time of the entire wash cycle can be calculated. Yet, from this information there is no way to determine how long the operator is in the same room with the machine and thus primarily exposed to its noise and how long the person is subjected to secondary exposure. Likewise, since there are no data regarding the time of day when a particular appliance is likely to be used, it is virtually impossible to estimate how many people may be subjected to its noise as bystanders (e.g., in another room or in an adjacent dwelling unit), what activities they may be engaged in during the time the product is operating (sleep, speech, watching TV, etc.), and for how long. Such information is required, however, to assess the overall impact of noise from consumer products.

4.4 INFORMATION GAPS

In summary, information gaps exist in both the time and product utilization areas. With regard to time utilization, the main problems are that the data

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* Subsequent to writing this report, another publication was located on time utilization of Americans. In this report a survey method was used that is similar to that used and reported earlier in Ref. 2. Further, its results help to substantiate the results of the earlier study. The results of the later study are summarized in Robinson, John P., How Americans Use Time (MacMillan, New York, New York, 1977).

do not cover all of the potentially exposed population groups and that the activity categories considered are so broad that it is not possible to know, in sufficient detail, how people actually use their time. Second, data for computing exposure to appliance noise are, for all practical purposes, nonexistent. The unverified information available is generally not suitable; consequently many assumptions must be relied upon.

Table 5. Percentage of employed men engaged in various activities at given times during a 24-hour period. (Survey made in Jackson, Michigan, in 1965 [19]).

Time of Day	Percentage Engaged in							
	Sleep	Eat	Work	Travel	Home and Family	Leisure	Mass Media	TV
00:00	73	0	11	5	1	4	1	5
01:00	79	2	9	1	1	3	0	5
02:00	88	0	5	0	0	6	0	1
03:00	90	2	6	0	0	1	1	0
04:00	92	0	6	0	0	2	0	0
05:00	91	0	7	0	0	2	0	0
06:00	68	7	9	1	1	12	1	1
07:00	38	9	23	12	4	12	1	1
08:00	14	14	45	8	5	12	1	1
09:00	13	5	70	1	2	6	2	1
10:00	10	3	69	1	7	8	0	2
11:00	5	3	71	2	8	7	2	2
12:00	4	19	55	5	6	7	2	2
13:00	5	11	60	6	7	7	2	2
14:00	6	5	70	3	5	7	1	3
15:00	3	4	71	7	6	6	1	2
16:00	1	1	60	12	8	13	3	2
17:00	2	7	46	13	7	15	7	3
18:00	2	18	29	10	10	12	10	9
19:00	2	12	23	10	11	12	12	18
20:00	3	7	20	6	10	17	12	25
21:00	6	3	21	3	9	18	10	30
22:00	12	1	22	7	3	15	7	33
23:00	38	0	15	3	3	10	5	26

Table 6. Percentage of employed women engaged in various activities at given times during a 24-hour period. (Survey made in Jackson, Michigan, in 1965 [19]).

Time of Day	Percentage Engaged in							
	Sleep	Eat	Work	Travel	Home and Family	Leisure	Media	TV
00:00	84	2	0	3	3	3	5	0
01:00	92	2	0	2	2	1	1	0
02:00	97	1	0	0	1	0	1	0
03:00	97	1	0	0	1	0	1	0
04:00	95	1	2	0	2	0	0	0
05:00	92	1	1	0	1	3	1	1
06:00	59	3	3	0	4	29	2	0
07:00	30	7	25	0	20	18	0	0
08:00	10	8	32	21	12	15	0	2
09:00	7	2	63	5	12	9	1	1
10:00	4	0	69	6	10	9	1	1
11:00	3	1	72	9	4	7	2	2
12:00	2	26	49	5	9	6	2	1
13:00	2	10	60	9	12	5	1	1
14:00	2	8	62	7	12	4	0	5
15:00	2	1	68	9	12	5	1	2
16:00	2	0	51	12	18	13	2	2
17:00	0	4	36	13	23	18	3	3
18:00	1	17	13	16	35	11	5	2
19:00	1	17	10	6	26	18	12	10
20:00	2	5	10	7	32	16	16	12
21:00	3	0	7	9	32	24	8	17
22:00	16	2	3	8	16	24	12	19
23:00	40	0	1	8	10	20	11	10

Table 7. Percentage of housewives engaged in various activities at given times during a 24-hour period. (Survey made in Jackson, Michigan, in 1965 [19]).

Time of Day	Percentage Engaged in							
	Sleep	Eat	Work	Travel	Home and Family	Leisure	Mass Media	TV
00:00	85	0	-	0	4	4	3	4
01:00	91	0	-	0	1	4	2	2
02:00	96	0	-	0	1	1	0	2
03:00	96	0	-	0	1	2	0	1
04:00	95	0	-	0	3	2	0	0
05:00	88	0	-	0	9	2	0	1
06:00	71	4	-	0	15	8	1	1
07:00	55	5	-	0	28	10	1	1
08:00	27	11	-	2	34	23	2	1
09:00	10	9	-	2	60	15	2	2
10:00	2	3	-	5	58	23	7	2
11:00	0	2	-	7	62	20	8	1
12:00	0	13	-	8	58	14	5	2
13:00	2	11	-	8	48	21	3	7
14:00	5	5	-	5	53	14	7	11
15:00	5	3	-	10	48	22	4	8
16:00	1	4	-	9	47	23	9	7
17:00	2	9	-	8	58	9	10	4
18:00	0	17	-	8	46	11	7	11
19:00	0	11	-	8	42	12	10	17
20:00	0	4	-	9	30	24	12	21
21:00	2	2	-	5	26	25	10	30
22:00	10	2	-	5	15	28	9	31
23:00	43	3	-	0	8	14	4	28

Table 8. Percentage of time children spend at home by mother's employment [20].

Hours Spent	Mother Employed		Mother Not Employed	
	Children aged 6-11 yrs.	Children aged 12-17 yrs.	Children aged 6-11 yrs.	Children aged 12-17 yrs.
16-24	79%	58%	84%	64%
7-15	20%	40%	16%	32%
<7	1%	2%	--	4%

Table 9. Distribution of time spent on household obligations, according to different social contacts a/ [19].

Percentage distribution of daily time b/

	Forty-four Cities, U.S.A.	Jackson, Michigan
A. Single men		
total minutes = 100%	52.1 min	62.0 min
alone	43.0%	43.3%
with spouse (fiancee)	2.7	1.0
with other members of households	13.6	21.0
with friends and neighbords	16.7	24.2
with work colleagues	0.8	0.5
with others	23.2	10.0
B. Married men		
total minutes = 100%	68.8 min	79.2 min
alone	36.5%	43.3%
with spouse	12.2	11.4
with other members of household	33.1	23.2
with friends and neighbors	9.7	7.1
with work colleagues	0.0	0.1
with others	8.5	14.9
C. Employed married women		
total minutes = 100%	223.9 min	216.5 min
alone	59.0%	49.6%
with spouse	9.6	9.5
with other members of household	25.1	27.1
with friends and neighbors	5.8	8.5
with work colleagues	0.2	0.9
with others	0.3	4.4
D. Married housewives		
total minutes = 100%	358.1 min	350.3 min
alone	55.2%	55.3%
with spouse	6.8	5.7
with other members of household	26.8	29.0
with friends and neighbors	6.4	6.9
with others	4.8	3.1

a/ Data are weighted to ensure equality of days of the week and number of eligible respondents per household.

b/ The data may total more than 100% because of overlapping categories in case of simultaneous presence of several family members.

Table 10. Usage data currently available on household and consumer products.

Product	Usage Data Available
FOOD PREPARATION/DISPOSAL	
Blender	Yes [13]
Electric mixer	Yes [13]
Coffee grinder	Yes [13]
Ice crusher	No
Electric knife	Yes [13]
Slicer	No
Can opener/knife sharpener	Yes [13]
Garbage disposer	Yes [13]
Dishwasher	Yes [12]
Trash compactor	No
PERSONAL HYGIENE/GROOMING	
Oral hygiene device	Yes [13]
Hair dryer/blower	Yes [13]
Electric razor	Yes [13]
Electric hair clipper	No
CLIMATE/ENVIRONMENTAL CONTROL	
Exhaust fan, range hood	Yes [13]
Central heat/air conditioning	No
Room air conditioner	Yes [13]
Humidifier	Yes [13]
Dehumidifier	Yes [13]
Electric fan	Yes [13]
Electric air cleaner	No
Heater	No
Space heater	Yes [13]
INDOOR MAINTENANCE	
Vacuum cleaner	Yes [13]
Rug cleaner/floor waxer	Yes [22]
Floor scrubber	Yes [22]
CRAFTS, HOBBIES, NON-WORKSHOP TOOLS	
Sewing machine	Yes [13]
Electric typewriter	No
LAUNDRY EQUIPMENT	
Washing machine	Yes [13]
Clothes dryer	Yes [13]
LAWN AND GARDEN CARE AND MAINTENANCE	
Powered lawn mower	Yes [13]
Edger/trimmer/grass shears	Yes [13]
Chain saw	Yes [13]
Incinerator	No
Lawn thatcher	No
Weed eater	No
Leaf blower	Yes [13]
Leaf sweeper/mulcher/shredder	Yes [13]
Rotor tiller	Yes [13]

Product	Usage Data Available
Snow blower	Yes [13]
Hedge trimmer	Yes [13]
Garden tractor	No
HOME WORKSHOP TOOLS	
Power shears	No
Sabre saw	Yes [13]
Pneumatic power chisel	No
Circular saw	Yes [13]
Abrasive cut-off machine	No
Radial arm saw	Yes [13]
Table saw	No
Power hacksaw	No
Scroll saw	No
Band saw	No
Reciprocating saw	No
Motorized mitre box	No
Router	No
Lathe	No
Shapers	No
Drill press	No
Portable electric drill	Yes [13]
Impact drill	No
Pneumatic air drill	No
Nail gun	No
Electric staple gun	No
Pneumatic chipping hammer	No
Belt sander	No
Pneumatic sander	No
Vibration sander	No
Sander/polisher	No
Disc sander	Yes [13]
Planer/jointer	No
Sand blaster	No
Grinder	No
Saw blade sharpener	No
Drill bit sharpener	No
Impact wrench	No
Molder	No
Air compressor	No
Power generator	Yes [13]
Motor	No
Shop vacuum	No
Chipper cleaner	No
Paint sprayer	No
Spray gun	No

Table 11. Presumed or potential primary exposure (in hours) for a variety of consumer products. [12]

Appliances	Presumed or Potential Primary Exposure (Hours of Use per day)
1. FOOD PREPARATION, DISPOSAL, STORAGE	
a. Mixing, straining, crushing	
Blender	0.25
Food mixer	0.25
Coffee grinder	0.25
b. Cutting, slicing	
Electric knife	0.1
c. Opening	
Electric can opener	0.02
d. Clean up/disposal	
Garbage disposer	0.1
Dishwasher	0.7
2. PERSONAL HYGIENE/GROOMING	
Hair dryers/blowers	0.3
Electric razor	0.1
Oral hygiene devices	
Electric toothbrush	0.1
Dental irrigator	0.5
3. CLIMATE AND ENVIRONMENTAL CONTROL	
Exhaust fan	1.5
Room air conditioner	6.0
Humidifier	6.0
Dehumidifier	6.0
Electric window and floor fans	12.0
Space heater	6.0
4. INDOOR MAINTENANCE	
Vacuum cleaner	0.2
Rug cleaner/floor waxer	--
Floor scrubber	--
5. CRAFTS, HOBBIES, NON-WORKSHOP TOOLS	
Sewing machine	0.5
6. LAUNDRY EQUIPMENT	
Clothes washer	1.0
Clothes dryer	1.0
7. LAWN AND GARDEN CARE AND MAINTENANCE	
Electric lawn mower	0.1
Gasoline-powered lawn mower	0.1
Riding mower	0.1
Electric edger/trimmer	0.05

Lawn edger	0.05
Chain saw	0.05
Leaf blower	0.05
Shredder	0.05
Rotor tiller	0.05
Snow blower	0.02
Hedge clippers	0.05
8. HOME WORKSHOP TOOLS	
a. Cutting	
Sabre saw	0.02
Circular saw	0.02
Radial saw	0.02
b. Drilling	
Portable drill	0.02
c. Sanding	
Sander	0.02
d. Power generating	
Generator	0.25

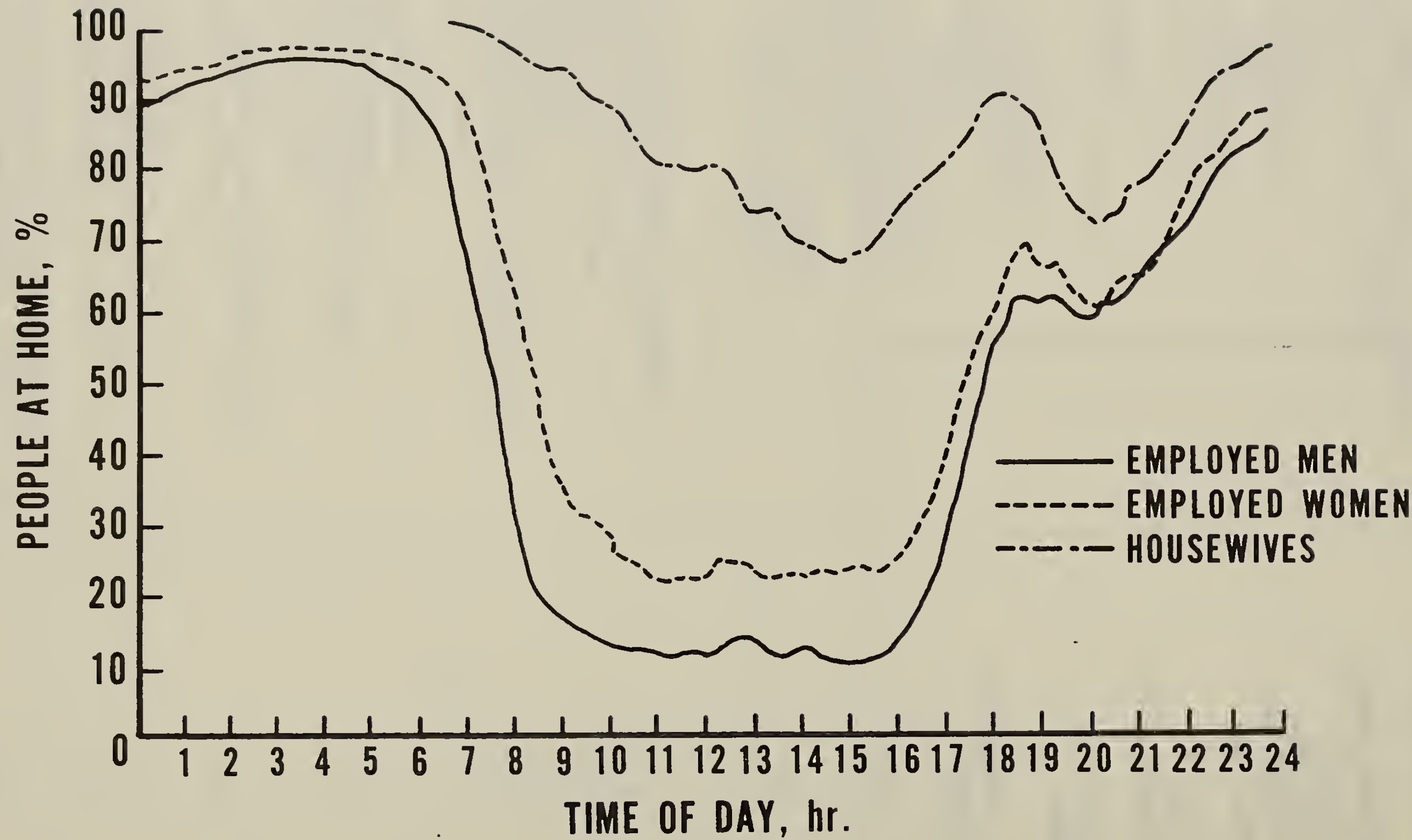

Figure 5. Percentage of people being at home during various periods throughout the day [19].

5. CRITERIA USED TO ASSESS NOISE IMPACT FROM CONSUMER PRODUCTS ON PUBLIC HEALTH AND WELFARE

People react to noise in a complex manner which depends both on the physical nature of the noise and on less well-defined psychological and sociological factors. The problem is further complicated by the fact that, for any given socio-economic level, each individual may react differently to the same noise environment. For this reason what are sought, and have been for many years, are "single-figure ratings" of the noise environment which can be used to predict, with a reasonable degree of certainty, the average response of groups of people. This is not to say that individuals have the same susceptibility to noise; they do not. Even different groups of people may vary in response, depending upon previous exposure, age, socio-economic status, political cohesiveness, and other psycho-social variables. However, at the present time the state-of-the-art is such that these individual differences cannot be predicted *a priori*.

Once the "average response" is known, a "population impact" can be derived from a knowledge of the number of people subjected to various noise exposures. By population impact is meant some metric that includes considerations of how many people are impacted and how severely.

In order to compare the effects on the public health and welfare of noise emission from various products or the consequences of regulatory actions, it is desirable to derive a single number descriptor of the impact of the noise relative to each effect of concern. In doing so, certain assumptions are usually made which are often not explicit in spite of the fact that they may have significant implications. Usually the assumptions behind such analyses are:

- that the intensity of the human response to the physical characteristics of the noise is a function of the sound pressure level and the time of exposure, whether this response is expressed in terms of hearing loss, speech interference, or the general adverse response.

- that the impact of high noise levels on a small number of individuals can be statistically treated as being "equivalent" to the impact of moderate noise levels on a large number of people. Accordingly, the Accordingly, the properties of extent and intensity can be combined through some mathematical function.

Once such a function is defined, a "partial" impact can be assigned to each segment of the population subjected to a specific yearly exposure level. Once the various degrees of impact have been identified, the total impact may be taken as the summation of these partial impacts. Specifically, a "Weighted Population," WP(k), is defined as

$$WP(k) = \sum_{i}^{N} W_i(k) P_i \quad , \qquad (5.1)$$

where

P_i = the sub-population subjected to the i-th level of yearly exposure,

$W_i(k)$ = a weighting factor derived from a function describing the cause-effect relationship for the k-th effect (e.g., hearing loss, speech interference, etc.) for the i-th level of yearly exposure,

and the summation is taken over the N sub-populations potentially exposed to the noise emission from various classes of products.

Implicit in such analyses is the assumption that, for instance, a 10 dB threshold shift in X people is equivalent to a 20 dB hearing threshold shift in only Y people, where Y is significantly smaller than X. However, the individual effect of a hearing threshold shift may be quite different, depending on the original threshold of the person experiencing the shift. Thus a 10 dB shift occurring in a person who has already incurred a severe loss may be devastating, while a 10 dB shift occurring in a person who has "good" hearing may be barely noticeable.

As additional data on the relative impacts on public health and welfare of various noise exposures become available, it may be necessary to refine the various relationships used to combine the properties of intensity and extent.

The impact of product noise upon the public health and welfare can only be assessed with respect to those responses for which cause-effect relationships are relatively well-defined. Accordingly, in this report, attention is directed to the following human responses:

- physiological response, which in study is treated as synonymous with hearing damage (owing to lack of well-defined criteria regarding extra-auditory physiological effects),

- the general adverse response to noise, often referred to as annoyance, which itself may result from a combination of several factors including speech interference, sleep interference, desire for a quiet environment, and the ability to use TV, telephone and radio satisfactorily,

- speech communication;

- sleep interference.

In the model used in the present report, the Weighted Population, WP(k), as defined in Eq. (5.1), is computed using several cause-effect relationships for the responses listed above. In addition, in order to compare the relative impact of one noise exposure to another, it is convenient to define the Noise Impact Index, NII(k), an average degree of impact for the defined population group, defined mathematically as:

$$NII(k) = \frac{WP(k)}{PR} \quad , \qquad (5.2)$$

where

PR = the unweighted population at risk, i.e., the number of people that could potentially be exposed to the noise emitted by a particular class of products.

Several weighting factors, $W_i(k)$ are available. These are described below.

5.1 CRITERIA FOR HEARING DAMAGE RISK

The EPA Levels Document [23] identifies an A-weighted equivalent level (LEQ) of 70 dB averaged over a 24-hour period on a long-term basis as the level below which no risk to hearing exists for virtually the entire population.* This level represents a yearly average level. Above this level a potential risk to hearing could exist. This risk is normally expressed in terms of noise-induced permanent threshold shift (NIPTS) that is predicted for various segments of the population over an exposure of 40 years.

Generally speaking, the risk to hearing accelerates rapidly as the noise exposure increases above an LEQ level of 70 dB (the EPA criterion level). Table C-1 of the EPA Levels Document shows the change in hearing threshold that may be expected for an average of four audiometric frequencies (.5, 1, 2, and 4 kHz) and at 4 kHz as a function of exposure level for various segments of the population. These data are presented in Figure 6 in terms of the average over the total population for 4 kHz and for the average of the 4 audiometric frequencies.

The EPA Levels Document thus provides a useful measure for assessing hearing risk for noise exposures that are above the identified criterion level. However, inherent in the EPA criterion is the assumption that the A-weighted sound pressure level provides an adequate means of assessing noise impact with respect to its potential to produce hearing damage. Although the A-weighted level is widely accepted as an adequate way of weighting noise spectra with respect to hearing damage, most of the data upon which various damage risk criteria rest are based upon studies of populations exposed to industrial noises.

Industrial noises by and large tend to have spectra that display little acoustic energy in the high frequency region. While many consumer products, such as lawn mowers and clothes washers, have spectra similar to industrial spectra, many others do not. For example, electric shavers, blenders and some other products have significant amounts of energy in the 2-4 kHz region where the ear is most sensitive.

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* For consistency the notation "LEQ" rather than the more common "L_{eq}" is used in this report since the computer printer cannot handle lower case letters.

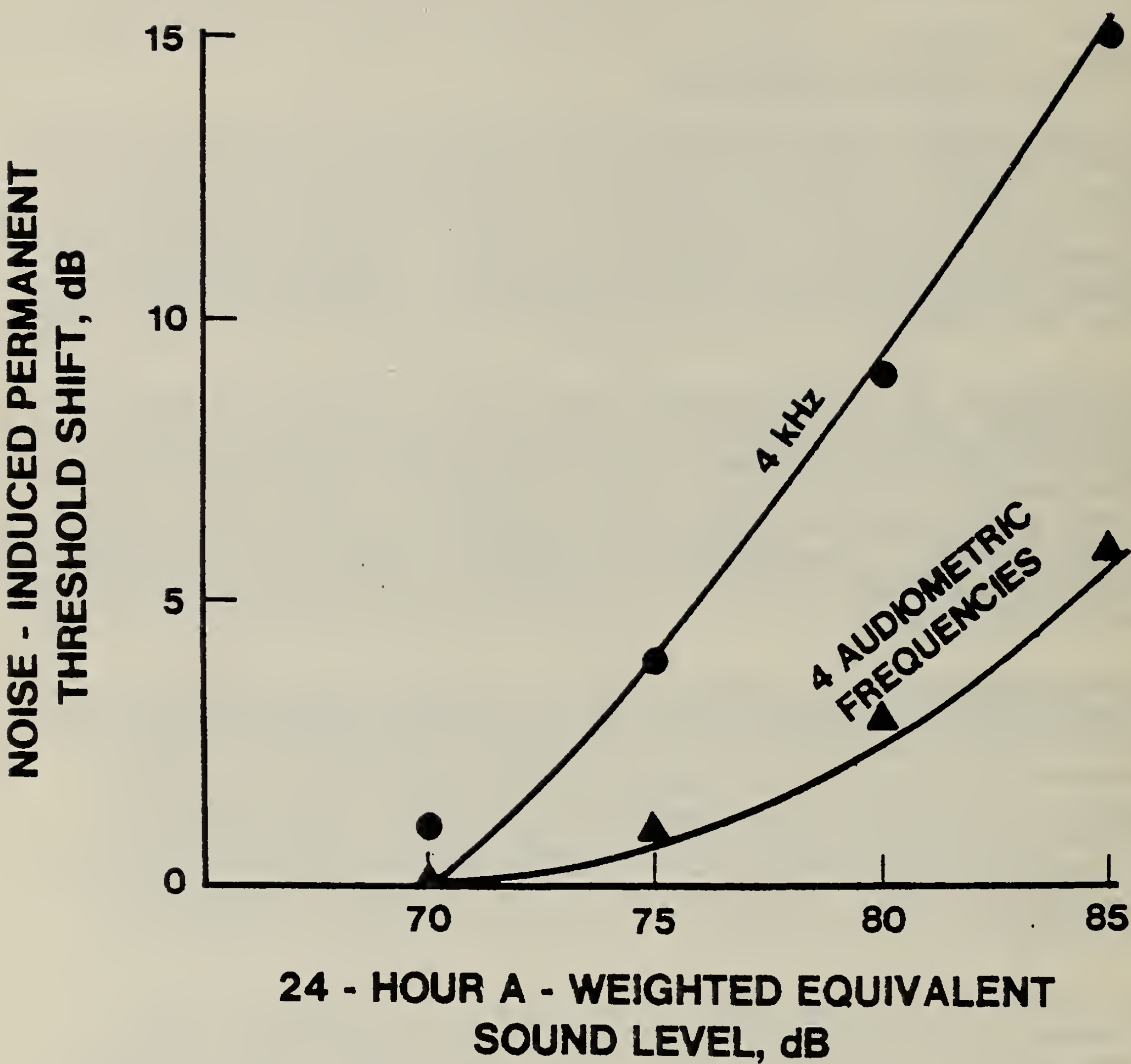

Figure 6. Average noise-induced permanent threshold shift expected as a function of the continuous A-weighted equivalent sound level. The data points are from the EPA Levels Document [23]. The lower curve corresponds to Eq. (5.4) while the upper curve is for Eq. (5.5).

Miller [24] reports that studies of temporary threshold shift (TTS) show that noises with concentrations of energy in the 2-4 kHz region produce greater TTS than noises concentrated elsewhere in the audible range. He also notes that people differ in their susceptibility to TTS and that these susceptibilities are not uniform across the audio frequency range. Thus, some people are especially sensitive to high frequencies while others are especially sen-ensitive to low frequencies. Although there is some controversy regarding the ability of TTS to predict NIPTS, the possibility does exist that "measurements on the A-weighting scale may underestimate hazard to hearing" [25] for those noises that either contain a large amount of energy in the high frequency region or else have strong tonal components. For this reason, the possibility should be considered that the A-weighted level may not be sensitive enough to assess the risk to hearing associated with those products that either contain a significant amount of energy in the high frequency region or else have strong tonal components.

Until additional research data become available, however, there is no choice but to base the analyses developed in this study on an A-weighted level, provided it is recognized that the risk to hearing may be underestimated in certain instances.

Also inherent in the EPA criterion is the use of the "equal energy" concept, wherein doubling the time of exposure at a given sound level is equivalent to holding the time of exposure constant but increasing the sound level by 3 dB. There is ongoing controversy over the best way to account for time-varying noise exposure. If a different procedure were selected, the impact assessment model could be modified accordingly.

In this report hearing damage risk due to noise from consumer products is evaluated in three ways, each using as a basis the criterion level and a method derived from the information contained in the EPA Levels Document.

5.1.1. Fractional Exposure

To account for the fact that most noise exposures are not steady but vary with time, the Levels Document recommended that hearing damage risk be evaluated in terms of the whole time-varying pattern of sound levels. Accordingly, in the EPA document, an equivalent sound level (LEQ) was defined and used to arrive at the criterion level which assesses hearing damage risk from environmental noise.

The level identified by the Environmental Protection Agency, when combined with the equal energy hypothesis which states that equal amounts of acoustic energy will cause equal amounts of noise-induced hearing damage, provides a convenient way of comparing the exposures of people to different noise levels and durations. This is done by comparing the exposure time due to the operation of a given product to the allowable safe exposure of an individual exposed to a steady state noise for 24 hours at the criterion level. (For an example of the use of a similar concept, see Reference 26.) The reference level is an A-weighted level of 70 dB; thus an exposure to a steady level of 70 dB for 24 hours would have a fractional exposure of 1.0.

Similarly an exposure to a level of 73 dB for 12 hours would yield a fractional exposure of 1.0, as would an exposure lasting 6 hours at 76 dB. What this means practically is that an exposure of 6 hours to a level of 76 dB uses up 100 percent of the daily allowable dose, as would an exposure of 12 hours to 73 dB.

Since the criterion level identified by EPA represents the safe level of exposure and is computed on a yearly basis, the equivalent level for a product must also be computed on a yearly basis and take into account the length of each exposure and the number of exposures that occur during the whole year.

The weighting factor (see Eq. (5.1) and accompanying text) for computing the fractional exposure is defined by:

$$W_i(1) = \begin{cases} 10^{(LEQ_i - 70)/10} & , LEQ_i < 70 \text{ dB} \\ 1 & , LEQ_i \geq 70 \text{ dB} \end{cases} \quad , \qquad (5.3)$$

where LEQ_i represents the yearly average level for the i-th sub-population due to the noise from the product of concern. The resulting value for $W_i(1)$ is to be substituted into Eq. (5.1) in order to obtain the corresponding weighted population.

Whenever the fractional exposure exceeds 1.0 a potential impact on hearing exists since 100 percent of the daily dose has been used. However, when a fractional exposure is less than 1.0 it may not have a direct impact upon hearing but a certain amount of the allowable daily dose is consumed, thereby decreasing the remaining amount of exposure allowed for the rest of the day. A combination of exposures, each less than 1.0, may result in a combined equivalent sound level greater than 70 dB and thus present a hearing damage risk (see Section 5.1.2).

For example, suppose a person operates a home tool that produces an A-weighted level of 90 dB at the ear of the operator for 2 hours a day, 25 days per year. Then, the yearly equivalent level <u>for the tool alone</u> is given by:

$$LEQ = 90 + 10 \log \frac{2 \times 25}{24 \times 365} = 67.6 \text{ dB}.$$

A <u>priori</u> the tool would appear to be safe. However, another way to look at the risk involved is to consider, from Eq. (5.3), that use of this tool for only 2 hours a day, 25 days a year, consumes 57% of the allowable daily dose on an energy basis leaving, therefore, little room for other exposures.

An alternative way to approach this problem is to use the concept of an equivalent daily exposure time (cf. Reference 26), and multiply $W_i(1)$, as defined above, by 1440, the number of minutes in a day. Thus in the example above, the use of this product, as described, is equivalent to exposure to a sound level of 70 dB for (0.57 x 1440 =) 821 minutes per day, on each day of the year.

5.1.2. Potential Hearing Damage for Products That Exceed The Allowable Exposure Time

For those products that produce high noise levels and are used for prolonged periods of time; the fractional exposure time is likely to exceed unity -- that is the dose used by exposure to these products may exceed 100 per cent and thus a risk of hearing damage may exist. In such cases, the potential degradation in hearing acuity is to be assessed.

In the present impact assessment model, two different weighting functions are available to examine potential hearing damage. The first of these, corresponding to the lower curve in Figure 6, is the equation developed for this purpose by the NAS-NRC Committee on Hearing, Acoustics, and Bioacoustics (CHABA), Working Group 69 [27]. This weighting function represents the average threshold shift for 4 audiometric frequencies (i.e., 0.5, 1, 2, and 4 kHz). It is the mean value for the entire exposed population. Accordingly, this weighting function cannot be used to predict the threshold shift that would occur at a particular frequency, in a particular individual and at a particular time.

In the nomenclature of the present report, the weighting function for the average NIPTS for the 4 audiometric frequencies is given by the expression*:

$$W_i(2) = \begin{cases} 0.025(LEQ_i - 70)^2 & , \quad LEQ_i > 70 \text{ dB} \\ 0 & , \quad LEQ_i \leq 70 \text{ dB.} \end{cases} \tag{5.4}$$

This weighting factor represents the average NIPTS over a 40-year period for the i-th subpopulation. As in the previous case, and for the remaining responses to be considered, the value derived from Eq. (5.4) is the weighting factor to be used in Eq. (5.1)

Since in the 4-kHz region the ear is very susceptible to noise-induced hearing loss, the hearing level at 4 kHz is an early indication of potential loss of hearing acuity. Accordingly, another weighting factor has been derived, based upon the data given in Table C-1 of the EPA Levels Document [23] for the average hearing loss at 4 kHz. These data are well approximated by the upper curve in Figure 6, which corresponds to

$$W_i(3) = \begin{cases} 0.6(LEQ_i - 70)^{1.2} & , \quad LEQ_i > 70 \text{ dB} \\ 0 & , \quad LEQ_i \leq 70 \text{ dB.} \end{cases} \tag{5.5}$$

Again the weighting factor represents the expected average NIPTS (at 4 kHz) over a 40-year period for the i-th subpopulation.

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* In the CHABA document [29], the yearly average level is approximated by the yearly day-night average sound level.

5.2. GENERAL ADVERSE RESPONSE

The EPA Levels Document [23] defines the general adverse response to noise as a combination of responses to several factors such as speech interference, sleep interference, the desire for a quiet environment, and the ability to use TV, telephone, and radio satisfactorily. General adverse response is frequently expressed in terms of the percentage of the population that would be expected to express a high degree of annoyance, in a social survey, as a result of a specific exposure level. Since people differ significantly in their responses to noise, only the average responses for groups of people can be considered.

As was shown in EPA documents [23-25], the magnitude of this general adverse response is stable and can be related to a cumulative measure of noise, such as the A-weighted day-night average level (LDN). For this reason this basic metric is used in the present document to assess, in terms of the general adverse response, noise impact to be expected from consumer products.

The Levels Document further specifies that for noise exposures not exceeding a yearly LDN of 55 dB outdoors and 45 dB indoors, no significant effects occur. These levels are used in the present report to define safe limits for assessing the general adverse response. Above these levels noise becomes a factor that may lead to a generalized adverse response, the magnitude of which must be assessed both in terms of its severity and extent (i.e., number of people affected).

As noted in Section 3.1, in many instances people are located at different places relative to a noise source. They may either be at different locations within the source room, or in different rooms, or indoors relative to an outdoor source. Consequently, in computing the level at a listener's position it is necessary to account for either indoor-to-indoor isolation, or, for sources located outdoors, outdoor-to-indoor isolation.

Even within a given room the levels may vary from one location to another, depending on whether the listener is in the near field or the reverberant field of the source. Procedures for computing sound levels at listeners' locations have been described in Section 3.1.

Thus for each source several levels of exposure must be computed, each corresponding to locations of listeners.

Recently EPA has used the fractional impact methodology in which the intensity of the general adverse response to a given noise exposure is expressed in terms of the Fractional Impact [3, 28-30], which is analogous to the weighting factors used in the present report; specifically:

$$W_i(6) = \begin{cases} 0.05(LDN_i - 55), & LDN_i > 55 \text{ dB} \\ 0, & LDN_i \leq 55 \text{ dB} \end{cases} \quad (5.6)$$

where

LDN_i = the i-th (A-weighted) yearly day-night average sound level.

More recently, the functional relationship between general adverse response and noise exposure has been further refined [27,31]. This function, arbitrarily normalized to unity at 75 dB for evaluation of population impact, is shown in Figure 7. This weighting factor has been expressed [27] as:

$$W_i(4) = \frac{3.36 \times 10^{-6} \left(10^{0.103 LDN_i}\right)}{0.2 \left(10^{0.03 LDN_i}\right) + 1.43 \times 10^{-4} \left(10^{0.08 LDN_i}\right)} . \qquad (5.7)$$

Since the function represented by Eq. (5.7) was derived from studies of outdoor environmental noise, for sources that are located outdoors the function is used as given. For sources that are located indoors, it may be appropriate for the function to be shifted by 15 decibels to account for the "typical" outdoor-to-indoor noise isolation. This value is based upon current but scare knowledge regarding noise isolation; accordingly, as more data become available regarding outdoor-to-indoor noise isolation provided by various building envelopes there may be a need to revise the value used in this report. It follows, that in the above equation and for indoor sources the term LDN_i might be replaced by the term $(LDN_i + 15)$ such that the equation reads as follows:

$$W_i(5) = \frac{3.36 \times 10^{-6} \left(10^{0.103(LDN_i+15)}\right)}{0.2 \left(10^{0.03(LDN_i+15)}\right) + 1.43 \times 10^{-4} \left(10^{0.08(LDN_i+15)}\right)} . \qquad (5.8)$$

Other industrialized nations have also been concerned with the assessment of the population impact of noise. Alexandre and Barde [32] have proposed several additional weighting factors. In the computer program it was decided to incorporate three of these weighting factors, each expressed as a function of the (A-weighted) yearly day-night average sound level.

The first of these, in the present nomenclature, is

$$W_i(7) = \begin{cases} 0.01\left[10^{(LDN_i - 55)/10} - 1\right] & , LDN_i > 55 \\ 0 & , LDN_i \leq 55 \end{cases} . \qquad (5.9)$$

This weighting factor varies for 0 to 1 as LDN goes from 55 to 75 dB. In this regard, the normalization is similar to that for Fractional Impact (i.e., W_i (6)). However, the growth of this weighting function parallels the growth of acoustical energy (i.e., similar to the growth for $W_i(1)$).

Another of Alexandre and Barde's weighting functions can be expressed as:

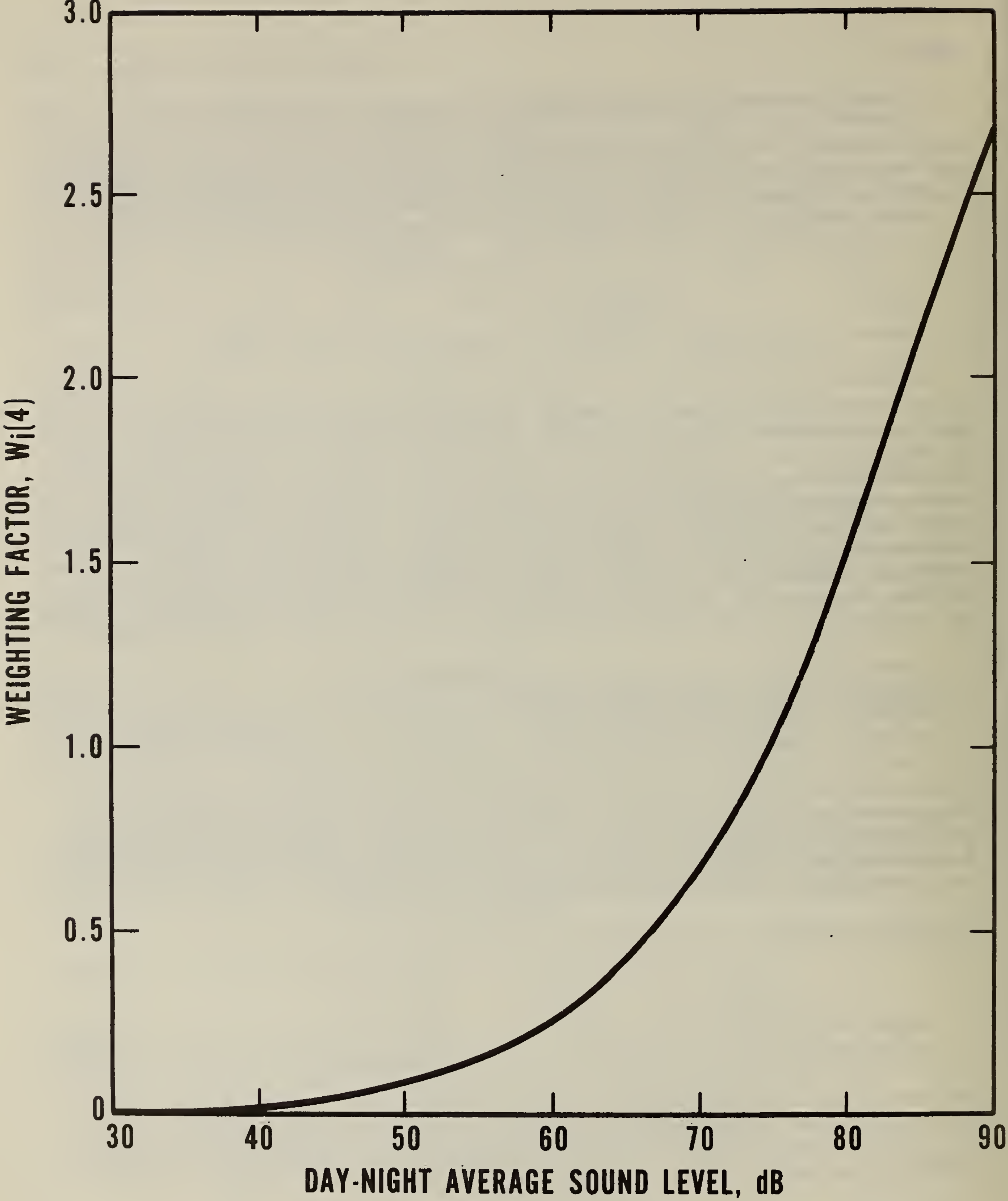

Figure 7. Weighting function for assessing the general adverse response to noise [27, 31].

$$W_i(8) = \begin{cases} \frac{1}{3}\left[2^{(LDN_i - 55)/10} - 1\right], & LDN_i > 55 \\ 0 & , LDN_i \le 55 \end{cases} \quad (5.10)$$

This function also is normalized to zero at 55 dB and unity at 75 dB. However, the function approximates the growth of loudness with increasing sound level.

The third of Alexandre and Barde's weighting functions included in the present model is:

$$W_i(9) = \begin{cases} 0.0125(LDN_i - 55) \times 2^{(LDN_i - 55)/10} & , LDN_i > 55 \\ 0 & , LDN_i \le 55 \end{cases} \quad (5.11)$$

This function lies between that derived on the basis of energy growth ($W_i(7)$) and that based on loudness growth ($W_i(8)$), hence, it is a compromise between these two functions.

The three weighting factors proposed by Alexandre and Barde are shown in Figure 8 as functions of day-night average level. Each of the relations developed by Alexandre and Barde can be used with Eqs. (5.1) and (5.2) to assess noise impact.

Although the day-night average level is probably a good predictor of general adverse response to noise, it uses as a basic metric the A-weighted level. Some questions have been raised as to the degree to which the A-weighted level accounts for either tonal components or significant variation in their spectral shapes. Accordingly, in the course of the development of this report, the question of the order in which different rating schemes would rank order products having either similar and/or significantly varied spectral shapes was investigated. The results of these investigations are described in Appendix C. Here, it is sufficient to say that:

(1) the A-, D-, and E- weighted levels agree well, both in terms of differentiating among products contained within a class and among products belonging to different classes.

(2) the complex schemes examined, including several loudness indices and perceived noise levels, do not appear to yield results that are very different from those obtained using the simple A-, D-, or E-weighted levels.*

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* These conclusions should be viewed with caution because of the limited quantity of data available and because it was not possible to conduct meaningful statistical tests of significance.

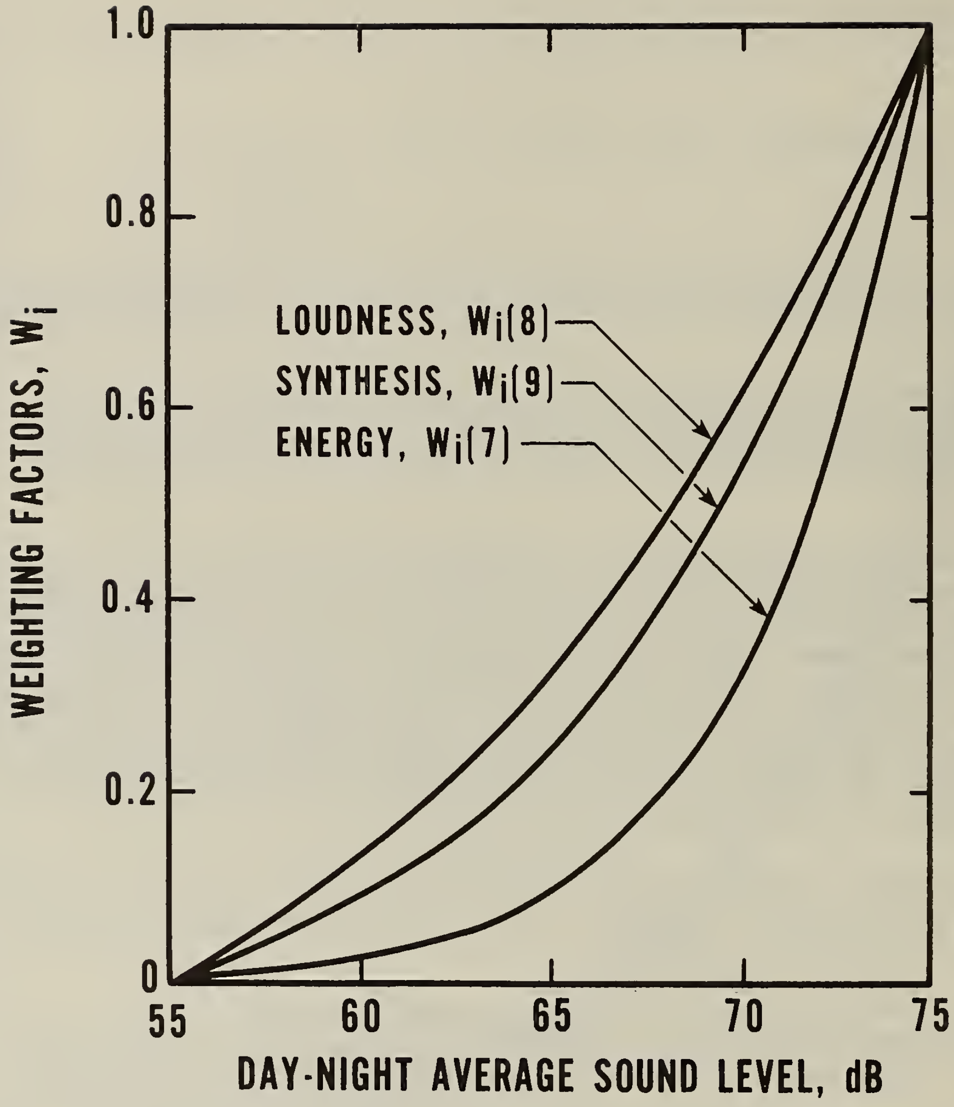

Figure 8. Weighting functions proposed by Alexandre and Barde [32].

For the sake of simplicity and consistency, the A-weighted level appears to be a reasonable choice for assessing consumer products. However, this conclusion is based on limited information and is therefore only tentative. For that reason, and because the application of A-weighted LDN to consumer products is questionable, a number of weighting functions based upon loudness or perceived noisiness have been incorporated into the model. These are summarized below. In computing the loudness or loudness level, in the impact assessment model, the yearly equivalent sound level for each frequency band of interest is computed and the appropriate frequency weighting is applied to these yearly average levels.

At present, two standardized procedures and one proposed procedure are available for computing loudness and loudness level (auditory magnitude) [33-35]. The Federal Aviation Administration has established [36] a procedure for computing perceived noisiness and perceived noise level (unwantedness/annoyance due to sound). One can hypothesize that the corresponding weighting functions should grow in a manner that is proportional to the growth of either loudness (noisiness) or of loudness level (perceived noise level). The weighting functions, shown below and derived using these hypotheses, have been arbitrarily normalized to unity for a sound having the same loudness level, or perceived noise level, as would a band of noise centered at 1 kHz presented at a sound pressure level, re 20 μPa, of 75 dB.

The weighting factors based upon these functions are:

$$W_i(11) = \begin{cases} (1/35)(LLMK6_i - 40) & , \quad LLMK6_i > 40 \text{ dB} \\ 0 & , \quad LLMK6_i \leq 40 \text{ dB} \end{cases} , \qquad (5.12)$$

where

$LLMK6_i$ = loudness level computed using the Stevens Mark VI procedure [33] for the i-th sub-population;

$$W_i(12) = \begin{cases} \frac{1}{11.31} \times 2^{(LLMK6_1 - 40)/10} & , \quad LLMK6_i > 40 \text{ dB} \\ 0 & \quad LLMK6_i \leq 40 \text{ dB} \end{cases} , \qquad (5.13)$$

where $LLMK6_i$ is as above.

$$W_i(13) = \begin{cases} \frac{1}{32}(LLMK7 - 32) & , \quad LLML7 > 32 \text{ dB} \\ 0 & , \quad LLMK7_i \leq 32 \text{ dB} \end{cases} , \qquad (5.14)$$

where

$LLMK7_i$ = loudness level computed using the Stevens Mark VII procedure [34], for the i-th sub-population;

$$W_i(14) = \begin{cases} \frac{1}{14.81} \times 2^{(LLMK7_i - 32)/9} , & LLMK7_i > 32 \text{ dB} \\ 0 , & LLMK7_i < 32 \text{ dB} , \end{cases} \quad (5.15)$$

where $LLMK7_i$ is as above;

$$W_i(15) = \begin{cases} \frac{1}{35} (LLZ_i - 40) , & LLZ_i > 40 \text{ dB} \\ 0 , & LLZ_i \leq 40 \text{ dB}, \end{cases} \quad (5.16)$$

where LLZ_i = loudness level, for diffuse field conditions, computed using the Zwicker procedure [35], for the i-th sub-population,

$$W_i(16) = \begin{cases} \frac{1}{11.31} \times 2^{(LLZ_i - 40)/10} , & LLZ_i > 40 \text{ dB} \\ 0 , & LLZ_i \leq 40 \text{ dB}, \end{cases} \quad (5.17)$$

where LLZ_i is as above;

$$W_i(17) = \begin{cases} \frac{1}{35} (PNL_i - 40) , & PNL_i > 40 \\ 0 , & PNL_i \leq 40, \end{cases} \quad (5.18)$$

where PNL_i = Perceived Noise Level, as defined in FAR-36 [36] but with no tone corrections included, for the i-th sub-population, and

$$W_i(18) = \begin{cases} \frac{1}{11.31} \times 2^{(PNL_i - 40)/10} , & PNL_i > 40 \text{ dB} \\ 0 , & PNL_i \leq 40 \text{ dB}, \end{cases} \quad (5.19)$$

where PNL_i is as above.

5.3 SPEECH INTERFERENCE

The general adverse response to noise reflects reactions against communications interference, but the effect of noise on speech communication needs to be addressed in its own right, independent of the general adverse response. Criteria for speech communication typically are based on three factors:

(1) vocal power, as a function of frequency and time, achieved by various speakers under various conditions;

(2) the degree of speech recognition for speech material of different degrees of difficulty in the presence of various types of noise;

(3) the definition of "acceptable" speech communication for both speaker and listener.

The EPA Levels Document has identified a criterion level for speech in terms of the A-weighted average sound level, for both indoor and outdoor situations. At an indoor level of 45 dB the intelligibility of speech is considered to be good enough for normal conversation. At or below this level it is considered that noise has little effect on ordinary speech communication. At higher levels, speech communication starts to deteriorate to a degree that is related to the intensity of the noise and the unfamiliarity of the speech material. In this report, the impact of the noise is assessed in terms of the speech unintelligibility. However, before a specific method is defined for assessing noise impact on speech communication, it is desirable to review the basic parameters on which speech criteria are built.

Speech can be analyzed into a finite number of speech sounds which differ from each other in terms of their total intensity, characteristics of buildup and decay, and distribution of intensity with respect to frequency. For example, the vowels as a group carry relatively large amounts of energy which are distributed into harmonics of the fundamental frequency of the voice. These harmonics have distinguishable frequency regions which differ for each vowel and which are in the low frequencies. The consonants, on the other hand, carry much less energy but that which they do carry is in the higher frequency region (relative to the vowels). In general it is known that the frequency range of speech covers the region between 0.1 and 10 kHz. However, most of the information contained in speech is carried by the consonants, which, because they carry little energy, are easily masked.

When speech sounds are spoken, the various basic sounds are combined into orderly sequences to form syllables which in turn are grouped into words and sentences. Speech is an acoustical signal that constantly undergoes very rapid fluctuations both in intensity and frequency. In order for a listener to understand speech he must be able not only to detect the various sounds but also to integrate and recognize the constantly shifting patterns. When noise is present, some of the sounds are lost and the shifting patterns become more difficult to resolve. As a result, speech intelligibility deteriorates in amounts related to the intensity of the noise and its bandwidth relative to the speech signal.

Observations such as those described above are the basis of the Articulation Index developed by French and Steinberg [37] as a means of predicting speech intelligibility from a knowledge of speech and noise spectra. This index represents a measure of the portion of speech which is available to the listener when communication occurs in a noisy environment. In effect, the Articulation Index takes into account the sound level differential between speech and noise (i.e., signal-to-noise ratio) in 20 contiguous bands located between 0.2 and 6 kHz which, under optimal conditions, contribute equal amounts to the Articulation Index.

The basic assumptions underlying the Articulation Index can be summarized as follows:

- the total variation in intensity levels of successive speech sounds is constant throughout each frequency region and roughly equal to 30 dB,

- the relative occurrences of intervals of different intensities are roughly identical for each frequency region for both men and women,

- the average (1/8 second) peak levels of single speech phonemes exceed the long-term average of the speech levels by about 12 dB for 10 percent of the time.

The Articulation Index is at present the best available predictor of speech intelligibility in the presence of steady state noise; it also contains provisions for predicting the effects of noise having a definite duty cycle. Thus, it would be a good candidate for rating consumer products in terms of their ability to interfere with speech while they are on. However, the method is complex and thus not very practical for the purposes of this study. Nevertheless the relationships between sentence intelligibility and the Articulation Index for listeners with good hearing are shown in Figure 9.

By and large, speech criteria have been derived from studies involving young adults with good hearing and speaking the same dialect. In the home environment these criteria may underestimate the effects of noise on speech. Children, particularly young children, have a more limited vocabulary than adults. This, combined with their relative lack of knowledge of language, often makes them less able to understand or "hear" speech when some of the cues in the speech stream are lost. Likewise, older listeners with presbyacusis or persons with some hearing impairment are less able to understand partially-masked speech than the young adult subjects for which speech criteria were derived. Finally, in the United States several dialects are spoken; this in turn could affect the estimates of speech unintelligibility based on present criteria. However, little, if any quantitative data exist to date to account for such effects.

The Speech Interference Level [38-39] is a simple method for estimating the speech-interfering aspects of noise based on physical measurements of the noise. Unlike the Articulation Index, SIL does not include specific consideration of the level and spectrum of the speech but employs a table or a nomogram for estimating the noise levels that will seriously restrict speech communication in terms of general voice level and the distance between communicators. Indoors, however, the distance between the speaker and the listener is less critical, since the listener often is likely to be in a reverberant sound field and the speech levels do not decrease as rapidly as they would outdoors. This is particularly true in cases where the listener is at distances equal to or greater than 1 meter -- a situation typical of the home environment.

The Speech Interference Level is also considered to be a good predictor of the selective ranking of noises with respect to their speech interfering properties. However, this procedure is not appropriate for noise spectra with considerably more energy at high frequencies than at low or when any of the

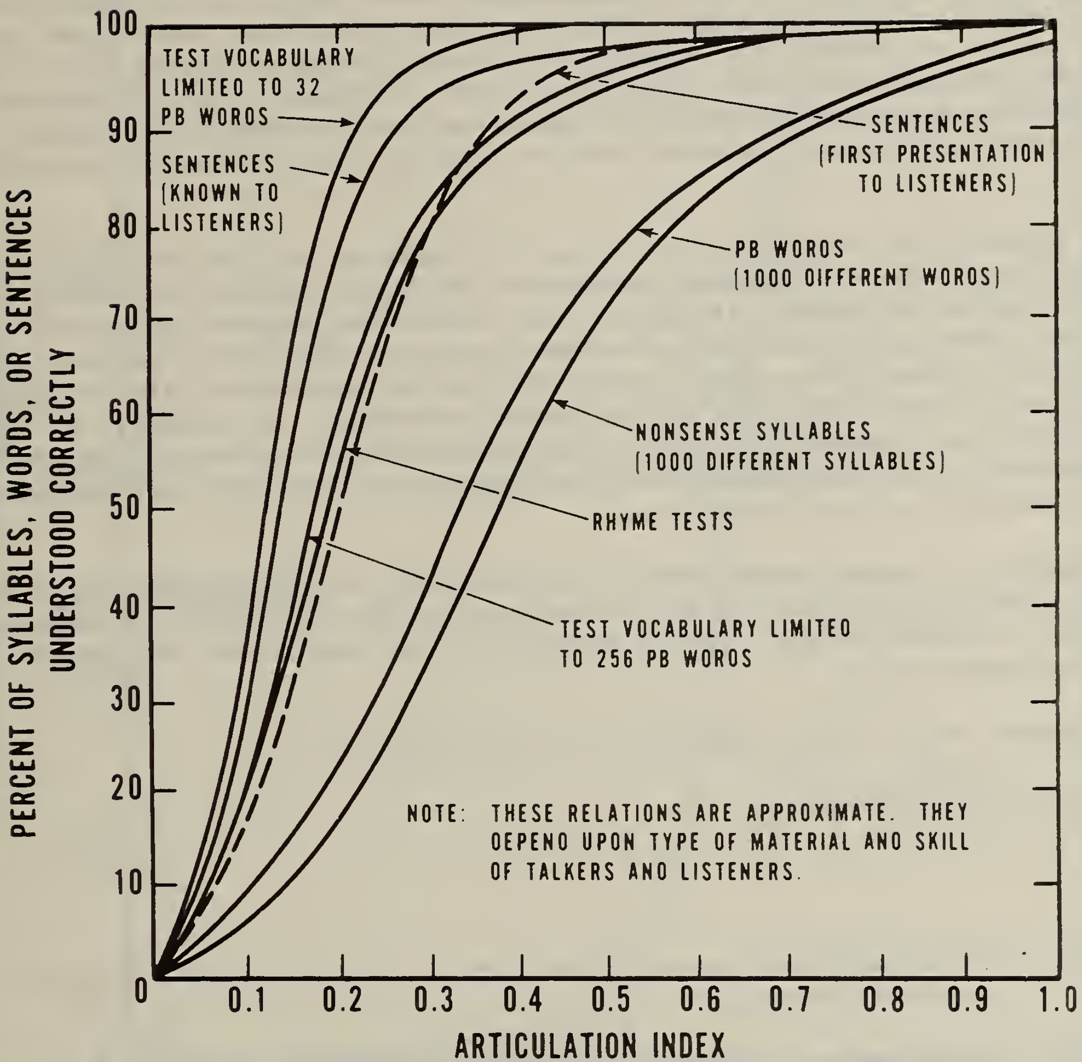

Figure 9. Relation between the Articulation Index and various measures of speech intelligibility [39]. (On the figure, "PB" designates phonetically balanced.)

following conditions exist: (1) the level of the noise is not of a steady-state nature, (2) the frequency spectrum of the noise is not constant with time, and (3) the speech and noise are subject to perceptible echo or reverberation (as could be the case in some rooms).

For many types of noise spectra, the Speech Interference Level can be approximated fairly well from the A-weighted sound level. Because the A-weighted sound level can be read directly from a sound level meter, it is easier to obtain than SIL. However, since consumer products may have unusual and uneven spectra containing acoustical energy in the high frequency region where the consonants lie, it is possible that use of the A-weighted level to predict speech interference from household products may underestimate the actual interference with speech (as would also be the case with Speech Interference Level).

For the purposes of this study, the data of Figure D-1 of the EPA Level Documents [23] were used to estimate fractional (sentence) unintelligibility for steady noises in an indoor situation. The curve thus derived is shown in Figure 10. This curve also is approximately correct for predicting sentence interference outdoors for normal voice and 2 meter separation between speaker and listener -- see Figure D-4 of the Levels Document. The severity of speech interference for a particular noise exposure is assumed to be the product of the fractional unintelligibility and the fraction of the time that the listener is exposed to that sound level.

The intensity of speech interference over an entire day (0700-2200 only) is assumed to be the summation of the severities, as defined above, of single exposures. In other words, it is a measure of the fraction of sentences* lost during an average day.

The weighting factor to be used in Eq. (5.1) is given by

$$W_i(10) = \frac{1}{T} \sum_j U(L_j) T_{ij} \qquad (5.20)$$

where

$U(L_j)$ = the fractional unintelligibility for the j-th noise level, as shown in Figure 10,

T_{ij} = the time during which a given listener in the i-th population sub-group is exposed to the j-th noise level, and

T = the total daytime period (i.e., 15 hours).

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* Sentences are assumed to contain words that are both familiar and unfamiliar to the listener.

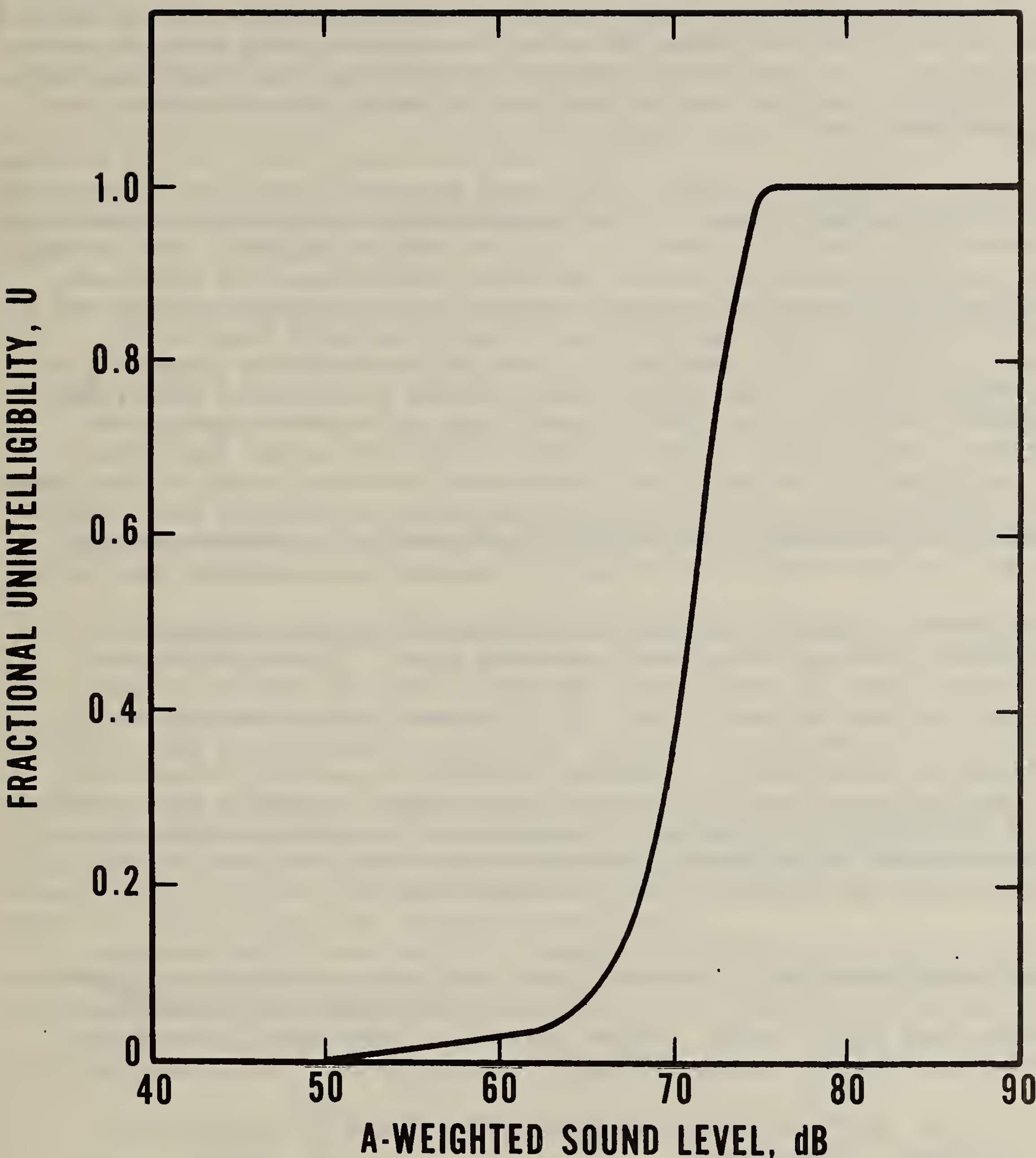


Figure 10. Relationship between A-weighted sound pressure level and fractional sentence unintelligibility ([23], Fig. D-1).

5.4 SLEEP INTERFERENCE

The accumulated evidence of research on the effects of noise on sleep indicates that noise may arouse a person from sleep, and/or prevent a person from falling asleep. At sub-arousal levels, noise may shift a person's sleep from a deep, dreamless stage to a lighter stage of sleep. However, much of what is known about the effects of noise on sleep comes from laboratory observations on a few people. Therefore, caution must be exercised in making generalizations about people under widely differing circumstances.

Sleep is a very complex phenomenon, comprising several stages. It is generally agreed that as a person relaxes, the electroencephalographic (EEG) pattern changes from rapid irregular waves to a pattern that is regular. This is followed by a prolonged reduction in the amplitude and frequency of the waves. Later this pattern changes to one where bursts of waves (spindle waves) are mixed with relatively large amplitude and single slow waves known as K-complexes. Typically, this sleep stage lasts 30 to 45 minutes (depending on age) and then yields to a new pattern characterized by bursts of relatively high amplitude and slow waves. The deepest sleep occurs when these later waves, known as delta waves, occur for about 50 percent of the recording period. Approximately one and a half hours after this deep stage of sleep has occurred, the EEG pattern starts to change again and to resemble that seen at the beginning of the sleep cycle except that, typically, electrodes located near the eye indicate rapid eye movements. Dreaming occurs during this period.

In the laboratory, a person normally goes through the whole progression described above, although occasional reversals occur. The amount of time which a person spends in each sleep stage varies with his age and psychophysiological and motivational state. It is generally believed that all stages of sleep are important for good "health", at least in the short term, since, typically, when sleep is severely disturbed the subject reports the next day that he feels lethargic, nervous, and unable to perform work. Some unanswered questions exist, however, regarding the long-range effects of sleep disturbance on physiological and psychological health since little experimental data are available from prolonged studies.

Survey data indicate that sleep disturbance is often one of the principal complaints about noise [40]. Recently Lukas [41] has reviewed the experimental sleep and noise literature for EPA and derived a method for assessing sleep disturbance due to noise. In the context of that study, sleep disturbance includes either of two phenomena:

- o a change in the electroencephalographic pattern to at least one "shallower" sleep stage,
- o a complete behavioral awakening.

In addition, the Lukas study yielded some functional relationships between noise levels and probabilities of sleep disruptions. These relationships are shown in Figures 11 and 12, and provide the basis for the method developed by EPA [42,43] for assessing the impact of noise on sleep. It must be recognized, however, that in addition to the fact that most of the data upon which these relationships rest were obtained under laboratory conditions (and thus may not accurately represent real life conditions), about 75 percent of the test stimuli used were from transportation systems, in particular from subsonic and/or supersonic aircraft. Accordingly, caution must be exercised in applying the results of these studies to noises of other types. In the absence of other data, however, one can only assume that relationships based on transportation noises hold for other types of noise.

The curve shown in Figure 11 indicates the frequency of sleep disturbance (as measured by both sleep change rate and awakening) as a function of the Sound Exposure Level (SEL) of the intruding noise. This curve can be used to approximate the degree of partial impact which results from a specified noise exposure level for an individual.

For the purposes of this study the Sound Exposure Level was defined as

$$SEL_j = \begin{cases} L_j + 10 \log(t_j/t_o) , & t_j \leq 120 \text{ sec} \\ L_j + 20.8 , & t_j > 120 \text{ sec} , \end{cases} \tag{5.21}$$

where

L_j = the steady j-th noise level produced in a bedroom by the product of concern,

t_j = the duration (sec) of exposure due to a single operation of the product, and

t_o = reference time = 1 sec.

At the request of EPA, an upper limit of 2 min (120 sec) was placed on the integration time for SEL. It was felt that it would be unreasonable to extrapolate Lukas' data beyond this duration. Thus, it is implicitly assumed that if sleep were not disrupted within the first two minutes, it would be unlikely that any disruption would occur.

Two weighting factors, corresponding to Figures 11 and 12, respectively, are incorporated into the model.

The weighting factor corresponding to sleep disruption is defined as

$$W_i(19) = \begin{cases} \frac{1}{100} \sum_j (1.35 \times SEL_j - 50) , & SEL_j > 37 \text{ dB} \\ 0 , & SEL_j \leq 37 \text{ dB} , \end{cases} \tag{5.22}$$

where SEL is as defined in Eq. (5.22) and the summation is only over the nightime hours (2200-0700). In the computation of the Weighted Population, using Eq. (5.1), only persons in bedrooms are included.

The weighting factor corresponding to behavioral awakening is defined as

$$W_j(20) = \begin{cases} \frac{1}{100} \sum_j (1.01 \times SEL_j - 49.5), & SEL_j \geq 50 \text{ dB} \\ 0 & , \quad SEL_j \leq 50 \text{ dB} \end{cases} \qquad (5.23)$$

where SEL_j is as defined above, the summation again is only over the night-time hours, and in the computation of weighted population only persons in bedrooms are included.

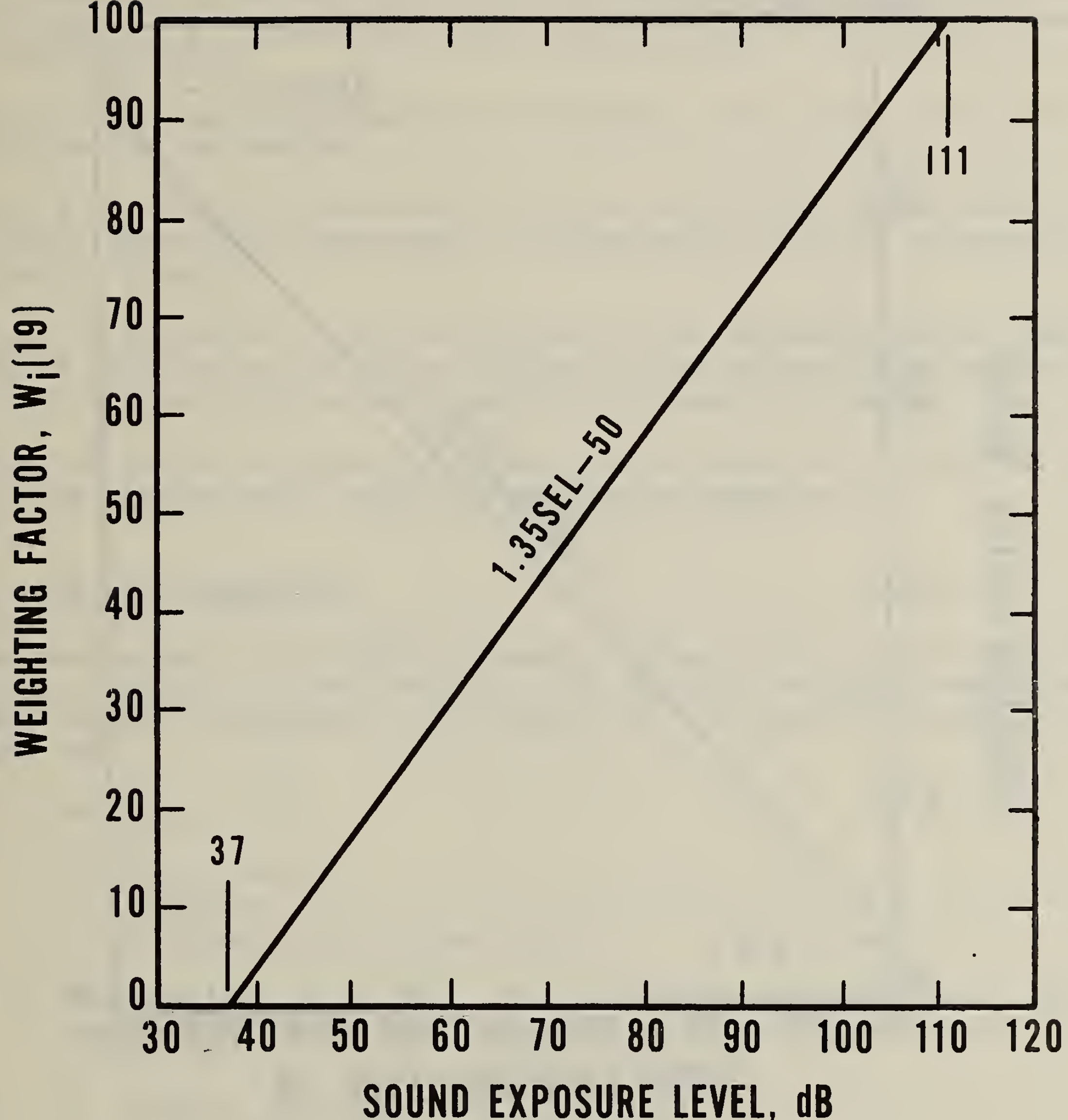


Figure 11. Weighting factor for sleep disruption as a function of sound exposure level [42-43]. (Note: In this figure $W_i(19)$ is given in percent; in the computer program it is used as a fraction going from 0.0 to 1.0.)

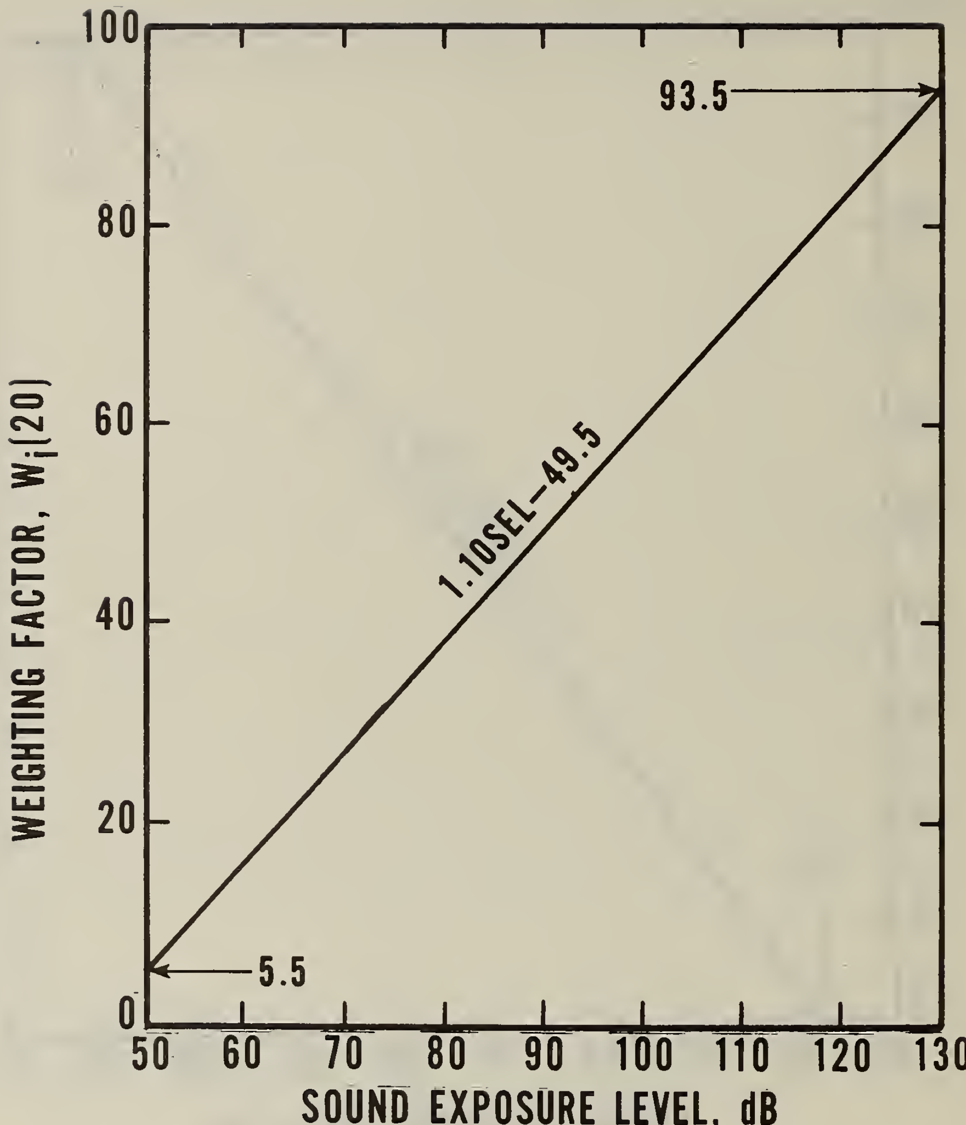


Figure 12. Weighting factor for frequency of arousal or awakening from sleep as a function of sound exposure level [42-43]. (Note: in this figure $W_i(20)$ is given in percent, in the computer program it is used as a fractions group from 0.0 to 1.0).

6. IMPACT ASSESSMENT MODEL

As noted in the introduction of this report, the main objective of the present study was the development of a conceptual approach and a procedure for assessing the impact of noise from consumer products on the health and welfare of the national population. The complexity of the calculations involved, and the large quantity of data to be handled, convinced the authors that the only practical procedure for using this conceptual model was to embody it into a computer program. This program, the imputs required, and the outputs obtained are described below.

Section 6.1 defines the categories of dwellings, rooms, people, days, and time periods used in the program.

Section 6.2 provides an overview of the type of data required in order to use the model. These data requirements are commensurate with the discussions in Sections 2, 3, and 4.

Section 6.3 provides a conceptual flowchart of the FORTRAN program, indicating how these data are read in and manipulated, using the procedures outlined in Section 5, to yield the desired descriptors of population impact.

Section 6.4 details the specific formats for the data that are required for use in the program, which itself is contained in Appendix C.

6.1 INPUT DATA PARAMETERS

In the development of the FORTRAN program, categorization of identified parameters has been made. These categories, the subscript variable used in the FORTRAN program to designate each category, and the specific parameter subscripts are:

- Dwellings -- (I):

  1. single family
  2. townhouse
  3. multifamily (i.e., apartments)

- Living spaces -- (J), (K), or (L) for source room, receiving room in primary dwelling, or room in secondary dwelling, respectively:

  1. kitchen
  2. living room/dining room/family room
  3. bathroom
  4. bedroom
  5. basement/utility room/ garage
  6. outdoors

o People -- (M):

1. unemployed or working-at-home adult male
2. employed adult male
3. unemployed or working-at-home adult female
4. employed adult female
5. school age or nursery child
6. preschool child at home

o Day -- (N):

1. weekday with school
2. weekday with no school
3. weekend and holidays

o Period of day -- (P):

1. 0700-0900 hours
2. 0900-1700 hours
3. 1700-2200 hours
4. 2200-0700 hours

o Octave band center frequency -- (S):

1. 63 Hz
2. 125 Hz
3. 250 Hz
4. 500 Hz
5. 1000 Hz
6. 2000 Hz
7. 4000 Hz
8. 8000 Hz

6.2 INPUT DATA REQUIRED FOR IMPLEMENTATION OF THE MODEL

In assessing the impact of noise from consumer products, several categories of data inputs are required. These include: population parameters, sound isolation data, and product noise emission data. In these categories, the following input data are required (in order of input):

1. Population Parameters

   o Length of time, in minutes, spent in different rooms as a function of building type, room type, person type, period of the day, and type of day. TIMEIN(I,K,M,P,N)

   o The number of people of each type that lives in each type of dwelling. PEOPLE(I,M)

2. Sound Isolation

- o Noise reduction from room to room for the primary dwelling for each pair of source and receiving rooms, for each octave band, as a function of building type. NRP(S,K,J,I)

- o Noise reduction from the primary to the secondary dwelling for each combination of source room and receiving room, for each octave band, as a function of building type. NRS(S,L,J,I).

3. Product Noise Emission (for each product)

- o Title describing the appliance.

- o Distribution of operators, in percent, among person types. OPTYP(I,M)

- o The fraction of each dwelling type having the appliance. PERC(I)

- o Relative length of time, in minutes/day, of operation as a function of dwelling type and day. ONTIM(I,N)

- o The length of time, in minutes, of each operation as a function of dwelling type and day type. TIM(I,N)

- o The relative probability of an appliance being operated in a given time period in a given house type on a given day type. TP9(P,I,N) (The sum of TP9 (P,I,N) over P must equal one.)

- o The relative probability of an appliance being operated in a given room type in a given house type on a given day type. RMP9 (K,I,N) (The sum of RMP9 (K,I,N) over K must equal one).

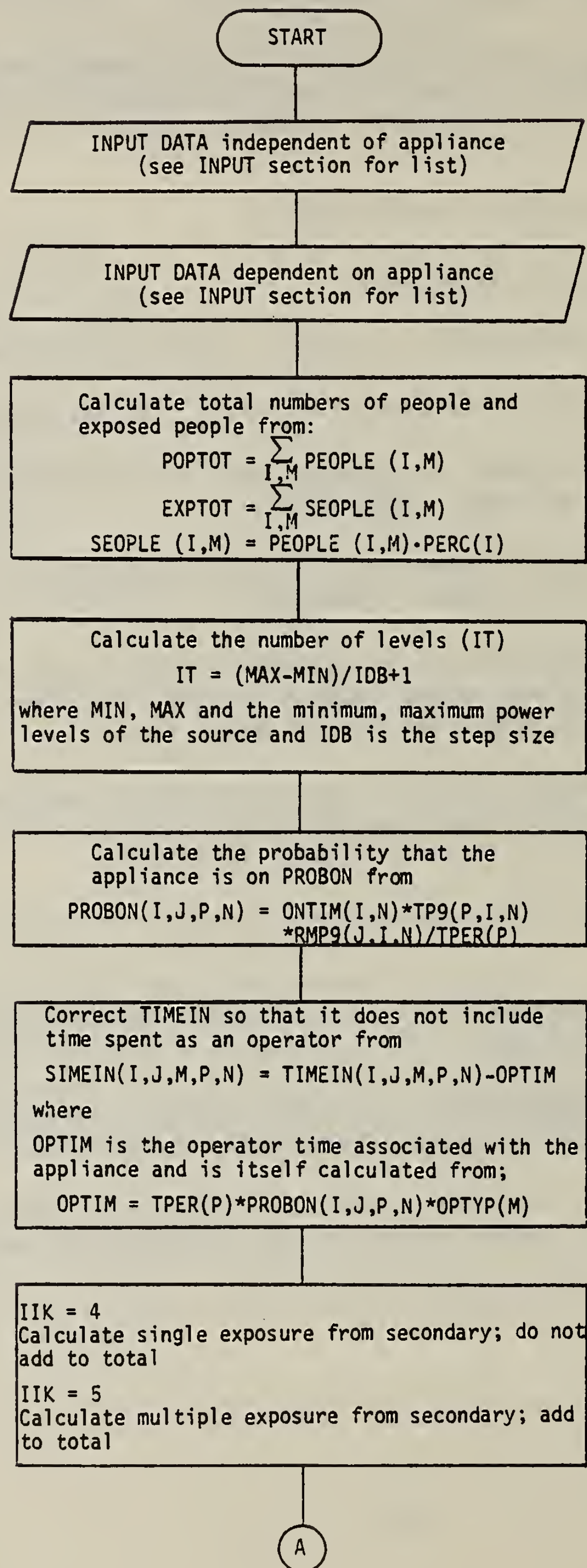
- o Octave band sound level spectrum (in decibels) of the product class. SPECTR(S).

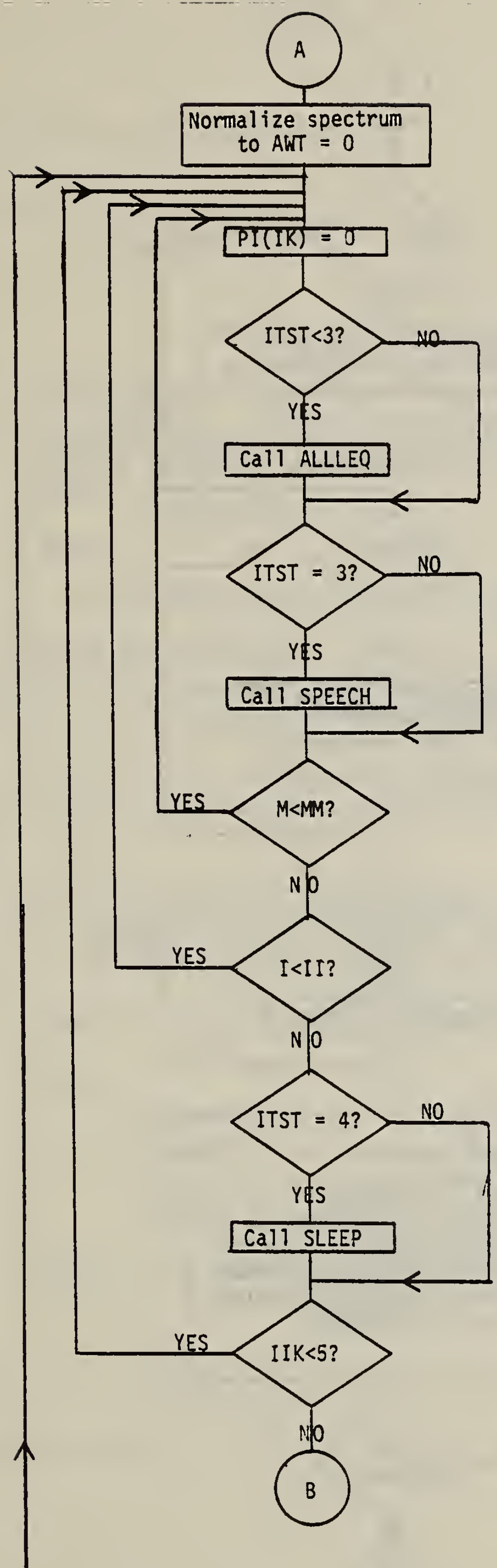
- o The minimum and maximum source sound power level and step size (in decibels). MIN,MAX,IDB

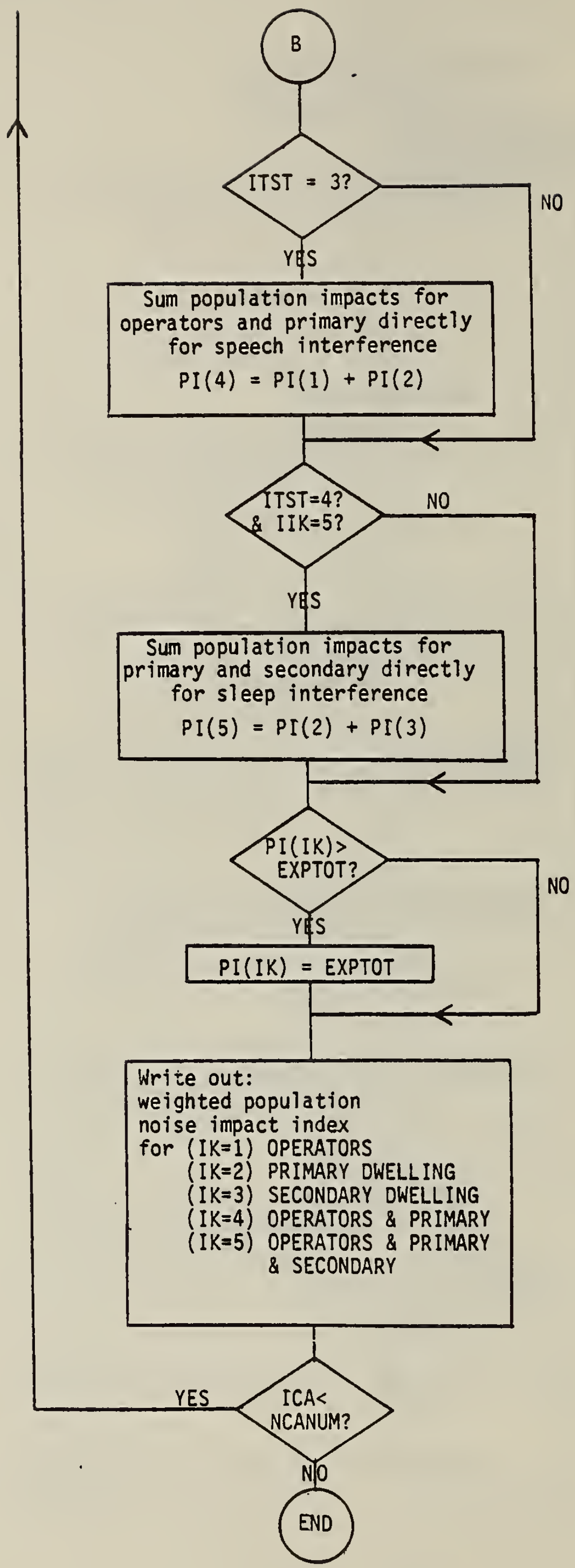
- o The difference (assumed to be constant) between the sound power level and the sound pressure level at the operator position. OPDIFF

- o The probability of the power level in the source room being in a particular decibel range (specified by MIN,MAX,IDB from above).

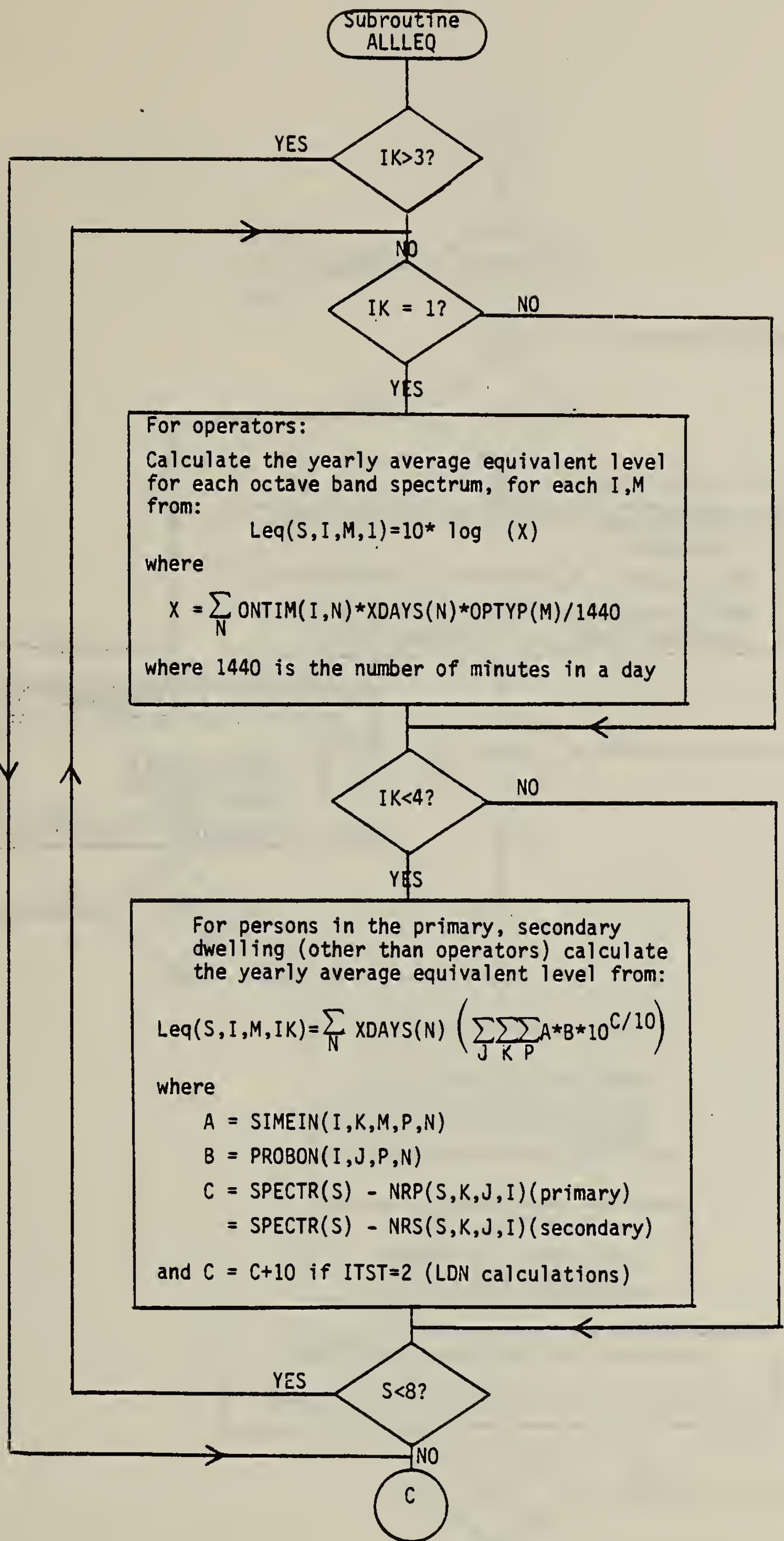
6.3 Flow Chart for Computer Program

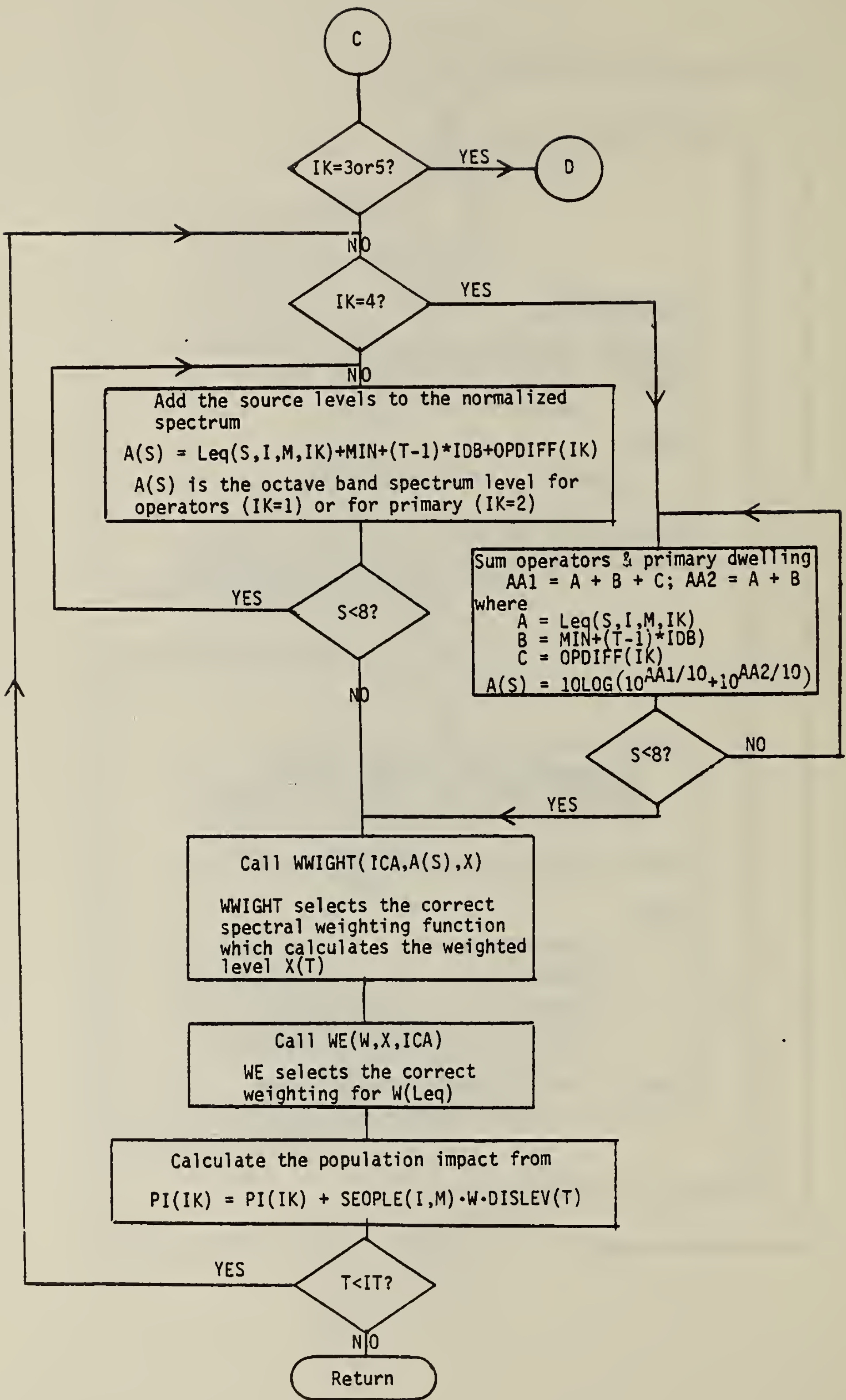


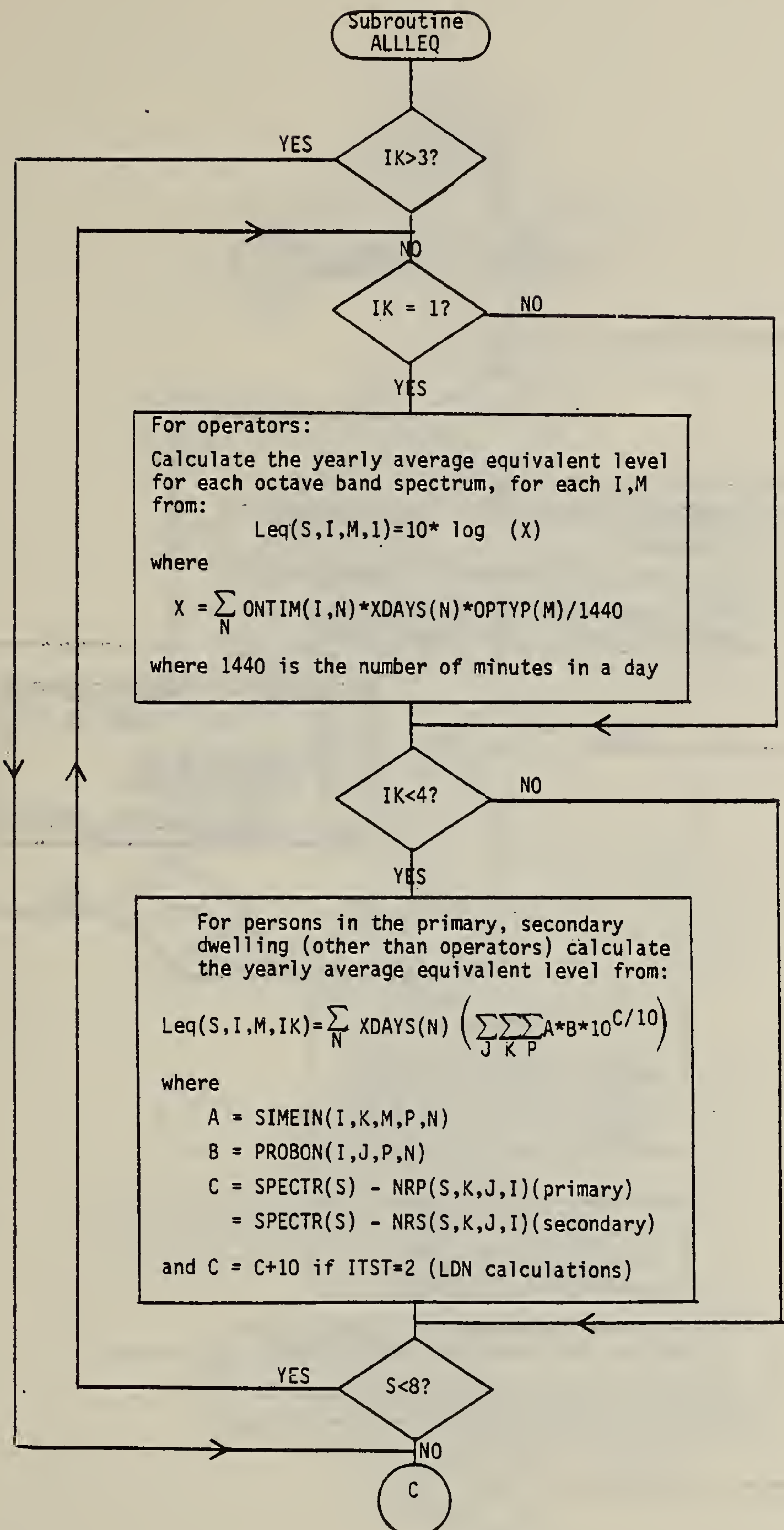

A
Normalize spectrum to AWT = 0
PI(IK) = 0
ITST<3?
NO
YES
Call ALLLEQ
ITST = 3?
NO
YES
Call SPEECH
M<MM?
YES
NO
I<II?
YES
NO
ITST = 4?
NO
YES
Call SLEEP
IIK<5?
YES
NO
B

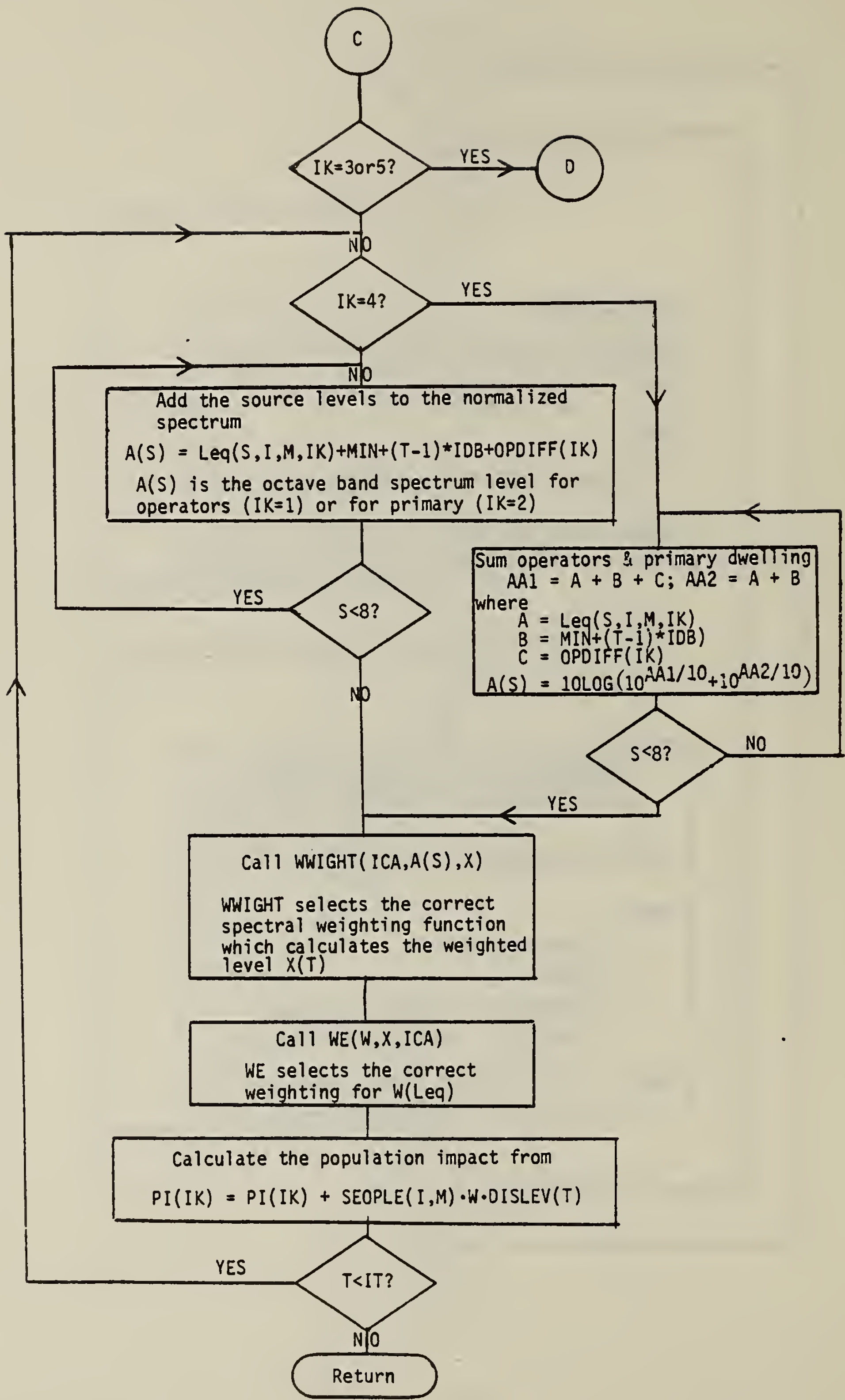


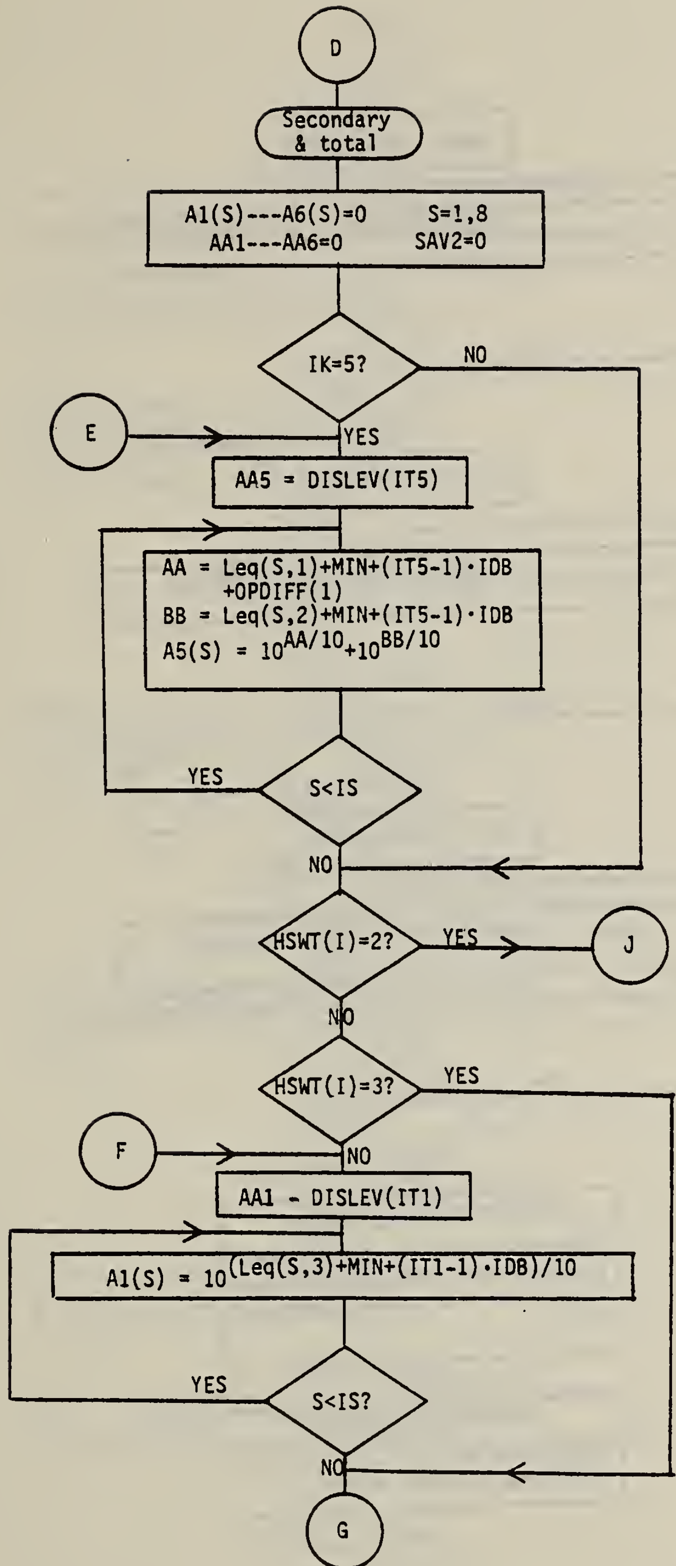
B
ITST = 3?
NO
YES
Sum population impacts for operators and primary directly for speech interference
PI(4) = PI(1) + PI(2)
ITST=4? & IIK=5?
NO
YES
Sum population impacts for primary and secondary directly for sleep interference
PI(5) = PI(2) + PI(3)
PI(IK)> EXPTOT?
NO
YES
PI(IK) = EXPTOT
Write out:
weighted population
noise impact index
for (IK=1) OPERATORS
(IK=2) PRIMARY DWELLING
(IK=3) SECONDARY DWELLING
(IK=4) OPERATORS & PRIMARY
(IK=5) OPERATORS & PRIMARY & SECONDARY
YES
ICA< NCANUM?
NO
END

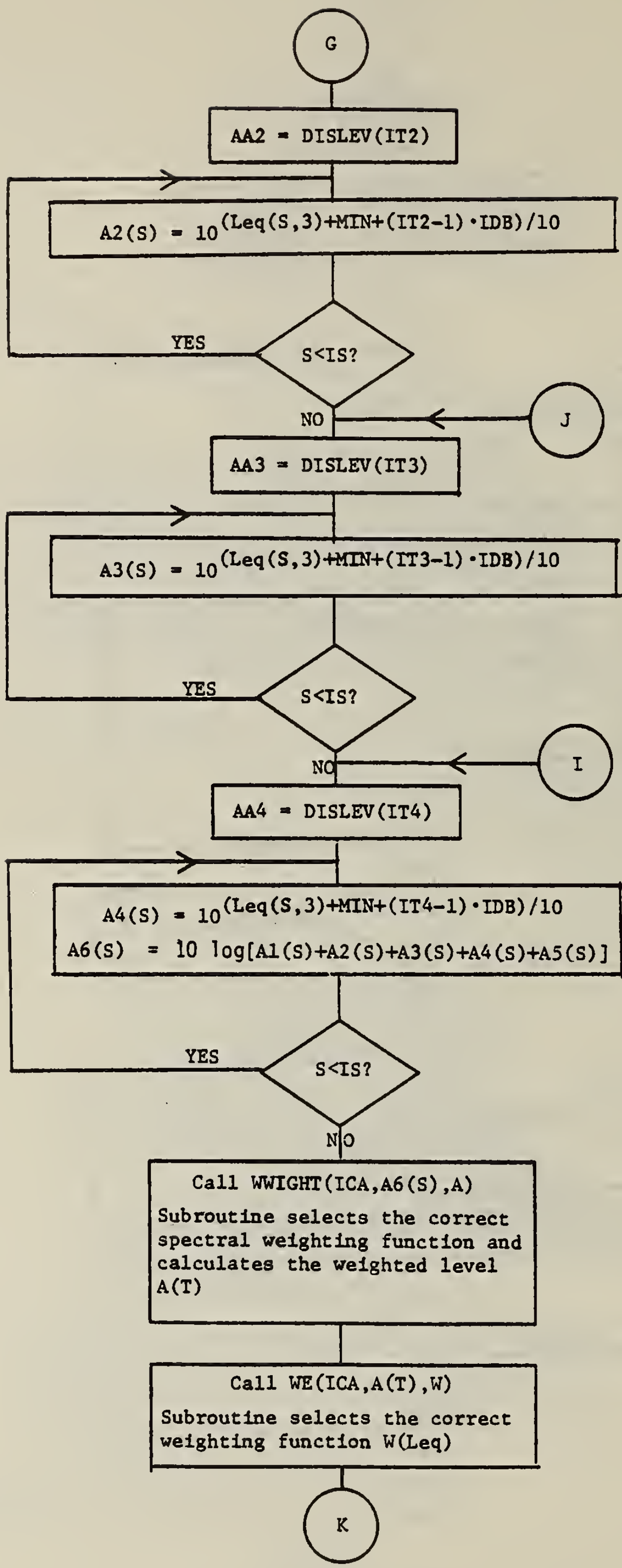

Subroutine ALLLEQ
IK>3?
YES
NO
IK = 1?
NO
YES
For operators:
Calculate the yearly average equivalent level for each octave band spectrum, for each I,M from:
Leq(S,I,M,1)=10* log (X)
where
X = Σ_N ONTIM(I,N)*XDAYS(N)*OPTYP(M)/1440
where 1440 is the number of minutes in a day
IK<4?
NO
YES
For persons in the primary, secondary dwelling (other than operators) calculate the yearly average equivalent level from:
Leq(S,I,M,IK)=Σ_N XDAYS(N) (Σ_J Σ_K Σ_P A*B*10^(C/10))
where
A = SIMEIN(I,K,M,P,N)
B = PROBON(I,J,P,N)
C = SPECTR(S) - NRP(S,K,J,I)(primary)
= SPECTR(S) - NRS(S,K,J,I)(secondary)
and C = C+10 if ITST=2 (LDN calculations)
YES
S<8?
NO
C

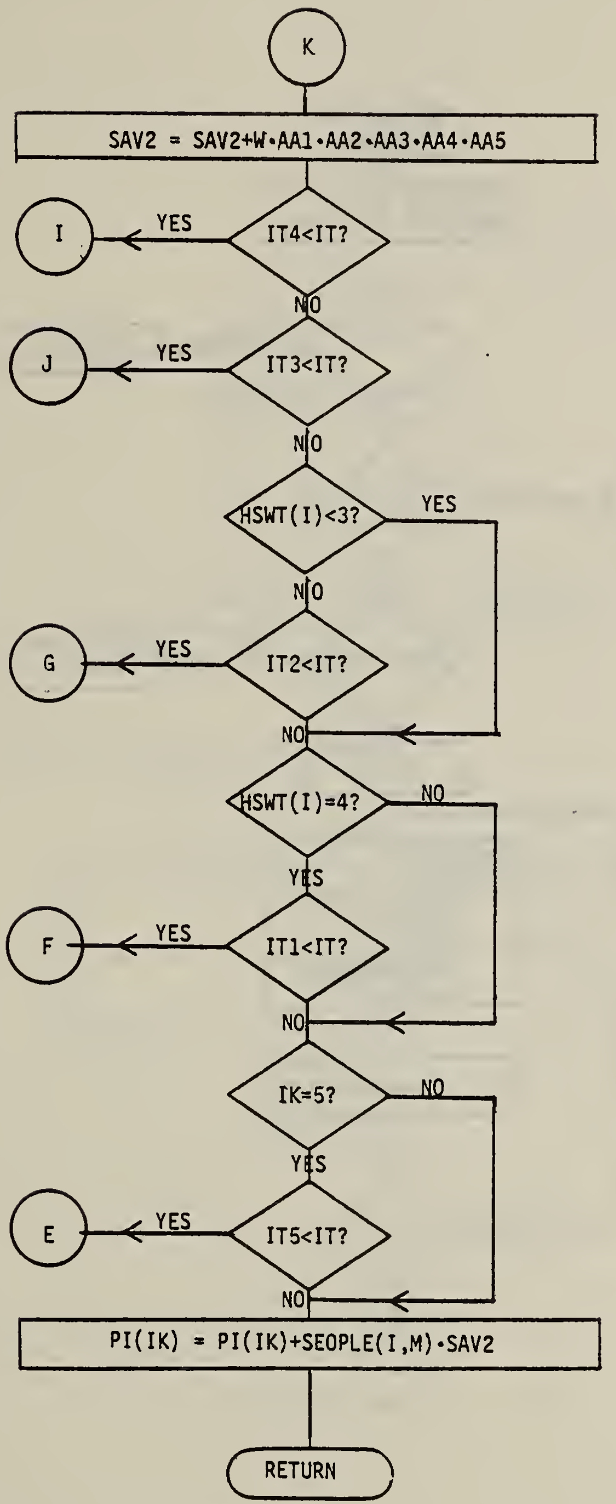

C
IK=3or5?
YES
D
NO
IK=4?
YES
NO
Add the source levels to the normalized spectrum
A(S) = Leq(S,I,M,IK)+MIN+(T-1)*IDB+OPDIFF(IK)
A(S) is the octave band spectrum level for operators (IK=1) or for primary (IK=2)
YES
S<8?
NO
Sum operators & primary dwelling
AA1 = A + B + C; AA2 = A + B
where
A = Leq(S,I,M,IK)
B = MIN+(T-1)*IDB)
C = OPDIFF(IK)
A(S) = 10LOG(10^AA1/10+10^AA2/10)
S<8?
NO
YES
Call WWIGHT(ICA,A(S),X)
WWIGHT selects the correct spectral weighting function which calculates the weighted level X(T)
Call WE(W,X,ICA)
WE selects the correct weighting for W(Leq)
Calculate the population impact from
PI(IK) = PI(IK) + SEOPLE(I,M)·W·DISLEV(T)
YES
T<IT?
NO
Return

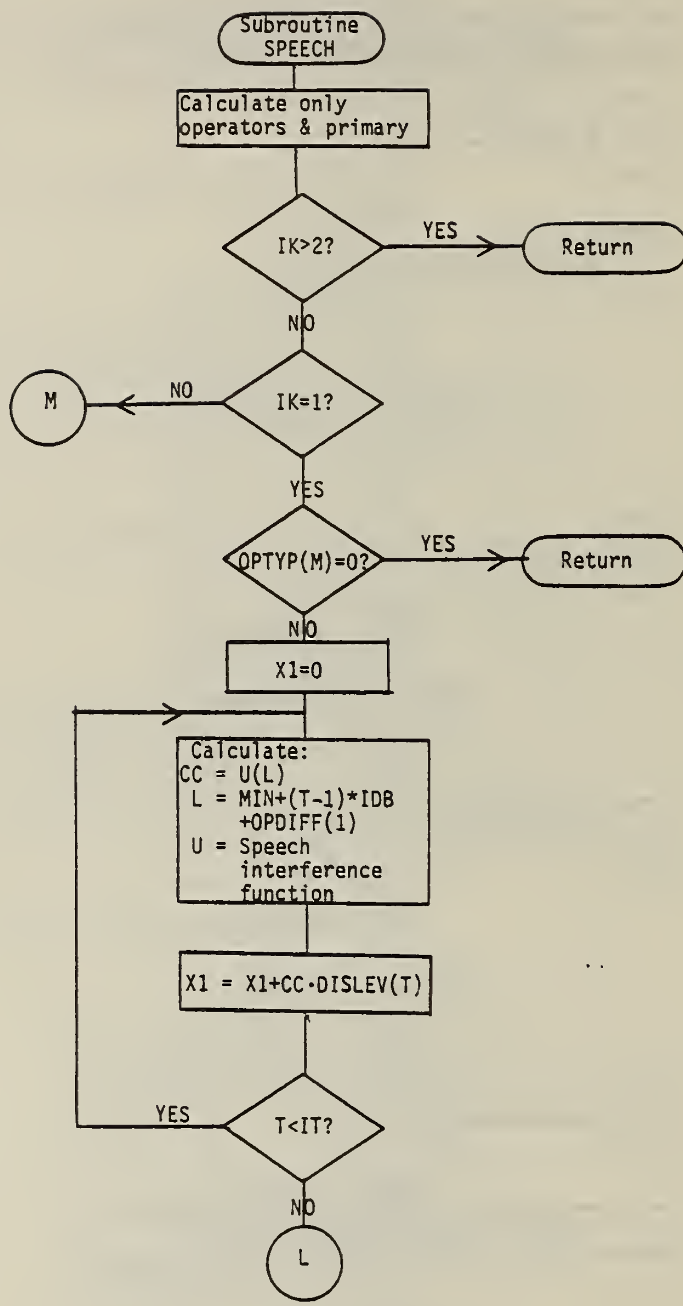

Subroutine ALLLEQ
IK>3?
YES
NO
IK = 1?
NO
YES
For operators:
Calculate the yearly average equivalent level for each octave band spectrum, for each I,M from:
Leq(S,I,M,1)=10* log (X)
where
X = Σ_N ONTIM(I,N)*XDAYS(N)*OPTYP(M)/1440
where 1440 is the number of minutes in a day
IK<4?
NO
YES
For persons in the primary, secondary dwelling (other than operators) calculate the yearly average equivalent level from:
Leq(S,I,M,IK)=Σ_N XDAYS(N) (Σ_J Σ_K Σ_P A*B*10^(C/10))
where
A = SIMEIN(I,K,M,P,N)
B = PROBON(I,J,P,N)
C = SPECTR(S) - NRP(S,K,J,I)(primary)
= SPECTR(S) - NRS(S,K,J,I)(secondary)
and C = C+10 if ITST=2 (LDN calculations)
YES
S<8?
NO
C

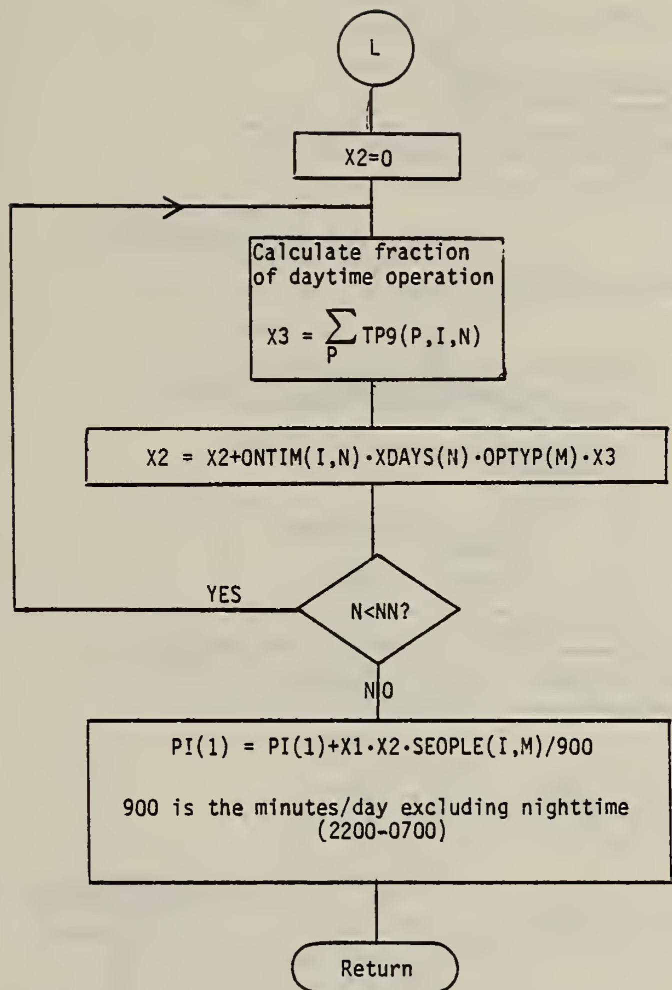

C
IK=3or5?
YES
D
NO
IK=4?
YES
NO
Add the source levels to the normalized spectrum
A(S) = Leq(S,I,M,IK)+MIN+(T-1)*IDB+OPDIFF(IK)
A(S) is the octave band spectrum level for operators (IK=1) or for primary (IK=2)
YES
S<8?
NO
Sum operators & primary dwelling
AA1 = A + B + C; AA2 = A + B
where
A = Leq(S,I,M,IK)
B = MIN+(T-1)*IDB)
C = OPDIFF(IK)
A(S) = 10LOG(10^AA1/10+10^AA2/10)
S<8?
NO
YES
Call WWIGHT(ICA,A(S),X)
WWIGHT selects the correct spectral weighting function which calculates the weighted level X(T)
Call WE(W,X,ICA)
WE selects the correct weighting for W(Leq)
Calculate the population impact from
PI(IK) = PI(IK) + SEOPLE(I,M)·W·DISLEV(T)
YES
T<IT?
NO
Return


D
Secondary & total
A1(S)---A6(S)=0 S=1,8
AA1---AA6=0 SAV2=0
IK=5?
NO
E
YES
AA5 = DISLEV(IT5)
AA = Leq(S,1)+MIN+(IT5-1)·IDB +OPDIFF(1)
BB = Leq(S,2)+MIN+(IT5-1)·IDB
A5(S) = 10AA/10+10BB/10
YES
S<IS
NO
HSWT(I)=2?
YES
J
NO
HSWT(I)=3?
YES
F
NO
AA1 - DISLEV(IT1)
A1(S) = 10(Leq(S,3)+MIN+(IT1-1)·IDB)/10
YES
S<IS?
NO
G

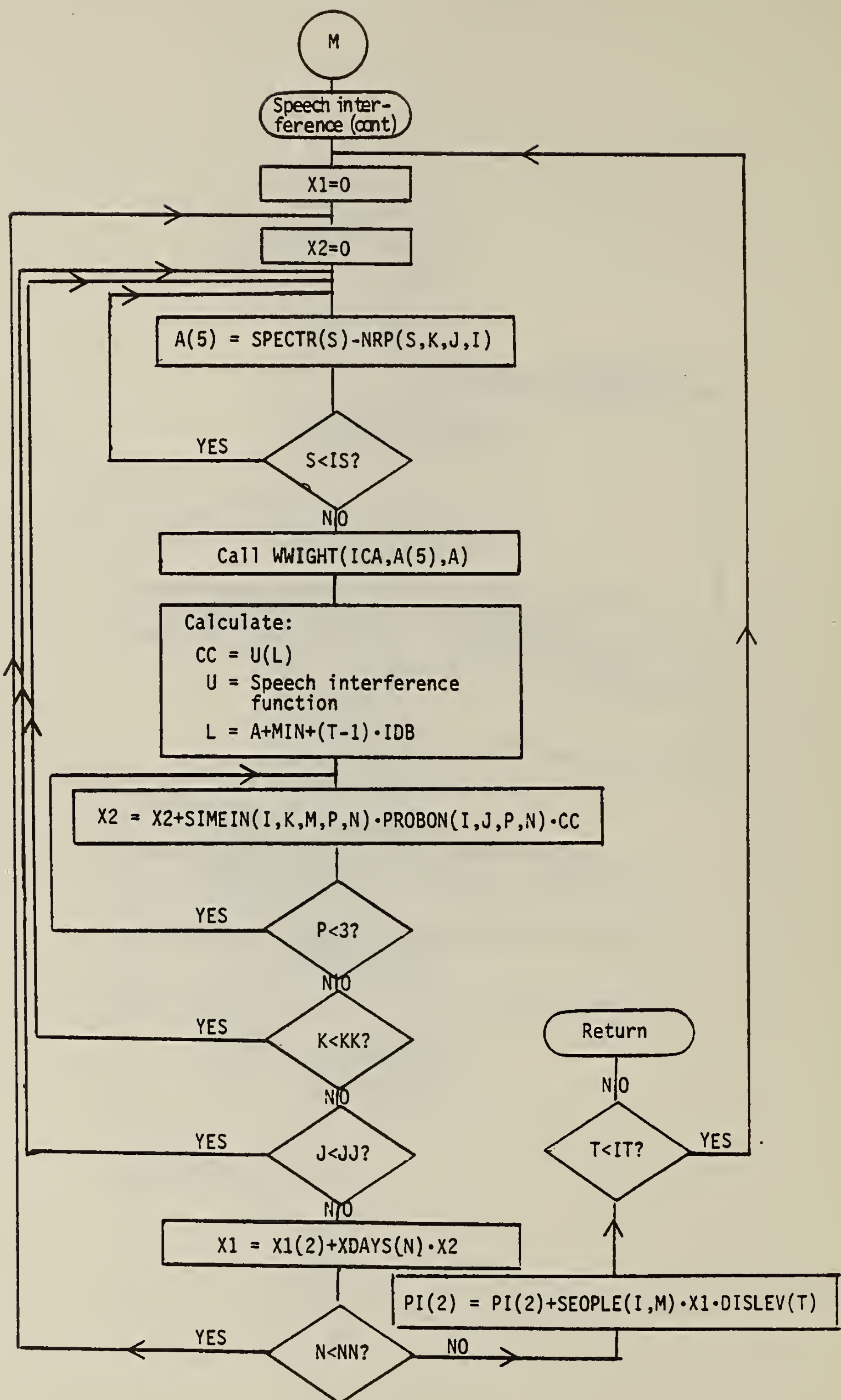

G
AA2 = DISLEV(IT2)
A2(S) = 10^(Leq(S,3)+MIN+(IT2-1)·IDB)/10
YES
S<IS?
NO
J
AA3 = DISLEV(IT3)
A3(S) = 10^(Leq(S,3)+MIN+(IT3-1)·IDB)/10
YES
S<IS?
NO
I
AA4 = DISLEV(IT4)
A4(S) = 10^(Leq(S,3)+MIN+(IT4-1)·IDB)/10
A6(S) = 10 log[A1(S)+A2(S)+A3(S)+A4(S)+A5(S)]
YES
S<IS?
NO
Call WWIGHT(ICA,A6(S),A)
Subroutine selects the correct spectral weighting function and calculates the weighted level A(T)
Call WE(ICA,A(T),W)
Subroutine selects the correct weighting function W(Leq)
K


K
SAV2 = SAV2+W·AA1·AA2·AA3·AA4·AA5
I
YES
IT4<IT?
NO
J
YES
IT3<IT?
NO
HSWT(I)<3?
YES
NO
G
YES
IT2<IT?
NO
HSWT(I)=4?
NO
YES
F
YES
IT1<IT?
NO
IK=5?
NO
YES
E
YES
IT5<IT?
NO
PI(IK) = PI(IK)+SEOPLE(I,M)·SAV2
RETURN

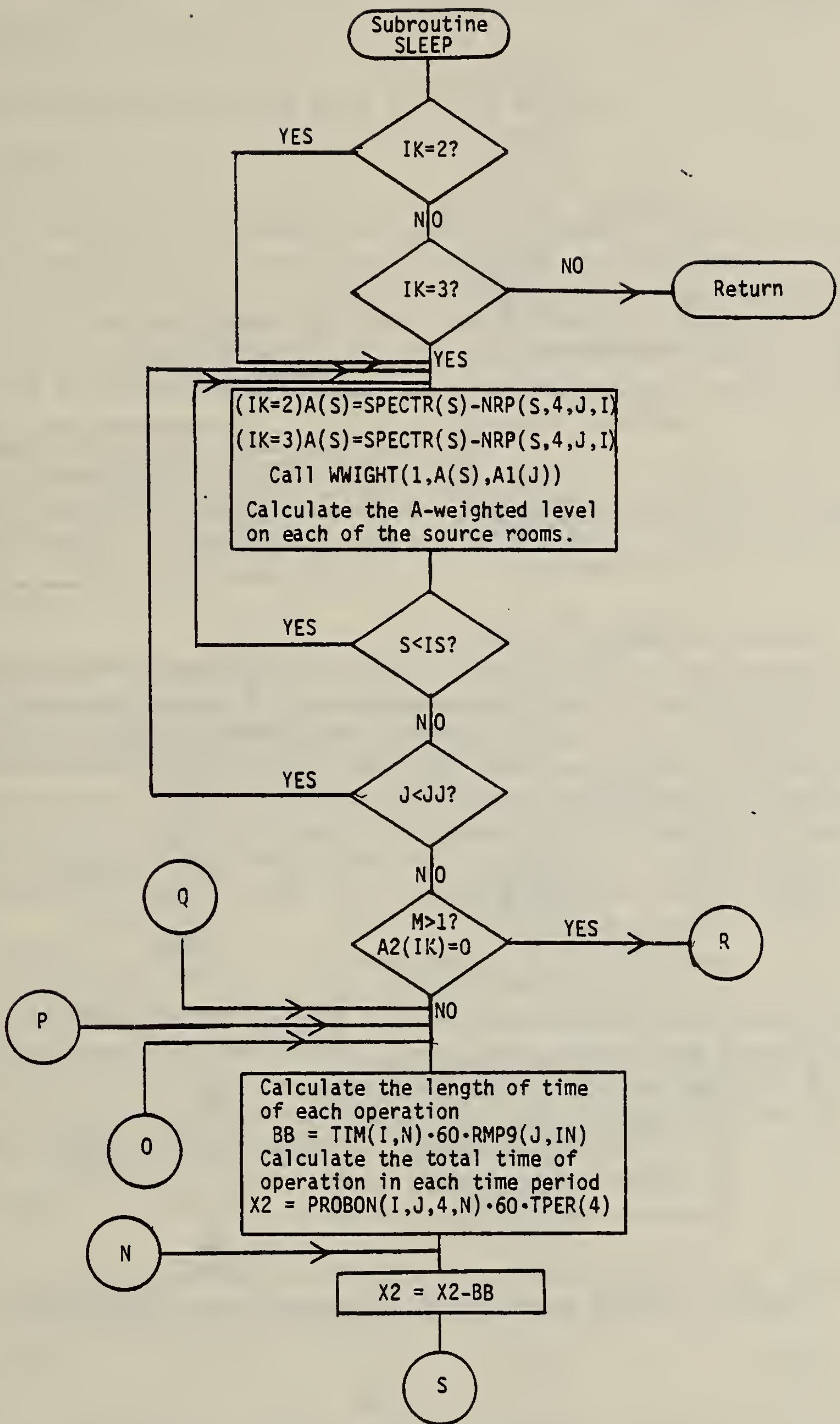

Subroutine SPEECH
Calculate only operators & primary
IK>2?
YES
Return
NO
IK=1?
NO
M
YES
OPTYP(M)=0?
YES
Return
NO
X1=0
Calculate:
CC = U(L)
L = MIN+(T-1)*IDB +OPDIFF(1)
U = Speech interference function
X1 = X1+CC·DISLEV(T)
T<IT?
YES
NO
L

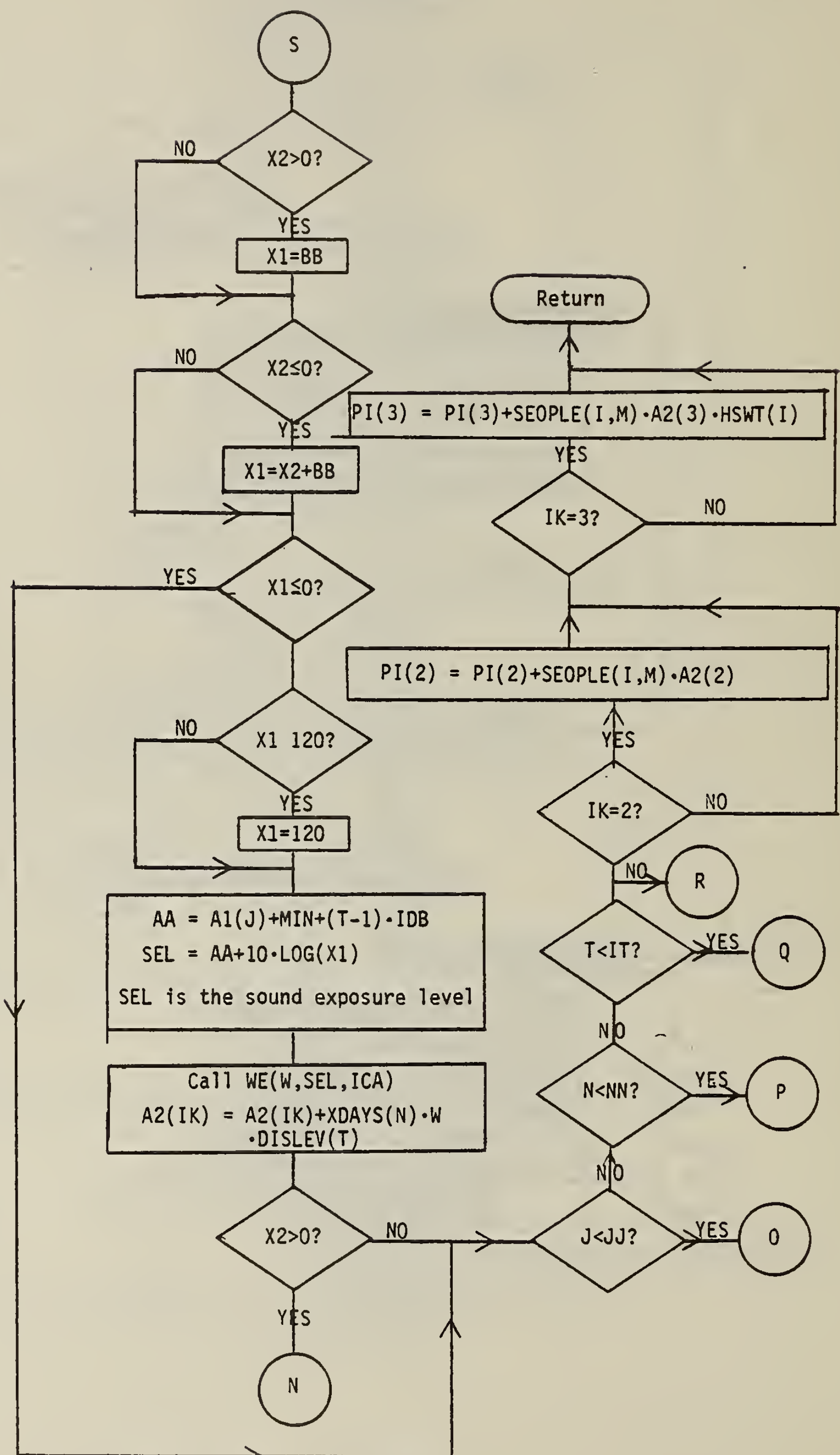


L
X2=0
Calculate fraction of daytime operation
X3 = Σ_P TP9(P,I,N)
X2 = X2+ONTIM(I,N)·XDAYS(N)·OPTYP(M)·X3
YES
N<NN?
NO
PI(1) = PI(1)+X1·X2·SEOPLE(I,M)/900
900 is the minutes/day excluding nighttime (2200-0700)
Return



M
Speech inter-ference (cont)
X1=0
X2=0
A(5) = SPECTR(S)-NRP(S,K,J,I)
S<IS?
YES
NO
Call WWIGHT(ICA,A(5),A)
Calculate:
CC = U(L)
U = Speech interference function
L = A+MIN+(T-1)·IDB
X2 = X2+SIMEIN(I,K,M,P,N)·PROBON(I,J,P,N)·CC
P<3?
YES
NO
K<KK?
YES
NO
J<JJ?
YES
NO
X1 = X1(2)+XDAYS(N)·X2
N<NN?
YES
NO
PI(2) = PI(2)+SEOPLE(I,M)·X1·DISLEV(T)
T<IT?
YES
NO
Return


Subroutine SLEEP
IK=2?
YES
NO
IK=3?
NO
Return
YES
(IK=2)A(S)=SPECTR(S)-NRP(S,4,J,I)
(IK=3)A(S)=SPECTR(S)-NRP(S,4,J,I)
Call WWIGHT(1,A(S),A1(J))
Calculate the A-weighted level on each of the source rooms.
YES
S<IS?
NO
YES
J<JJ?
NO
Q
M>1? A2(IK)=0
YES
R
P
NO
O
Calculate the length of time of each operation
BB = TIM(I,N)·60·RMP9(J,IN)
Calculate the total time of operation in each time period
X2 = PROBON(I,J,4,N)·60·TPER(4)
N
X2 = X2-BB
S


S
X2>0?
NO
YES
X1=BB
X2≤0?
NO
YES
X1=X2+BB
X1≤0?
YES
X1 120?
NO
YES
X1=120
AA = A1(J)+MIN+(T-1)·IDB
SEL = AA+10·LOG(X1)
SEL is the sound exposure level
Call WE(W,SEL,ICA)
A2(IK) = A2(IK)+XDAYS(N)·W ·DISLEV(T)
X2>0?
NO
YES
N
Return
PI(3) = PI(3)+SEOPLE(I,M)·A2(3)·HSWT(I)
YES
IK=3?
NO
PI(2) = PI(2)+SEOPLE(I,M)·A2(2)
YES
IK=2?
NO
NO
R
T<IT?
YES
Q
NO
N<NN?
YES
P
NO
J<JJ?
YES
O

6.4 FORMAT OF DATA INPUTS

The format and order of data inputs for the FORTRAN program is:

1. (20 cards)

TITCAL-Titles associated with $W_i(1)$ - $W_i(20)$.

2. (72 cards)

TIMEIN(I,K,M,P,N) - Length of time, in minutes, spent in various room types. Input on each card the time spent in each of I = 1 to 3 building types for each of K = 1 to 6 room types. Each card corresponds to one of M = 1 to 6 person types, for each of P = 1 to 4 periods of the day, for each of N = 1 to 3 day types. The subscripts should be varied systematically in the order stated with data input on each card in FORMAT (18F4.0).

3. (1 card)

People(I,M) - The total number of people of each type in each dwelling (in millions). Input using FORMAT (18F4.0)

4. (54 cards)

NRP(S,K,J,I) - Room-to-room noise reductions in the primary dwelling. Input data for each of the eight octave bands centered at frequencies from 0.063 to 8 kHz with S=1 corresponding to the 0.063 kHz band, S=2 to the 0.125 kHz band, S=3 to the 0.25 kHz band, etc. Input two rooms, with values for S=1 to 8 on each card (16 values) for each combination of K=1, 2; 3,4; 5,6 (3 cards) receiver rooms, J=1 to 6 source rooms, and I=1 to to 3 building types, with each of these subcripts varied systematically in the stated order. The input should be made using FORMAT (16F5.0).

5. (54 cards)

NRS(S,L,J,I) - Noise reductions between rooms in primary dwellings and rooms in secondary dwelling. Input two rooms with values for the octave bands corresponding to S=1 to 8 on each card (16 values) for each combination of L=1 to 6 rooms in the primary dwelling, and I=1 to 3 building types. Input is to be made in FORMAT (16F5.0).

6. (1 card)

TITLE - Title to include product name and description. Input limited to one card with 60 characters; read in using FORMAT (10A6).

7. (1 card)

NCANUM - Indicator of which weighting factors are to be used to determine Weighted Population and which type of calculation is to be done. Input integers 1 through 4 in free format. If it is desired not to calculate a a particular weighting factor $W_i(k)$ for the k-th weighting factor, the k-th integer should be zero. If the integer is 1, 2, 3, 4 the calculation is LEQ, LDN, speech interference, sleep interference. The ordering of the weighting factors (which are discussed in detail in Section 5) is:

$W_i(1)$ - Hearing: Fractional Exposure (Criterion Level - 70 dB)

$W_i(2)$ - Hearing: Four-Frequency Average NIPTS (corresponds to PHL from CHABA WG 69 report)

$W_i(3)$ - Hearing: Average NIPTS at 4 kHZ

$W_i(4)$ - General Adverse Response: CHABA WG 69 report, LWP(LDN)

$W_i(5)$ - General Adverse Response: CHABA WG 69 report, LWP(LDN+15)

$W_i(6)$ - General Adverse Response: Fractional impact

$W_i(7)$ - General Adverse Response: Alexandre and Barde, energy indicator (LDN)

$W_i(8)$ - General Adverse Response: Alexandre and Barde, loudness indicator (LDN)

$W_i(9)$ - General Adverse Response: Alexandre and Barde, synthetic indicator (LDN)

$W_i(10)$ - Speech Interference: Fractional unintelligibility based on A-level

$W_i(11)$ - General Adverse Response: Stevens Mark VI loudness level

$W_i(12)$ - General Adverse Response: Stevens Mark VI loudness

$W_i(13)$ - General Adverse Response: Stevens Mark VII loudness level

$W_i(14)$ - General Adverse Response: Stevens Mark VII loudness

$W_i(15)$ - General Adverse Response: Zwicker loudness level

$W_i(16)$ - General Adverse Response: Zwicker loudness

$W_i(17)$ - General Adverse Response: Perceived noise level (FAR 36)

$W_i(18)$ - General Adverse Response: Noisiness (FAR 36)

$W_i(19)$ - Sleep Interference: Disruption (from A-weighted Sound Exposure Level)

$W_i(20)$ - Sleep Interference: Awakening (from A-weighted Sound Exposure Level)

8. (1 card)

OPTYP(M) - Distribution of operators among person types. Input percent for each of M=1 to 6 operator types in FORMAT (12F6.0).

9. (1 card)

Perc(I) - Percentage of each dwelling type having the appliance. Input for each of I=1 to 3 dwelling types in FORMAT (12F6.2).

10. (1 card)

ONTIM(I,N) - Length of time, in minutes/day, that appliance operates. If ONTIM is independent of N, input only first three numbers; program fills in the blanks. FORMAT (9F6.0).

11. (1 card)

TIM(I,N) - Length of each use in each building on each day. If TIM is independent of N, input only first three numbers; program fills in the blanks. FORMAT (9F6.0).

12. (1 card)

NT,MT - If NT equals 3, input three cards for TP9(P,I,N), N =1,3. If NT =1, TP9(P,I,N) is independent of N and input one card for TP9. (NT=1 for test case.) Program fills in the blanks. If MT equals 3 input three cards for RMP9(J,I,N), N =1,3. MT=1 if RMP9(P,I,N) is independent of N and input one card for RMP9. (MT=1 for test case.) Program fills in blanks. Free format (integers separated by commas).

13. (1 card)

TP9(P,I,1)-The relative probability of the appliance being operated in a given time period on a given type of day (The sum of TP9(P,I,1) over P must equal one). Input 1 card FORMAT (12F6.0).

14. (1 card)

RMP9 (J,I,1)- The relative probability of the appliance being operated in a given room type on a given type of day. (the sum of RMP9(J,I,1) over J must equal one.) Input 1 card FORMAT (18F6.0).

15. (1 card)

SPECTR(S) - Octave band levels (re arbitrary reference level) for the product in the particular mode of operation. The same spectrum shape is used for the sound power levels and the sound pressure levels at the operator position. Input data for each of the eight octave bands centered at frequencies from 0.063 to 8 kHz with S=1 corresponding to the 0.063 kHz band, etc. Input values for S=1 to 8 in FORMAT (12F6.2).

16. (1 card)

IDB, MIN, MAX, OPDFF - The stepsize (IDB), the minimum (MIN), and the maximum (MAX) sound power level of the source. OPDFF is the constant difference between the sound power level of source and the sound pressure level at the operator position. Input four numbers in free format (3 integers, 1 floating point number).

17. (1 card)

DISLEV(T) - The probability of the power level being in a particular decibel range specified by MIN, MAX,IDB (above). The number of levels is given by ((MAX-MIN)/IDB) + 1. Maximum of 18 values. Input in FORMAT (18F4.0).

Many of the data inputs required by the FORTRAN program will not necessarily change from product to product. These inputs are those corresponding to population parameters, data arrays TIMEIN and PEOPLE, and those corresponding to sound isolation, NRP and NRS. The data input has been, therefore, structured so that data which are not related to the product are input first, thus segregating them from product-related data inputs which will necessarily change with each class of products.

In addition to the data which must be input to the program on cards, limited data are in the program through FORTRAN DATA statements. These data include:

- U(ID) - Percent of speech unintelligibility as a function of discrete indoor A-weighted sound levels. The subscript ID runs from ID=1 to 16.

- LEV(IC) - A-weighted sound levels corresponding to the percent of speech unintelligibility defined by U. The subscript ID runs from IC=1 to 16.

- XDAYS(N) - Fraction of types of days in a year for N=1 to 3 day types.

- TPER(P) - Number of hours in each of the periods of the day for P=1 to 4 period types.

7. REFERENCES

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[3]. Yaniv, S. L., Evaluation of the effects of motor vehicle noise regulations on population, Motor Vehicle Noise Control, Special Report 152, pp. 77-84 (Transportation Research Board, National Research Council, Washington, D.C., 1975).

[4]. Noise Emission Standards for Construction Equipment: Background Document for Portable Air Compressors, Report No. EPA 550/9-76-004 (U.S. Environmental Protection Agency, Washington, D.C., December 1975).

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[6]. American Society of Heating, Refrigerating, and Air-Conditioning Engineers Methods of Testing for Sound Rating Heating, Refrigerating, and Air-Conditioning Equipment, 36-72 (American Society of Heating, Refrigerating, and Air-Conditioning Engineers, New York, New York, 1972).

[7]. Air Moving and Conditioning Association Test Code for Sound Rating, Standard 300-67 (Air Moving and Conditioning Association, Arlington, Heights, Illinois, 1967).

[8]. Society of Automotive Engineers Recommended Practice for Exterior Sound Level Measurement Procedures for Small Engine Powered Equipment, J1046 (Society of Automotive Engineers, Inc., Warrendale, Pennsylvania, 1974).

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APPENDIX A
EXISTING MEASUREMENT PROCEDURES

As was noted in the main body of the report, very few standards currently exist which specify how consumer product noise emission is to be measured. In addition, even though there is keen interest in developing such standards, there are such large differences among the various concerned parties regarding what ought to be measured, where, how and to what level of accuracy, that relatively few measurement standards have been proposed. A number of measurement standards which do exist are listed in one or both of the following publications:

Quindry, T. L. (Ed.), Standards on Noise Measurements, Rating Schemes, and Definitions: A Compilation, NBS Special Publication 386, (National Bureau of Standards, Washington, D.C. 1976).

Brenig, A., and Corcoran, P. A. (eds.), Index to Noise Standards, ASA STDS INDEX 1-1976 (Acoustical Society of America, New York, N.Y., 1976).

Later information on new or pending measurement standards can be obtained from the various organizations responsible for different classes of equipment. Addresses for most such organizations are listed in the two publications just cited.

APPENDIX B
CORRELATIONS AMONG RATINGS FOR DIFFERENT SPECTRA

A viable method for assigning noise ratings to consumer products will depend primarily upon:

- the identification of those physical parameters of the noise that are of concern from a public health and welfare viewpoint;

- a well-defined procedure for quantifying these noise parameters; and

- the ability to relate the results of measurement to human response to noise.

As demonstrated, for example, in several EPA documents [1-5]*, the accumulated evidence of research on human response to noise indicates that the magnitude of sound and its variation as a function of frequency and time are the primary physical parameters affecting human response.

Much psychoacoustic research has focused on schemes for combining the frequency content and overall intensity of the noise into a metric related to the perceived magnitude (e.g., loudness) of the noise, presumably as experienced by a person.

Although various investigators disagree somewhat as to the exact functional relationship between a noise stimulus and the perceived magnitude, there appears to be a consensus regarding the general form of the function. Loudness is generally thought to grow as a power function of sound pressure [6,8]. Each time the sound pressure level is increased by 10 dB, the loudness experienced increases by approximately a factor of two.

Psychoacoustic research has established that the human ear is not equally sensitive to sounds at all frequencies. Generally, people are more senstive to sounds in the middle of the audible frequency range (i.e., 1-4 kHz) than to either low or high frequency sounds. Two basic approaches are used to obtain physical measurements that account for the differential sensitivity of the ear to sounds of various frequencies. The simpler approach consists of applying a single filter designed such that the contributions from various frequencies are weighted in a manner that approximates the way in which the ear hears them. The more involved approach consists of analyzing the noise sound pressure level in each of a number of bands and then combining these band pressure levels using a computational procedure that yields a predictor of perceived magnitude.

The simpler A-,B-, and C- networks of sound level meters were originally intended to represent the frequency response of the ear to low, moderate and high sound pressure levels, respectively. However, over the years it

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* Numbers in square brackets refer to the references listed at the end of this appendix.

became apparent that, in real-life situations, the A-weighted sound pressure level is a relatively good predictor of human response to environmental noise [9, 10] over a large range of levels.

Kryter [11] has indicated that in many situations it is not how "loud" a sound is that is of concern, but rather how "noisy" and unwanted it is. Inherent is this statement is the assumption that "loudness" and "noisiness" represent somewhat different attributes of the human response to noise. Investigations carried out in the late 1950's by Kryter [12-15] suggest that this may be the case and that, although loudness is a major contributor to noisiness (the unwantedness of a given noise), the two concepts are not synonymous. In later work, however, Stevens [7] argued that loudness and noisiness are not distinguishable.

Since the criteria used in developing the A-weighted network were first reported in the 1930's [16], psychoacoustic research has indicated that, for certain types of noises, particularly those associated with aircraft, a different frequency weighting which increases the relative weight of the 1-4 kHz region may be more representative of human response than A-weighting. Several alternatives to this weighting function have been proposed and are usually referred to as "D-weightings". Very recently one of the D-weighting networks was standardized [17] for use in sound level meters. This network is currently restricted to the measurement of aircraft noise, since most of the experimental evidence behind D-weighting comes from studies involving aircrat noises. Some suggestions have been made that D-weighting may be more reliable than A-weighting in predicting human response to a greater variety of noises. However, no firm evidence exists to support the general application of D-weighting to noises other than aircraft noises. Consideration should be given to the possibility that a D-weighting may be appropriate for rating consumer products.

At the present time, however, A-weighted sound level is most widely used for measurements made with a sound level meter. However, the A-weighted sound level is only an approximate predictor of human response. In particular, one of the major difficulties with the A-weighted sound level is that tonal components are sometimes not adequately accounted for when data are obtained with the simple sound level meter. For these reasons various investigators have attempted to improve the accuracy of prediction by using more detailed descriptors than the simple frequency-weighted sound level obtained with a sound level meter.

Generally, refined schemes are based on segmentation of the sound pressure spectrum of a noise into a series of contiguous frequency bands by means of electrical networks so as to display the distribution of sound energy over the audible frequency range. From data thus obtained, a "loudness level" is computed by: (1) assigning to each frequency band a loudness index designed to represent the potential contribution to the perceived loudness of that band; (2) correcting this index by applying a weighting to account for the fact that bands with higher loudness indices may inhibit or mask the contributions of other bands; and (3) summing up the loudness indices to estimate the overall loudness level of the noise. A number of variants to this basic procedure are now in existence. These include the Stevens Mark VI [18] and Mark VII [19] loudness computations and procedures developed by Zwicker [20].

Kryter [11-13], following the computational schemes derived from loudness experiments, developed a new scale for assessing noise called the Perceived Noise Level. The difference between loudness computations and Kryter's method is that instead of assigning loudness indices to each measured band level, a perceived noisiness index is assigned. The unit of perceived noisiness is the noy and values are obtained from contours of equal "noisiness," rather than contours of equal loudness.

Since it was originally proposed in the late 1950's and early 1960's, the Perceived Noise Level methodology has been further refined to account for discrete frequency components of tones associated with aircraft noise as well as to account for the fact that, all else being equal, long duration flyovers are more annoying than short duration flyovers [14,15]. All of these developments involve detailed studies of noise spectra and complex computational procedures which are embodied in a rating procedure known as the Effective Perceived Noise Level [13].

Detailed frequency analyses are complex and require sophisticated equipment that must be operated by trained personnel. Obviously, noise measurements with a sound level meter are far less complicated. Thus, there is some merit in examining the feasibility of rating consumer products in terms of one of the weighted levels obtainable with a sound level meter. Furthermore, whatever rating scheme is used to rate consumer product noise, this rating must be referable to the criteria discussed in Section 5. However, such an approach would be justified only if the differences obtained between appliance ratings derived from complex measurements do not differ significantly from those derived from sound level meter measurements.

In addition to the type of approach chosen to perform frequency analysis, there is the added difficulty of choosing the rating scheme to be used. For example, should a product be rated in terms of A-weighted sound level or D-weighted sound level? Or, by assuming that detailed frequency analysis is performed, should one then compute loudness level or Perceived Noise Level? Moreover, which of the various computational procedures should be utilized? Should tonal components be accounted for in all cases?

Finally, another type of question must be answered. While ultimately it may not matter which scheme is used to rate similar spectra (as would be the case for products contained within one class), some rating schemes might be more sensitive than others to differences among significantly different spectra, such as those contained in different product classes (e.g., blender vs. dishwasher). Consequently, the rating schemes must be evaluated in terms of their sensitivity to spectral differences in the noise emission both between and within classes of products.

In the present study, an attempt has been made to address some of the questions discussed above. Several appliances, for which spectral data were available in the literature, were selected, and Pearson correlation coefficients between rating schemes were computed for each product. The six products chosen for these analyses were: garbage disposals, electric shavers, dishwashers, food mixers, blenders, and centrifugal fans. The actual spectra used to make the computations reported here are presented in Figures B-1 through B-6. Observations of these spectra reveal that, within a given class of product, spectra are similar in shape; but, significant differences exist in spectral shapes between classes of products.

From the spectral data shown above, A-,B-, C-, D-, and E-weighted sound levels were computed, as were loudness levels using the Stevens Mark VI [18] and Mark VII [19] procedures. In addition, two perceived noise levels were computed: one with a tone correction (using the method described in FAR-36) and one without tone corrections. These computations were performed for each set of appliances. From these data the average levels and their ranges were also computed for each rating scheme. In addition, the Pearson correlation coefficients were computed among rating schemes. The results of these calculations are presented in Tables B-1 through B-6. Three decimal places are shown in these tables to facilitate comparisons. However, the data do not warrant such precision.

As can be observed through inspection of the above tables, the correlation coefficients among all ratings for a given product are very high -- usually above 0.85 -- except for the garbage disposal where B- and C-weighted sound levels have lower correlation coefficients with other ratings than the other schemes. These data suggest that it does not matter which scheme is used to rate products which are in the same class, since the correlation among the various schemes is high. Of particular interest is the fact that, for the sets of spectral data examined, the more complicated (loudness or noisiness) schemes, whether they make use of tone corrections or not, correlate highly with A-, D-, and E-weighted levels. Thus, on the basis of these analyses it could be argued that, for rating consumer products, any rating scheme is as good as any other, except for B- and C-weighting (see Tables B-1 through B-6). Consequently, for simplicity's sake, as well as for consistency with other regulatory actions involving other types of noise sources (e.g., trucks, air compressors) and with the criteria discussed in the EPA Levels Document, the A-weighted level would appear to be as reasonable a choice as any other for rating household products. (Note that these are correlations among ratings and not between ratings and subjective responses. Thus high correlations merely indicate that a pair of ratings are either about equally good or about equally bad in terms of their ability to predict human responses.)

Although correlation coefficients are often used to justify the use of a rating scheme, it should be observed that this approach in conjunction with this particular study could be somewhat misleading. For the range of intensity and frequency which are of concern in this study, if the overall sound pressure level is raised by, say, 10 dB, then any of the ratings would also be raised by a similar amount for any spectrum shape. The reason for this is that in the region between approximately 0.05 to 8 kHz and for low to moderate noise levels, the loudness contours (which are the basis for most of the rating schemes) are roughly parallel. Thus, the ratings are not independent variables. As a consequence, the larger the range of sound levels, the larger the correlation coefficent will be among the rating schemes. In terms of practicality, what this means is that if loudness contours are exactly parallel and if the spectra of consumer products are identical, then any two rating schemes could be related by an additive constant. One could predict what one rating would be from the actual rating obtained by simply adding some constant (i.e., the E-weighted sound level could be predicted from the A-weighted sound level by adding a constant).

However, since the loudness contours are only roughly parallel and since spectra within a given class of products are not exactly identical, the additive constant used to predict one rating from another will vary around some mean value. The standard deviation around this mean value is a measure of how well one can predict one rating scheme from another, for either similar spectra or significantly different spectra. Figure B-7 shows schematically what is meant by the above discussion in terms of predicting loudness level computed according to Stevens Mark VI method from a knowledge of the A-weighted level.

Using the rationale given above, standard deviations were computed for the additive constants that would be used to predict one rating from another (the Zwicker loudness [20] was added for these calculations). The spectra which were used to compute these standard deviation are those shown in Figures B-1 through B-6. The results of these computations for each product are given in Tables B-7 through B-12.

As can be seen from inspection of these tables, the A-, D-, and E-weighted sound levels can be predicted from each other well since the standard deviation is usually small. On the other hand, the B- and C-weighted sound levels cannot be predicted as well from the other weighted levels, as demonstrated by the fact that the standard deviation is usually larger. The loudness levels as computed by the Stevens Mark VI, Mark VII, and Zwicker procedures and the Perceived Noise Levels, whether tone corrected or not, do not appear to improve significantly predictability relative to the simple weighted levels (A, D and E). Thus in terms of a given product class, A-, D-, and E-weighted sound levels are as "good" as more complex methods to predict one rating from another.

Table B-13 is a summary of the same kind of computations, except that it displays the standard deviation around the mean of additive constants used to predict one scheme from another for all the products considered within this study. This table was derived by aggregating all spectra for the 6 products studied, thus looking at the effect of significantly varied spectral shapes. The results of Table B-13 are similar to those discussed for each individual product and indicate that use of either A-, D-, and E-weighted sound level is appropriate also for differentiating among several types of products that have significant spectral differences. After the analyses described in the appendix were completed, a parallel EPA-funded study [21] was published that compares various noise rating procedures.

TABLE B-1. 8 GARBAGE DISPOSALS (MEASURED AT 1 m)

	MEAN (dB)	RANGE (dB)	PEARSON CORRELATION COEFFICIENT								
			L_A	L_B	L_C	L_D	L_E	$L_{L(VI)}$	$L_{L(VII)}$	L_{PN}	L_{PNT}
L_A	67.6	10.6	1	.674	.587	.966	.946	.844	.908	.913	.961
L_B	71.9	10.5	.674	1	.972	.656	.744	.723	.596	.736	.648
L_C	74.3	10.4	.587	.972	1	.610	.696	.701	.566	.686	.608
L_D	74.8	12.2	.966	.656	.610	1	.985	.830	.918	.888	.988
L_E	72.9	11.3	.946	.744	.696	.985	1	.794	.866	.857	.966
$L_{L(VI)}$	80.8	9.6	.844	.723	.701	.830	.794	1	.941	.988	.853
$L_{L(VII)}$	68.6	10.6	.908	.596	.566	.918	.866	.941	1	.957	.945
L_{PN}	81.1	11.7	.913	.736	.686	.888	.857	.988	.957	1	.902
L_{PNT}	83.6	12.7	.961	.648	.608	.988	.966	.853	.945	.902	1

TABLE B-2. 12 ELECTRIC SHAVERS (MEASURED AT 1 m)

	MEAN (dB)	RANGE (dB)	PEARSON CORRELATION COEFFICIENT								
			L_A	L_B	L_C	L_D	L_E	$L_{L(VI)}$	$L_{L(VII)}$	L_{PN}	L_{PNT}
L_A	58.8	28.0	1	.998	.996	.996	.993	.977	.966	.979	.993
L_B	57.8	27.8	.998	1	.999	.988	.984	.969	.953	.971	.991
L_C	58.0	27.8	.996	.999	1	.987	.983	.972	.953	.973	.990
L_D	66.9	29.0	.996	.988	.987	1	.998	.984	.975	.982	.990
L_E	64.3	28.4	.993	.984	.983	.998	1	.972	.964	.969	.991
$L_{L(VI)}$	70.7	25.5	.977	.969	.972	.984	.972	1	.993	.998	.959
$L_{L(VII)}$	60.1	23.7	.966	.953	.953	.975	.964	.993	1	.994	.943
L_{PN}	70.3	29.1	.979	.971	.973	.982	.969	.998	.994	1	.959
L_{PNT}	73.6	30.4	.993	.991	.990	.990	.991	.959	.943	.959	1

TABLE B-3. 6 DISHWASHERS (MEASURED AT 1 m)

	MEAN (dB)	RANGE (dB)	PEARSON CORRELATION COEFFICIENT								
			L_A	L_B	L_C	L_D	L_E	$L_{L(VI)}$	$L_{L(VII)}$	L_{PN}	L_{PNT}
L_A	65.9	16.0	1	.942	.921	.966	.971	.982	.952	.983	.963
L_B	72.7	21.1	.942	1	.989	.996	.994	.952	.837	.966	.975
L_C	75.8	22.6	.921	.989	1	.986	.976	.950	.839	.960	.970
L_D	72.7	20.0	.966	.996	.986	1	.998	.971	.877	.982	.984
L_E	71.3	19.2	.971	.994	.976	.998	1	.968	.875	.980	.981
$L_{L(VI)}$	80.1	14.9	.982	.952	.950	.971	.968	1	.957	.997	.979
$L_{L(VII)}$	66.3	12.9	.952	.837	.839	.877	.875	.957	1	.934	.884
L_{PN}	79.9	18.1	.983	.996	.960	.982	.980	.997	.934	1	.992
L_{PNT}	82.1	19.2	.963	.975	.970	.984	.981	.979	.844	.992	1

TABLE B-4. 7 FOOD MIXERS (MEASURED AT 1 m)

	MEAN (dB)	RANGE (dB)	PEARSON CORRELATION COEFFICIENT								
			L_A	L_B	L_C	L_D	L_E	$L_{L(VI)}$	$L_{L(VII)}$	L_{PN}	L_{PNT}
L_A	69.1	15.5	1	.992	.982	.999	.994	.958	.973	.958	.993
L_B	69.5	15.4	.992	1	.998	.989	.991	.951	.971	.945	.993
L_C	70.1	.5.5	.982	.998	1	.979	.987	.936	.961	.926	.988
L_D	76.1	16.1	.999	.989	.979	1	.996	.953	.969	.953	.992
L_E	73.4	17.5	.994	.991	.987	.996	1	.932	.956	.930	.997
$L_{L(VI)}$	80.4	16.5	.958	.951	.936	.953	.932	1	.995	.997	.928
$L_{L(VII)}$	69.4	17.4	.973	.971	.961	.969	.956	.995	1	.989	.952
L_{PN}	81.4	18.2	.958	.945	.926	.953	.930	.997	.989	1	.927
L_{PNT}	84.3	13.6	.993	.993	.988	.992	.997	.928	.952	.927	1

TABLE B-5. 8 BLENDERS (MEASURED AT 1 m)

	MEAN (dB)	RANGE (dB)	PEARSON CORRELATION COEFFICIENT								
			L_A	L_B	L_C	L_D	L_E	$L_{L(VI)}$	$L_{L(VII)}$	L_{PN}	L_{PNT}
L_A	79.2	29.9	1	.994	.989	.992	.994	.984	.988	.980	.994
L_B	78.9	31.1	.994	1	.999	.973	.980	.963	.973	.957	.989
L_C	79.1	31.2	.989	.999	1	.965	.974	.956	.966	.949	.985
L_D	86.5	29.8	.992	.973	.965	1	.998	.982	.987	.980	.981
L_E	83.5	29.9	.994	.980	.974	.998	1	.975	.983	.971	.981
$L_{L(VI)}$	89.0	27.3	.984	.963	.956	.992	.975	1	.998	.999	.973
$L_{L(VII)}$	77.4	27.8	.989	.973	.966	.987	.983	.998	1	.995	.976
L_{PN}	91.5	29.4	.980	.957	.949	.980	.971	.999	.995	1	.973
L_{PNT}	94.8	29.4	.994	.989	.985	.981	.981	.973	.976	.973	1

TABLE B-6. 16 CENTRIFUGAL FANS (MEASURED AT 1 m)

	MEAN (dB)	RANGE (dB)	PEARSON CORRELATION COEFFICIENT								
			L_A	L_B	L_C	L_D	L_E	$L_{L(VI)}$	$L_{L(VII)}$	L_{PN}	L_{PNT}
L_A	43.5	59.2	1	.997	.993	.999	.999	.993	.997	.998	.999
L_B	47.6	59.5	.977	1	.999	.997	.998	.989	.991	.994	.995
L_C	50.4	58.5	.993	.999	1	.994	.994	.984	.986	.990	.990
L_D	49.6	59.9	.999	.997	.994	1	1.000	.995	.997	.999	.999
L_E	47.9	59.5	.999	.998	.994	1.000	1	.994	.996	.998	.999
$L_{L(VI)}$	50.9	68.5	.993	.989	.984	.995	.994	1	.997	.996	.996
$L_{L(VII)}$	39.8	66.0	.997	.991	.986	.997	.996	.997	1	.999	.998
L_{PN}	51.0	67.8	.998	.994	.990	.999	.998	.996	.999	1	.999
L_{PNT}	57.3	64.5	.999	.995	.990	.999	.999	.996	.998	.999	1

TABLE B-7. STANDARD DEVIATIONS for 8 GARBAGE DISPOSERS (MEASURED AT 1 m)

	MEAN (dB)	RANGE (dB)	STANDARD DEVIATION (dB) L_A	L_B	L_C	L_D	L_E	$L_{L(VI)}$	$L_{L(VII)}$	$L_{L(Z)}$	L_{PN}	L_{PNT}
L_A	67.6	10.6	0	2.6	3.0	1.1	1.1	1.8	1.6	1.6	1.5	1.3
L_B	71.9	10.5	2.6	0	0.8	3.0	2.4	2.4	2.4	3.2	2.5	3.2
L_C	74.3	10.4	3.0	0.8	0	3.2	2.7	2.5	2.6	3.3	2.8	3.4
L_D	74.8	12.2	1.1	3.0	3.2	0	0.7	2.2	2.0	1.5	1.8	0.7
L_E	72.9	11.3	1.1	2.4	2.7	0.7	0	2.1	2.0	1.8	1.9	1.2
$L_{L(VI)}$	80.8	9.6	1.8	2.4	2.5	2.2	2.1	0	0.3	1.8	0.8	2.2
$L_{L(VII)}$	72.2	9.6	1.6	2.4	2.6	2.0	2.0	0.3	0	1.6	0.8	2.0
$L_{L(Z)}$	85.7	9.95	1.6	3.2	3.3	3.3	1.5	1.8	1.6	0	1.7	1.2
L_{PN}	81.1	11.7	1.5	2.5	2.8	1.8	1.9	0.8	0.8	1.7	0	1.8
L_{PNT}	83.6	12.7	1.3	3.2	3.4	0.7	1.2	2.2	2.0	1.2	1.8	0

TABLE B-8. STANDARD DEVIATIONS for 8 BLENDERS (MEASURED AT 1 m)

	MEAN (dB)	RANGE (dB)	L_A	STANDARD DEVIATION (dB) L_B	L_C	L_D	L_E	$L_{L(VI)}$	$L_{L(VII)}$	$L_{L(Z)}$	L_{PN}	L_{PNT}
L_A	79.2	29.9	0	1.0	1.4	1.2	1.0	1.7	1.4	1.7	1.9	1.1
L_B	78.9	31.1	1.0	0	0.3	2.2	1.8	2.5	2.3	1.5	2.8	1.4
L_C	79.1	31.3	1.4	0.3	0	2.5	2.1	2.7	2.5	1.5	3.1	1.7
L_D	86.5	29.8	1.2	2.2	2.5	0	0.6	1.9	1.5	2.4	1.9	1.8
L_E	83.5	29.9	1.0	1.8	2.1	0.6	0	2.1	1.6	1.9	2.3	1.8
$L_{L(VI)}$	89.0	27.3	1.7	2.5	2.7	1.9	2.1	0	0.5	2.6	1.0	2.3
$L_{L(VII)}$	80.9	28.6	1.4	2.3	2.5	1.5	1.6	0.5	0	2.4	1.0	2.1
$L_{L(Z)}$	94.1	27.8	1.7	1.5	1.5	2.4	1.9	2.6	2.4	0	3.3	2.4
L_{PN}	91.5	29.4	1.9	2.8	3.1	1.9	2.3	1.0	1.0	3.3	0	2.2
L_{PNT}	94.8	29.4	1.1	1.4	1.7	1.8	1.8	2.3	2.1	2.4	2.2	0

TABLE B-9. STANDARD DEVIATIONS FOR FANS (MEASURED AT 1m)

	MEAN (dB)	RANGE (dB)	STANDARD DEVIATION (dB) L_A	L_B	L_C	L_D	L_E	$L_{L(VI)}$	$L_{L(VII)}$	$L_{L(Z)}$	L_{PN}	L_{PNT}
L_A	59.8	15.7	0	2.1	3.5	1.4	1.0	1.4	0.6	1.2	2.0	2.3
L_B	66.6	19.5	2.1	0	1.6	0.8	1.2	1.0	1.9	1.2	0.7	0.7
L_C	69.9	21.1	3.5	1.6	0	2.3	2.7	2.2	3.2	2.5	2.0	1.9
L_D	66.6	18.5	1.4	0.8	2.3	0	0.4	0.8	1.2	0.8	0.7	1.0
L_E	65.0	17.3	1.0	1.2	2.7	0.4	0	0.9	1.0	0.8	1.0	1.3
$L_{L(VI)}$	75.3	17.4	1.4	1.0	2.2	0.8	0.9	0	1.1	0.4	1.2	1.4
$L_{L(VII)}$	65.9	15.4	0.6	1.9	3.2	1.2	1.0	1.1	0	0.8	1.9	2.2
$L_{L(Z)}$	79.1	16.8	1.2	1.2	2.5	0.8	0.8	0.4	0.8	0	1.3	1.6
L_{PN}	74.3	20.2	2.0	0.7	2.0	0.7	1.0	1.2	1.9	1.3	0	0.4
L_{PNT}	76.2	20.5	2.3	0.7	1.9	1.0	1.3	1.4	2.2	1.6	0.4	0

TABLE B-10 STANDARD DEVIATIONS FOR 12 ELECTRIC SHAVERS (MEASURED AT 1m)

	MEAN (dB)	RANGE (dB)	STANDARD DEVIATION (dB) L_A	L_B	L_C	L_D	L_E	$L_{L(VI)}$	$L_{L(VII)}$	$L_{L(Z)}$	L_{PN}	L_{PNT}
L_A	58.8	28.0	0	0.6	0.7	0.9	1.0	1.7	2.2	1.1	1.9	1.2
L_B	57.8	27.8	0.6	0	0.3	1.4	1.5	2.0	2.4	0.9	2.2	1.4
L_C	58.0	27.8	0.7	0.3	0	1.4	1.6	1.9	2.4	0.7	2.2	1.4
L_D	66.9	29.0	0.9	1.4	1.4	0	0.6	1.6	2.2	1.7	1.7	1.2
L_E	64.3	28.4	1.0	1.5	1.6	0.6	0	2.0	2.6	1.8	2.2	1.2
$L_{L(VI)}$	70.7	25.7	1.7	2.0	1.9	1.6	2.0	0	0.8	1.6	1.2	2.5
$L_{L(VII)}$	62.5	24.4	2.2	2.4	2.4	2.2	2.6	0.8	0	2.0	1.4	3.1
$L_{L(Z)}$	75.0	26.6	1.1	0.9	0.7	1.7	1.8	1.6	2.0	0	2.0	1.9
L_{PN}	70.3	29.1	1.9	2.2	2.2	1.7	2.2	1.2	1.4	2.0	0	2.5
L_{PNT}	73.6	30.4	1.2	1.4	1.4	1.2	1.2	2.5	3.1	1.9	2.5	0

TABLE B-11. STANDARD DEVIATIONS FOR 6 DISHWASHERS (MEASURED AT 1 m)

	MEAN (dB)	RANGE (dB)	STANDARD DEVIATION (dB)									
			L_A	L_B	L_C	L_D	L_E	$L_{L(VI)}$	$L_{L(VII)}$	$L_{L(Z)}$	L_{PN}	L_{PNT}
L_A	65.9	16.0	0	2.6	3.5	2.0	1.7	1.1	1.1	1.7	1.3	1.9
L_B	72.7	21.1	2.6	0	1.3	0.7	1.0	2.6	3.0	3.7	1.9	1.7
L_C	75.8	22.6	3.5	1.3	0	1.7	2.1	3.2	3.6	4.0	2.5	2.2
L_D	72.5	20.0	2.0	0.7	1.7	0	0.5	1.9	2.3	3.0	1.3	1.2
L_E	71.3	19.2	1.7	1.0	2.1	0.5	0	1.8	2.2	2.9	1.3	1.3
$L_{L(VI)}$	80.1	14.9	1.1	2.6	3.2	1.9	1.8	0	0.7	1.3	1.0	1.6
$L_{L(VII)}$	71.1	13.7	1.3	3.0	3.6	2.3	2.2	0.7	0	1.1	1.6	2.3
$L_{L(Z)}$	84.1	13.3	1.7	3.7	4.0	3.0	2.9	1.3	1.1	0	2.0	2.7
L_{PN}	79.9	18.1	1.3	1.9	2.5	1.3	1.3	1.0	1.6	2.0	0	0.8
L_{PNT}	82.1	19.2	1.9	1.7	2.2	1.2	1.3	1.6	2.3	2.7	0.8	0

TABLE B-12. STANDARD DEVIATIONS FOR 7 FOOD MIXERS (MEASURED AT 1 m)

	MEAN (dB)	RANGE (dB)	STANDARD DEVIATION (dB)									
			L_A	L_B	L_C	L_D	L_E	$L_{L(VI)}$	$L_{L(VII)}$	$L_{L(Z)}$	L_{PN}	L_{PNT}
L_A	69.1	15.5	0	0.8	1.3	0.5	0.8	1.8	1.9	1.0	2.0	0.7
L_B	69.5	15.4	0.8	0	0.5	1.1	1.0	2.0	1.9	0.3	2.3	0.8
L_C	70.1	15.5	1.3	0.5	0	1.5	1.3	2.2	2.2	0.3	2.6	1.1
L_D	76.1	16.1	0.5	1.1	1.5	0	0.6	2.1	2.1	1.2	2.1	0.9
L_E	73.4	17.5	0.8	1.0	1.3	0.6	0	2.5	2.5	1.1	2.6	0.7
$L_{L(VI)}$	80.4	16.5	1.8	2.0	2.2	2.1	2.5	0	0.3	2.1	0.8	2.4
$L_{L(VII)}$	72.1	16.9	1.9	1.9	2.2	2.1	2.5	0.3	0	2.1	0.8	2.4
$L_{L(Z)}$	86.3	15.3	1.0	0.3	0.3	1.2	1.1	2.1	2.1	0	2.5	0.9
L_{PN}	81.4	18.2	2.0	2.3	2.6	2.1	2.6	0.8	0.8	0.8	0	2.6
L_{PNT}	84.3	16.4	0.7	0.8	1.1	0.9	0.7	2.4	2.4	2.4	2.6	0

TABLE B-13 STANDARD DEVIATION FOR THE 6 PRODUCTS OF TABLES B-7 THROUGH B-12

	MEAN (dB)	STANDARD DEVIATION (dB)									
		L_A	L_B	L_C	L_D	L_E	$L_{L(VI)}$	$L_{L(VII)}$	$L_{L(Z)}$	L_{PN}	L_{PNT}
L_A	66.3	0	3.6	5.0	1.2	1.2	2.4	2.1	1.9	2.0	1.5
L_B	68.6	3.6	0	1.5	4.0	3.5	2.8	3.2	2.9	3.0	3.2
L_C	70.0	5.0	1.5	0	5.4	4.8	3.8	4.3	4.0	4.3	4.5
L_D	73.7	1.2	4.0	5.4	0	0.8	2.7	2.5	2.5	2.2	1.6
L_E	71.4	1.2	3.5	4.8	0.8	0	2.4	2.3	2.2	2.2	1.4
$L_{L(VI)}$	78.7	2.4	2.8	3.8	2.7	2.4	0	0.8	1.8	1.5	2.6
$L_{L(VII)}$	70.2	2.1	3.2	4.3	2.5	2.3	0.8	0	1.8	1.5	2.6
$L_{L(Z)}$	83.4	1.9	2.9	4.0	2.5	2.2	1.8	1.8	0	2.2	2.1
L_{PN}	79.1	2.0	3.0	4.3	2.2	2.2	1.5	1.5	2.2	0	2.0
L_{PNT}	81.9	1.5	3.2	4.5	1.6	1.4	2.6	2.6	2.1	2.0	0

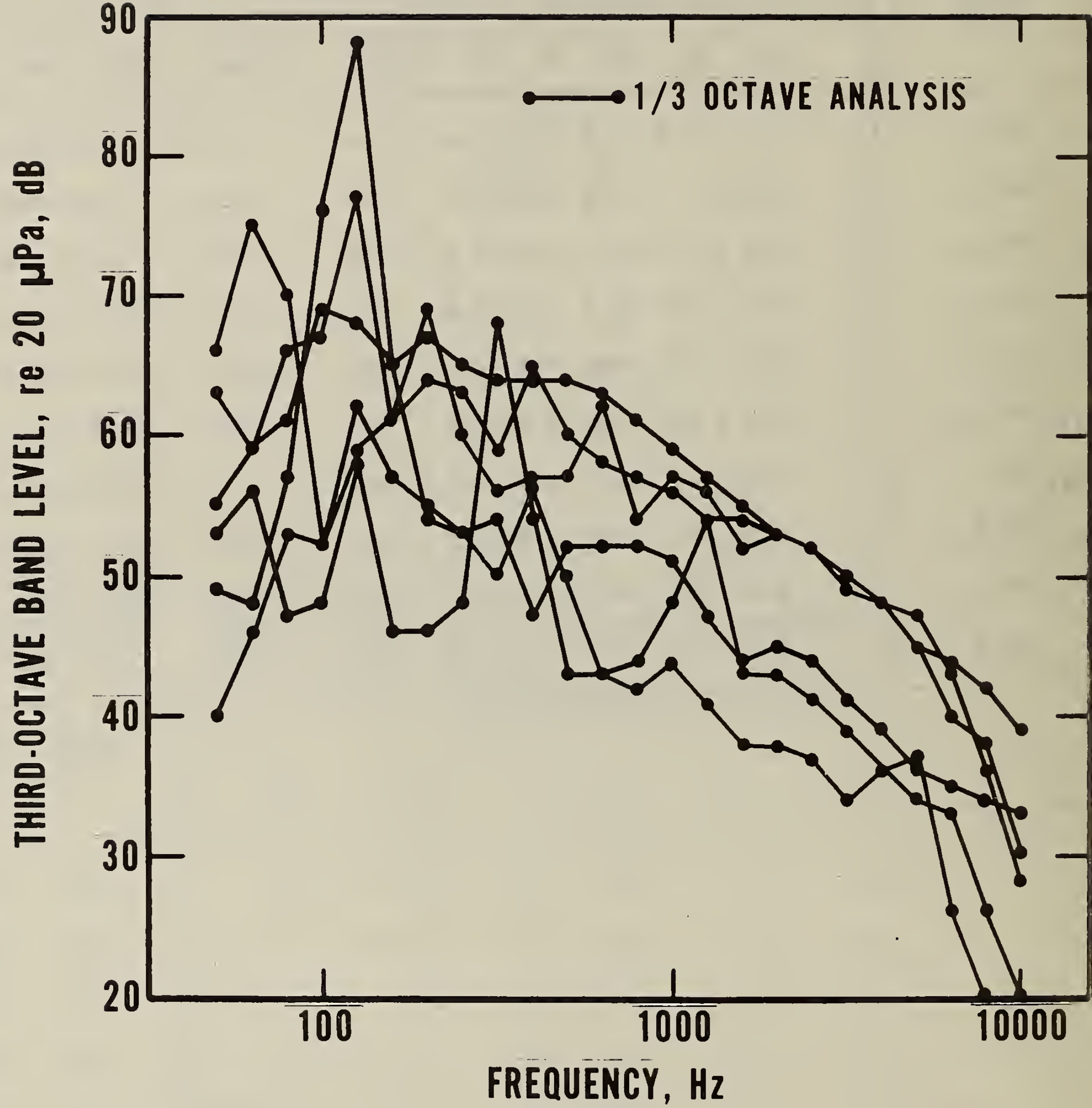


Figure B-1. Frequency spectra for dishwashers.

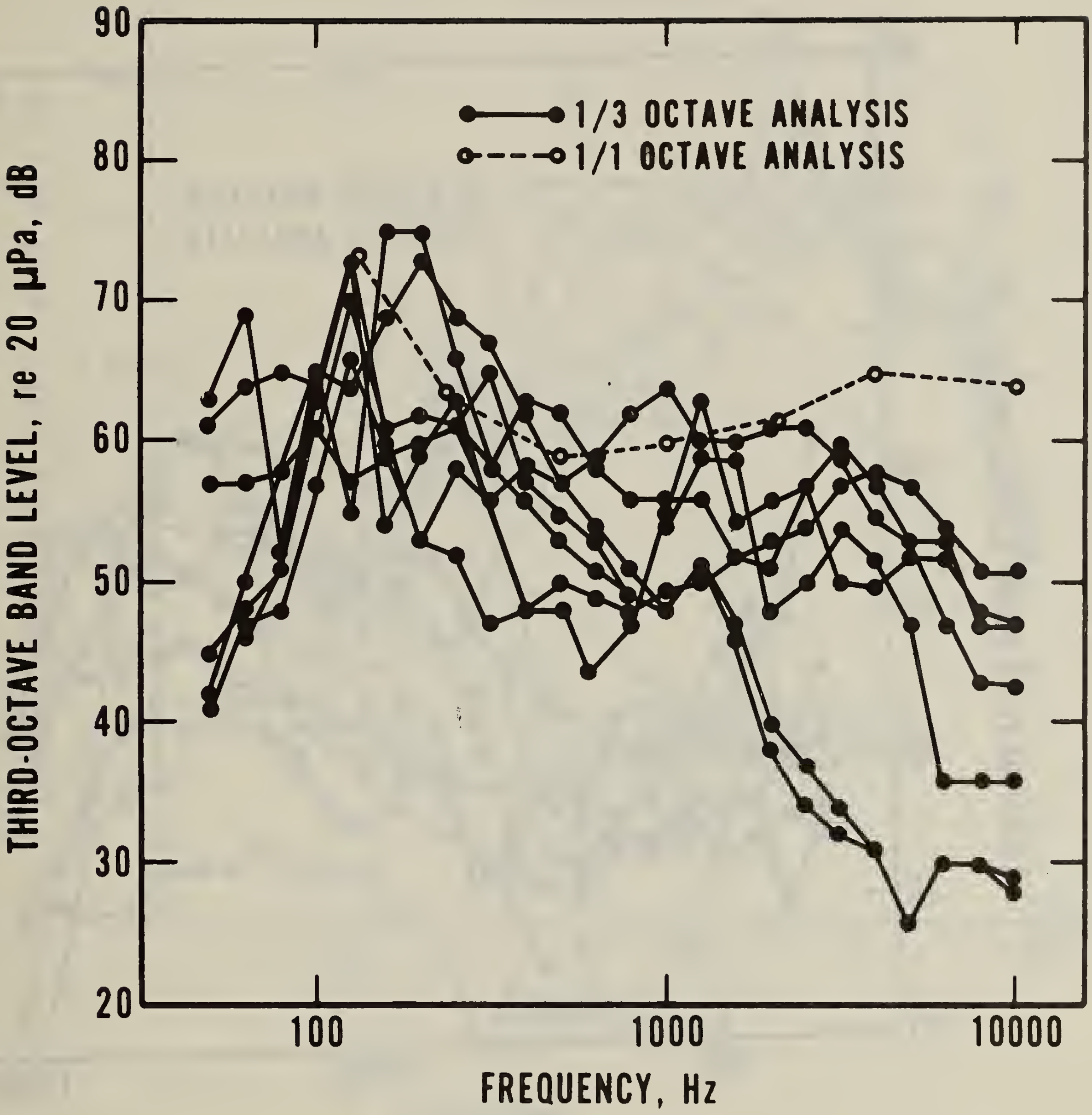


Figure B-2. Frequency spectra for garbage disposals.

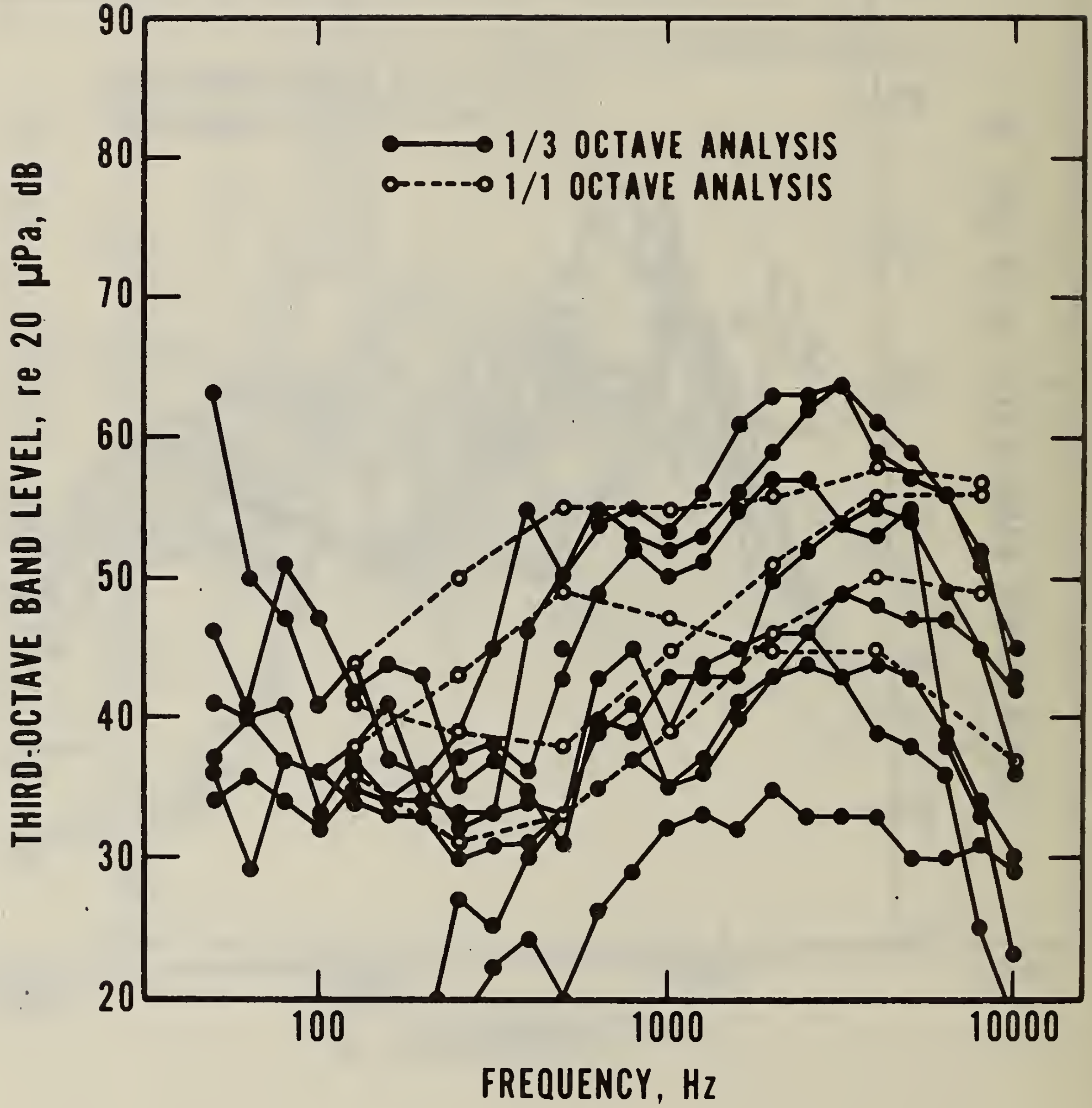


Figure B-3. Frequency spectra for electric shavers.

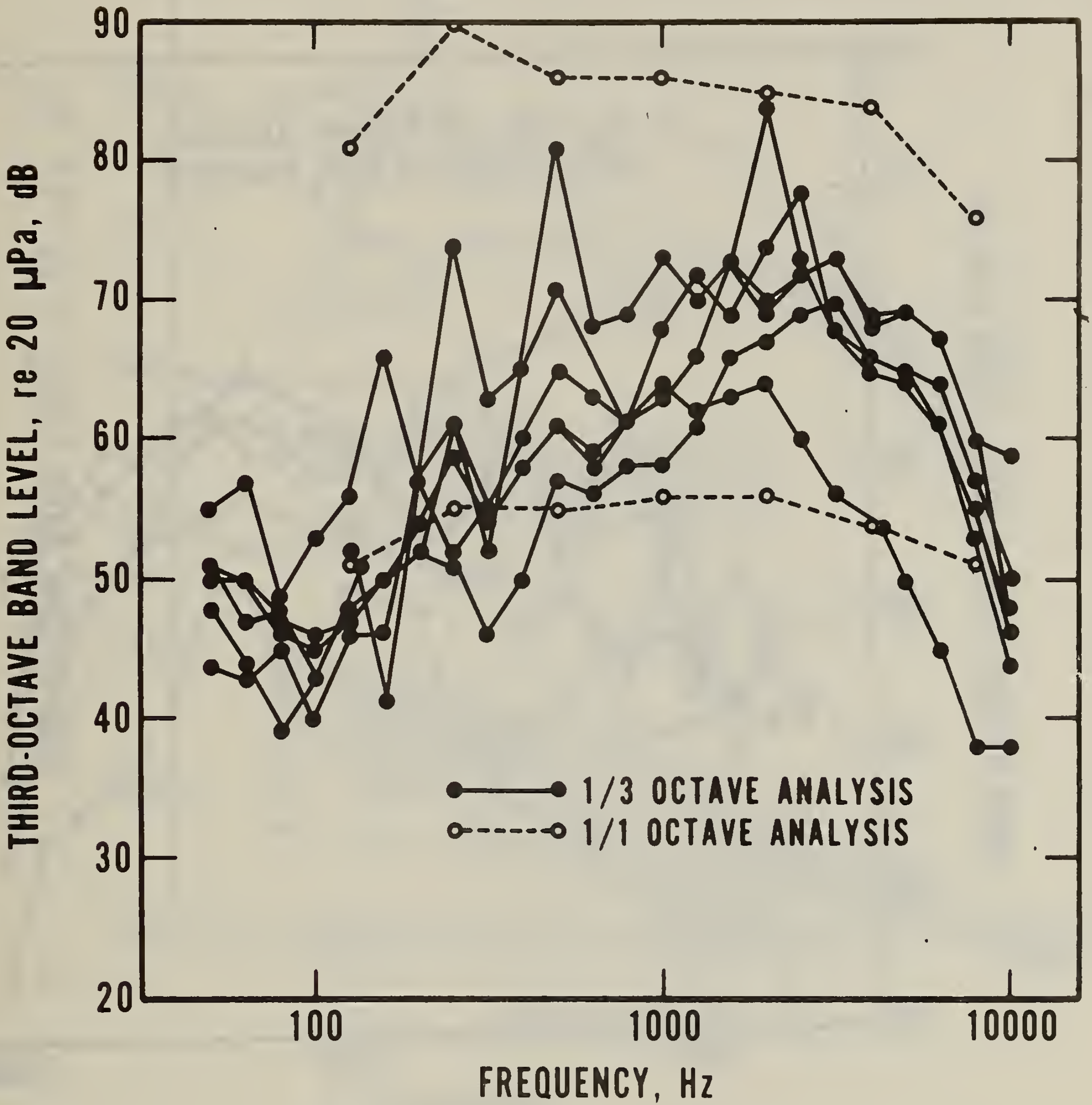


Figure B-4. Frequency spectra for food blenders.

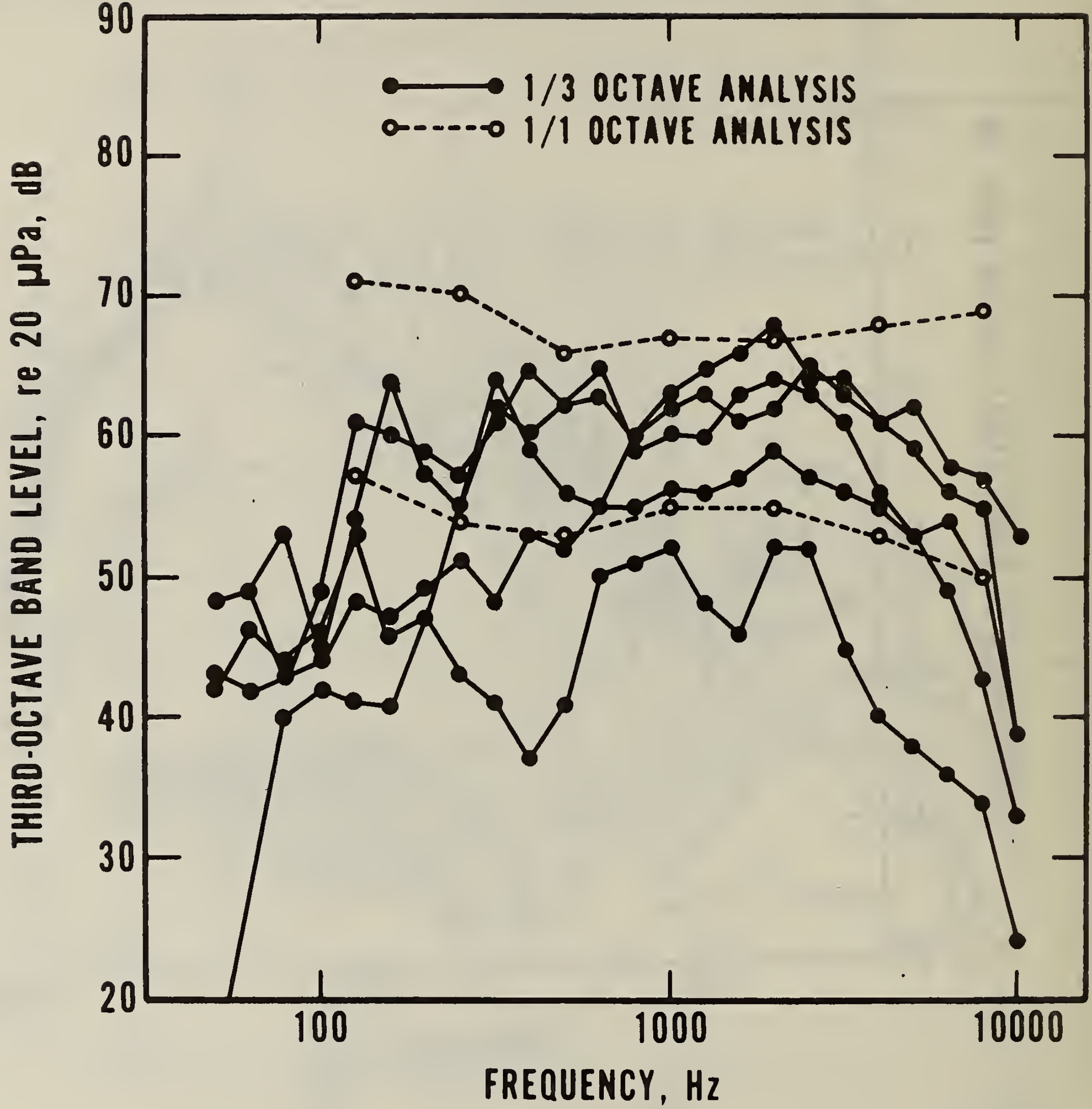


Figure B-5. Frequency spectra for food mixers.

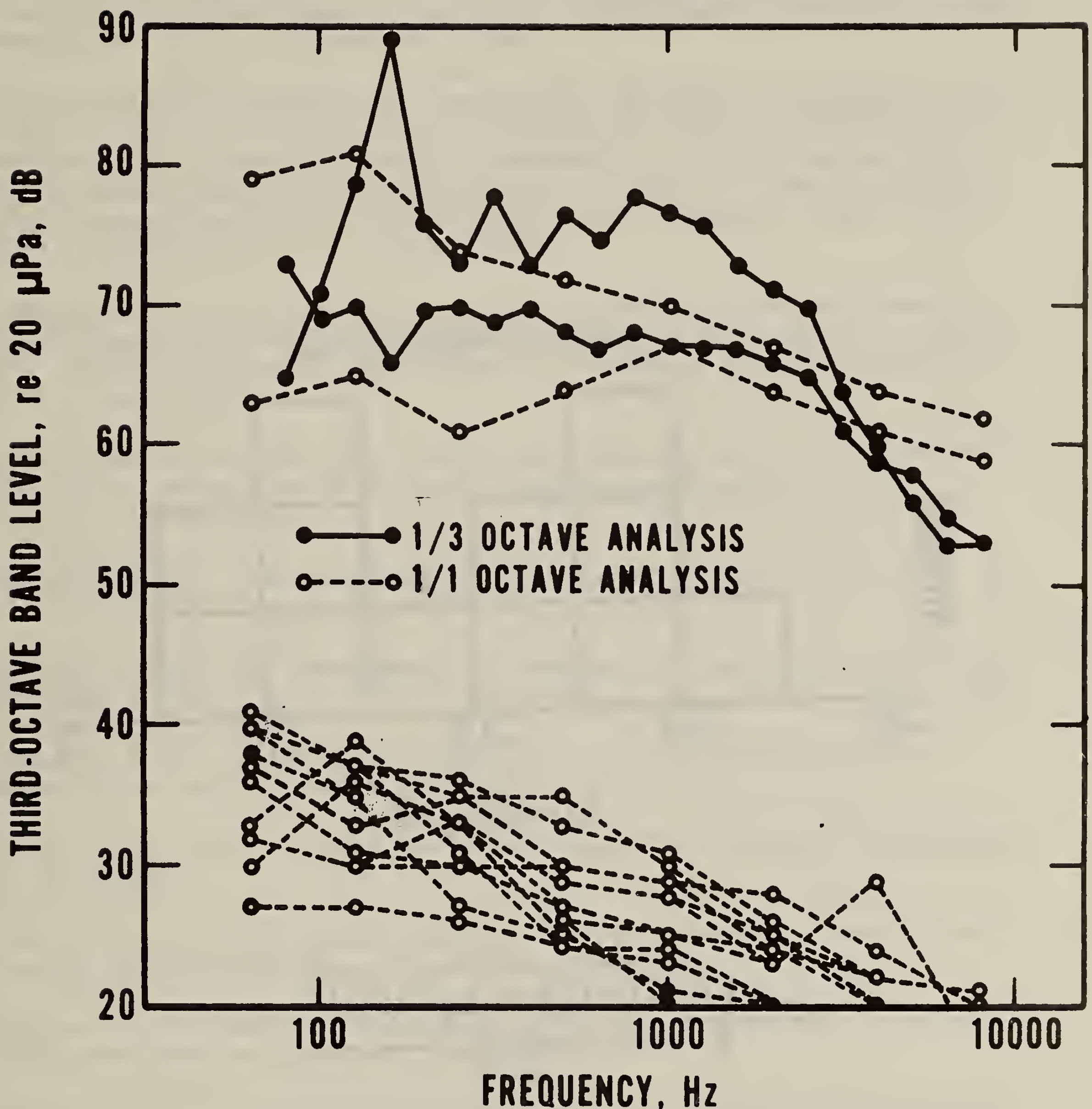
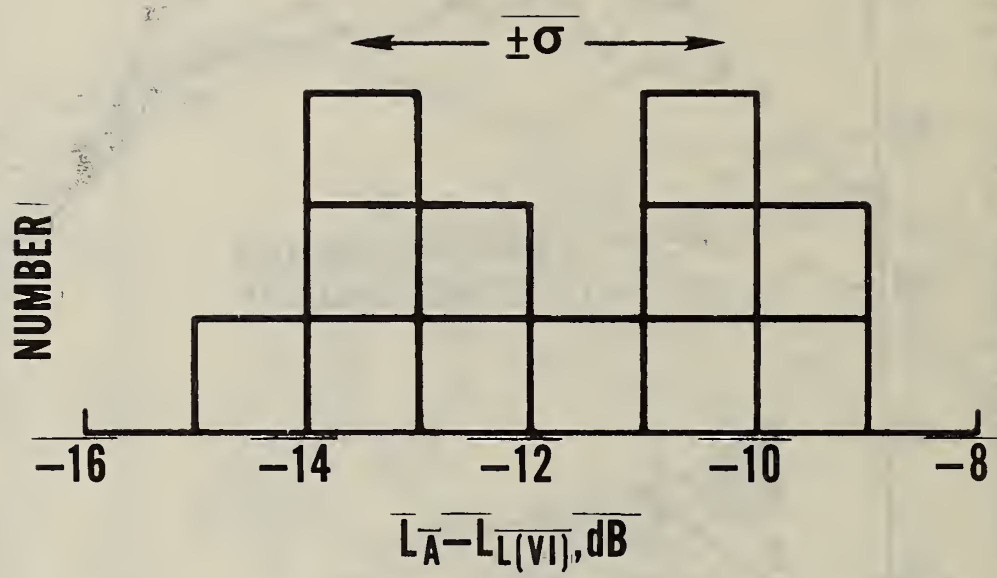


Figure B-6. Frequency spectra for centrifugal fans.



$$\sigma = \sqrt{\frac{\left[(L_A - L_L) - \langle L_A - L_L \rangle\right]^2}{n-1}}$$

Figure B-7. Schematic presentation of the variation in the standard deviation of the additive constant used to predict one rating from another, e.g., loudness level from A-weighted level.

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APPENDIX C

LISTING OF COMPUTER PROGRAM FOR ASSESSING THE IMPACT OF NOISE FROM CONSUMER PRODUCTS

C.1 Main Program

```
C      THIS CODES COMPUTES POPULATION IMPACTS FOR NOISE FROM HOUSEHOLD
C                   APPLIANCES AND CONSUMER PRODUCTS
C
C      I DESIGNATES TYPE OF DWELLING
C       I=1,SINGLE FAMILY  I=2,TOWNHOUSE  I=3,MULTIFAMILY
C      J DESIGNATES SOURCE ROOM
C      J=1,KIT  J=2,LR-DR-FR  J=3,BATH  J=4,BEDRM  J=5,BASEMENT-UTIL-GAR
C       J=6,OUTDOORS
C      K DESIGNATES RECEIVING ROOM WITHIN PRIMARY DWELLING
C      K SAME AS J
C      L DESIGNATES RECEIVING ROOM WITHIN SECONDARY DWELLING
C     L SAME AS J
C      M DESIGNATES TYPE OF PERSON
C       M=1,UNEM ADULT MALE  M=2,EM ADULT MALE  M=3,UNEM ADULT FEM
C      M=4,EM ADULT FEM  M=5,SCHOOL AGE CHILD M=6,PRESCHOOL CHILD
C      N DESIGNATES TYPE OF DAY
C    N=1,WEEKDAY(SCHOOL)  N=2,WEEKDAY(NO SCHOOL)  N=3,WEEKEND
C      P DESIGNATES TIME-PERIOD DURING DAY
C       P=1,0700-0900  P=2,0900-1700  P=3,1700-2200  P=4,2200-0700
C     S DESIGNATES THE OCTAVE BAND(S=1 FOR 63 HZ,S=2 FOR 125 HZ, ETC.)
C    T DESIGNATES THE SOUND POWER LEVEL OF THE SOURCE. A MAXIMUM OF 20
C          LEVELS IS ALLOWED,E.G. 20 DB IN 1 DB STEPS, 40 DB IN 2 DB STEPS
C      NRP(S,K,J,I) DESIGNATES NOISE REDUCTION WITHIN PRIMARY DWELLING
C      NRS(S,L,J,I) DESIGNATES NOISE REDUCTION BETWEEN PRIMARY DWELLING
C                   AND A SECONDARY DWELLING
C      TIMEIN(I,K,M,P,N) DESIGNATES THE LENGTH OF TIME DIFFERENT TYPES
C                   OF PEOPLE SPEND IN DIFFERENT TYPES OF ROOMS IN
C                   DIFFERENT TYPES OF DWELLINGS FOR DIFFERENT TIME
C                   PERIODS ON DIFFERENT TYPES OF DAY(IN MINUTES)
C      PEOPLE(I,M) DESIGNATES THE TOTAL NUMBER OF PEOPLE
C                   OF A GIVEN TYPE THAT LIVE IN A GIVEN TYPE OF
C                   DWELLING(IN MILLIONS)
C TIM(I,N) IS AVERAGE LENGTH OF EACH USE IN EACH BUILDING
C     ONTIM(I,N) IS AVERAGE LENGTH OF TIME IN MINUTES/DAY
C         A GIVEN PRODUCT OPERATES IN A GIVEN TYPE OF DWELLING
C       ON A GIVEN TYPE OF DAY
C      SPECTR(S)  DESIGNATES THE     OCTAVE BAND LEVEL, RELATIVE TO THE
C                   A-WEIGHTED LEVEL, FOR A GIVEN TYPE OF PRODUCT.
C                   IT IS ASSUMED THAT THE
C                   SPECTRUM SHAPE IS THE SAME FOR SOUND POWER AND FOR
C                   SOUND PRESSURE AT THE OPERATOR LOCATION
C     PERC(II) IS THE FRACTION OF EACH TYPE HOUSE THAT HAVE THE APPLIANCE
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C      DISLEV(T) IS THE PROBABILITY OF THE POWER LEVEL IN THE SOURCE
C                   ROOM BEING IN A PARTICULAR DECIBEL RANGE SPECIFIED BY
C                   MIN,MAX,IDB(MINIMUM,MAXIMUM,STEPSIZE IN DB)
C     OPDIFF IS THEDIFFERENCE(ASSUMED CONSTANT) BETWEEN THE SOUND LEVEL
C                   AT THE OPERATOR LOCATION AND THE POWER LEVEL IN THE
C                   SOURCE ROOM. SPL(OPERATOR)=PWL+OPDIFF
C      PROBON(I,J  ,P,N) DESIGNATES THE PROBABILITY OF A GIVEN TYPE
C                   OF PRODUCT BEING OPERATED IN A PARTICULAR TYPE
C                   OF DWELLING IN A PARTICULAR ROOM IN A GIVEN
C           TIME PERIOD ON A GIVEN TYPE DAY.EITHER INPUT DIRECT
C                 LY(NT=0) OR CALC FROM ONTIM,TPER,TP9,RMP9.
C TP9(P,I,N) IS RELATIVE PROB OF AN APPLIANCE BEING OPERATED IN A GIVEN
C                 TIME PERIOD IN A GIVEN TYPE HOUSE ON A GIVEN TYPE OF
C                 DAY(SUM OVER P=1)
C RMP9(J,I,N) IS RELATIVE PROB OF AN APPLIANCE BEING OPERATED IN A GIVE
C                 N ROOM IN A GIVEN HOUSE ON A GIVEN DAY(SUM OVER J=1)
C  OPTYP GIVES THE FRACTION     OF OPERATORS AS TO TYPE OF PERSON
C  NCA IS THE NUMBER OF DIFFERENT CALC OF POPIM
      PARAMETER II=3,JJ=6,KK=6,LL=6,MM=6,NN=3,IP=4,IS=8,NCA=20
      DIMENSION PEOPLE(II,MM),SEOPLE(II,MM),OPTYP(MM)
     1,TIMEIN(II,KK,MM,IP,NN),SIMEIN(II,KK,MM,IP,NN)
      DIMENSION A1(IS),A2(IS),A3(IS),A4(IS),A5(IS),A6(IS)
     1,NRP(IS,KK,JJ,II),NRS(IS,LL,JJ,II) ,SPECTR(IS),XLEQ(IS,II,MM,3)
      DIMENSION ONTIM(II,NN),PROBON(II,JJ,IP,NN),TP9(IP,II,NN)
      DIMENSION TPER(IP),XDAYS(NN),PI(5),LEV(16),U(16),XT(16)
      DIMENSION NCANUM(NCA),DISLEV(20),OPDIFF(3),TIM(II,NN)
      DIMENSION TITLE(10),PERC(II),TITCAL(13,NCA),RMP9(JJ,II,NN)
      INTEGER P,S,T,HSWT(3)
      REAL NRP,NRS,LEV
C  LEV AND U ARE FOR SPEECH INTERFERENCE CALCS
      DATA LEV/50.,55.,60.,64.,65.,66.,67.,68.,69.,70.,71.,72.,73.,74.,
     U75.,76./
      DATA U/0.,.01,.025,.05,.08,.1,.13,.18,.265,.37,.51,.68,.81
     U,.905,.99,1.0/
C  XDAYS GIVES FRACTION(OUT OF 365) OF EACH TYPE OF DAY
      DATA XDAYS/.534,.181,.285/
C  TPER(IP) GIVES TIME PERIODS AS FCN OF P(MINUTES)
      DATA TPER/120.,480.,300.,540./
C  HSWT IS NUMBER OF SECONDARY DWELLINGS AFFECTED(MINUTES)
      DATA HSWT/2,2,4/
C IIK=4 CALC SINGLE EXP FROM SEC ,DONT ADD TO TOTAL
C IIK=5 CALC MULTIPLE EXP FROM SEC ,ADD TO TOTAL
       IIK=5
C*************
C
C
C   THESE INPUTS ARE STANDARD AND SHOULD BE READ FROM FILE IMPACTDATA
C   TITCAL ARE NAMES OF THE NCANUM CALCS
C   ALL ARE READ IN HERE
       READ(5,4)TITCAL
     4 FORMAT(13A6)
C  TIMEIN INPUT II BUILD*KK RECEIV RMS/CARD*MM PERSONS*PP PERIODS*NN DAYS
       READ(5,11)TIMEIN
    11 FORMAT(18F4.0)
C  PEOPLE INPUT 1 CARD IIBUILDINGS*MM PERSONS
       READ(5,11) PEOPLE
C NRP,NRS INPUT 208 CARDS(NOISE REDUCTION MATRICES)
C      16   OCT/CARD*3 SOURCE RMS*6 REC RMS*3 BUILDINGS
```

```
         READ(5,5)NRP
         READ(5,5)NRS
       5 FORMAT(16F5.1)
C PEOPLE IN MILLIONS SO CONVERT
         DO 741 I=1,II
         DO 741 M=1,MM
     741 PEOPLE(I,M)=1E6*PEOPLE(I,M)
C
C
C*********)*
C  TITLE INCLUDES===APPLIANCE NAME,OPERATOR REQUIREMENT
       1 FORMAT()
         READ(5,3)TITLE
       3 FORMAT(10A6)
       2 FORMAT(1H1,10A6)
         WRITE(6,2)TITLE
C NCANUM ARE ALL CALC NUMBERS DESIRED(1 TO NCA, IF 0 NEGLECT
         READ(5,1)NCANUM
C  OPTYP INPUT 1 CARD MM PERSONS ,IF NO OPERATOR ENTER BLANK CARD
         READ(5,10)OPTYP
      10 FORMAT(12F6.2)
         OPTOT=0
         DO 24 M=1,MM
      24 OPTOT=OPTOT+OPTYP(M)
C  PERC INPUT II BUILDINGS
         READ(5,10)PERC
C  SAV1 IS TOTAL NUM OF POTENTIALLY EXPOSED PERSONS IN PRIMARY DWELLING
         SAV1=0
         POPTOT=0
         DO 29 I=1,II
         DO 29 M=1,MM
         SEOPLE(I,M)=PEOPLE(I,M)*PERC(I)
         POPTOT=POPTOT+PEOPLE(I,M)
      29 SAV1=SAV1+SEOPLE(I,M)
C  CNTIM,TIM INPUTII BUILDINGS X NN DAYS
C  IF CNTIM,TIM INDOF I AND N INPUT 1 NUM F6, IF INDEP OF N INPUT 3 NUM
         CALL INPUT(CNTIM,II,NN)
         CALL INPUT(TIM,II,NN)
C  IF NT=1 PROGRAM SETS N=2,3 TO N=1 (NT=1 OR 3),IF NT=0 READ DIRECTLY
         READ(5,1)NT,MT
         IF(NT.EQ.0) READ (7,11) PROBON
         DO 22 N=1,NT
      22 CALL INPUT(TP9(1,1,N),IP,II)
C  IF MT=1 PROGRAM SETS M=2,3 TO M=1 (MT=1 OR 3)
         DO 23 N=1,MT
      23 CALL INPUT(RMP9(1,1,N),JJ,II)
         K1=1
         K3=1
         DO 30 N=1,NN
         IF(NT.EQ.3)K1=N
         IF(MT.EQ.3)K3=N
         DO 30 I=1,II
         DO 30 J=1,JJ
         DO 30 P=1,IP
         RMP9(J,I,N)=RMP9(J,I,K3)
         TP9(P,I,N)=TP9(P,I,K1)
         IF (NT.NE.0) PROBON(I,J,P,N)=ONTIM(I,N)*TP9(P,1,N)*RMP9(J,I,N)/
        1 TPER(P)
```

```
      C TIMEIN AS INPUT INCLUDES OPERATOR TIME SO SUBTRACT OFF
            DO 30 M=1,MM
            OPTIM=TPER(P)*PROBON(I,J,P,N)*OPTYP(M)
            SIMEIN(I,J,M,P,N)=TIMEIN(I,J,M,P,N)-OPTIM
      C   ALLOW FOR SMALL DISCREPANCIES IN PROBON VS TIMEIN
            IF(SIMEIN(I,J,M,P,N).GT.-.2)GO TO 30
            WRITE(6,60)I,J,M,P,N
         60 FORMAT(1H ,' CALC ABORTED-TIMEIN LESS THAN OPTIM FOR I,J,M,P,N='
           U,5I5)
            GO TO 999
         30 CONTINUE
      C   SPECTR INPUT 1 CARD (8 FREQ)
            READ(5,10) SPECTR
            READ(5,1)IDB,MIN,MAX,OPDIFF(1)
            IT=(MAX-MIN)/IDB+1
            READ(5,11)(DISLEV(T),T=1,IT)
      C   NORMALIZE SPECTR TO AWT=0
            CALL WWIGHT(I,SPECTR,A)
            DO 21 S=1,IS
         21 SPECTR(S)=SPECTR(S)-A
            WRITE(6,12)
         12 FORMAT(1H , 'POPULATION IMPACTS FOR OPERATOR, PRIMARY , SECONDARY
           1DWELLINGS')
            WRITE(6,40)SAVI,POPTOT
         40 FORMAT(1H ,' EXPOSED PERSONS=',E9.4,'    TOTAL POPULATION=',E9.4)
            IF(OPTOT.EQ.0)WRITE(6,41)
         41 FORMAT(1H ,'NO OPERATOR FOR THIS APPLIANCE')
            ITST=0
      C    ICA IS REFERRED TO IN PAPER AS KTH EFFECT WP(K)
            DO 950 ICA=1,NCA
            ITST=NCANUM(ICA)
            IF(NCANUM(ICA).EQ.0)GO TO 950
            DO 39 IK=1,IIK
            IF(IK.EQ.1.AND.OPTOT.EQ.0.)GO TO 38
            IF(IK.EQ.4.AND.OPTOT.EQ.0.)GO TO 38
            PI(IK)=0
            IF(ITST.EQ.4)GO TO 39
            DO 28 M=1,MM
            DO 28 I=1,II
            IF(ITST.LE.2)CALL ALLLEQ
            IF(ITST.EQ.3)CALL SPEECH
         28 CONTINUE
         38 CONTINUE
         39 IF(ITST.EQ.4)CALL SLEEP
            IF(ITST.EQ.3)PI(4)=PI(1)+PI(2)
            IF(IIK.EQ.5.AND.ITST.EQ.4)PI(5)=PI(2)+PI(3)
            WRITE(6,13)ICA,(TITCAL(J,ICA),J=1,13)
         13 FORMAT(1H0,I5,3X,13A6)
            IF(ICA.EQ.10)WRITE(6,17)
         17 FORMAT(1H ,'*** NO SECONDARY CALC FOR SPEECH INT***')
            IF(ICA.GE.19)WRITE(6,18)
         18 FORMAT(1H ,'***NO OPERATOR CALC FOR SLEEP INT***')
            IF(ICA.GE.19)WRITE(6,19)
         19 FORMAT(1H ,'***NO NIGHT OPER FOR VACUUM USE TPER(3) FOR TEST')
            IF(IIK.EQ.5)WRITE(6,16)
            IF(IIK.EQ.4)WRITE(6,20)
         20 FORMAT(1H ,28X,'OPERATOR',8X,'PRIMARY',5X,'SECONDARY',8X,'PR+OP')
         16 FORMAT(1H ,28X,'OPERATOR',8X,'PRIMARY',5X,'SECONDARY',8X,'PRI+OP'
```

```
          1,8X,' TOTAL')
           WRITE(6,14)(PI(IK),IK=1,IIK)
        14 FORMAT(1H ,' WEIGHTED POPULATION',5E15.4)
           DO 740 I=1,IIK
       740 PI(I)=PI(I)/SAV1
           WRITE(6,15)(PI(IK),IK=1,IIK)
        15 FORMAT(1H ,' NOISE IMPACT INDEX ',5E15.4)
       950 CONTINUE
       999 STOP
      C  INPUT DETECTS BLANKS ON INPUT AND REPEATS ACCORDINGLY
           SUBROUTINE INPUT(X,N,M)
           DIMENSICN X(N,M)
           DIMENSICN VF(3),VA(3)
           DATA VF/'(12F','6','.3)'/
           DATA VA/'(12A','6',')'/
           BLANK='      '
           IF(N.LE.4)GO TO 10
           VF(1)='(18F'
           VF(2)='4'
           VA(1)='(18A'
           VA(2)='4'
        10 CCNTINUE
           M1=0
           N1=0
           READ(5,VA)X
           IF(X(2,1).EQ.BLANK)N1=1
           IF(X(1,2).EQ.BLANK)M1=1
           READ(0,VF)X
           IF(N1.EQ.0)GO TO 20
           DO 12 I=1,M
           DO 12 J=1,N
        12 X(J,I)=X(1,1)
           GO TO 25
        20 IF(M1.EQ.0)GO TO 25
           DO 14 I=2,M
           DO 14 J=1,N
        14 X(J,I)=X(J,1)
        25 CONTINUE
           RETURN
           SUBROUTINE ALLLEQ
      C***
           IF(IK.GT.3)GO TO 730
           IF(IK.NE.1)GO TO 24
           DO 23 S=1,IS
        23 XLEQ(S,I,M,1)=-1000
           IF(OPTYP(M).EQ.0)RETURN
        24 CCNTINUE
           DO 27 S=1,IS
           XLEQ(S,I,M,IK)=0
           IF(IK.NE.1)GO TO 705
      C    TO 705 FOPIM FOR OPERATORS
      C  24 HR LEQ FOR OPER(NO D-N PENALTY FOR OPERATORS)
           X1=0
           DO 718 N=1,NN
       718 X1=X1+CNTIM(I,N)*XDAYS(N)*OPTYP(M)
           XLEQ(S,I,M,1)=SPECTR(S)+10*ALOG10(X1/1440)
           GO TO 27
       705 CCNTINUE
```

```
      DO 39 N=1,NN
      SAV2=0
      DO 26 J=1,JJ
      DO 26 K=1,KK
      DO 26 P=1,IP
      AA=SIMEIN(I,K,M,P,N)
      BB=PROBCN(I,J,P,N)
      IF(IK.EQ.2)X1=SPECTR(S)-NRP(S,K,J,I)
      IF(IK.EQ.3)X1=SPECTR(S)-NRS(S,K,J,I)
      IF(ITST.EQ.2.AND.P.EQ.4)X1=X1+10
      CC=10.**(X1/10)
      SAV2=SAV2+AA*BB*CC
   26 CONTINUE
   39 XLEQ(S,I,M,IK)=XLEQ(S,I,M,IK)+XDAYS(N)*SAV2
      XLEQ(S,I,M,IK)=10*ALOG10(XLEQ(S,I,M,IK)/1440)
   27 CONTINUE
  730 CONTINUE
C  POPIM OPERATORS AND PRIMARY(TO 717)
      IF(IIK.EQ.5.AND.IK.EQ.3)GO TO 828
      IF(IIK.EQ.5.AND.IK.EQ.5)GO TO 828
C  IK=1 FOR OPERATORS, IK=2 FOR PRIMARY, IK=3 FOR SECONDARY ,IK=4 FOR OP
C     ER+PRIM ,IK=5 FOR TOTAL
      DO 717 IT1=1,IT
      IF(IK.EQ.4)GO TO 825
      DO 716 S=1,IS
  716 A1(S)=XLEQ(S,I,M,IK)+MIN+(IT1-1)*IDB+OPDIFF(IK)
      GO TO 826
  825 DO 827 S=1,IS
      AA1=XLEQ(S,I,M,1)+MIN+(IT1-1)*IDB+OPDIFF(1)
      AA2=XLEQ(S,I,M,2)+MIN+(IT1-1)*IDB
  827 A1(S)=10*ALOG10(10**(AA1/10)+10**(AA2/10))
  826 CALL WWIGHT(ICA,A1,A)
      CALL WE(W,A,ICA)
      A=SEOPLE(I,M)
  717 PI(IK)=PI(IK)+A*W*DISLEV(IT1)
      RETURN
  828 CONTINUE
C  POPIM FOR SECONDARY AND TOTAL TO 714
      SAV2=0
      DO 824 S=1,IS
      A1(S)=0
      A2(S)=0
      A3(S)=0
      A4(S)=0
      A5(S)=0
  824 A6(S)=0
      AA1=1
      AA2=1
      AA3=1
      AA4=1
      AA5=1
      IF(IK.NE.5)GO TO 722
      IT5=0
  724 IT5=IT5+1
      AA5=DISLEV(IT5)
      DO 723 S=1,IS
      AA=XLEQ(S,I,M,1)+MIN+(IT5-1)*IDB+OPDIFF(1)
      BB=XLEQ(S,I,M,2)+MIN+(IT5-1)*IDB
```

```
 723 A5(S)=10**(AA/10)+10**(BB/10)
 722 IF(HSWT(I)-3)713,712,
     IT1=0
 725 IT1=IT1+1
     AA1=DISLEV(IT1)
     DO 715 S=1,IS
 715 A1(S)=10**((XLEQ(S,I,M,3)+MIN+(IT1-1)*IDB)/10)
 712 IT2=0
 727 IT2=IT2+1
     AA2=DISLEV(IT2)
     DO 719 S=1,IS
 719 A2(S)=10**((XLEQ(S,I,M,3)+MIN+(IT2-1)*IDB)/10)
 713 IT3=0
 728 IT3=IT3+1
     AA3=DISLEV(IT3)
     DO 720 S=1,IS
 720 A3(S)=10**((XLEQ(S,I,M,3)+MIN+(IT3-1)*IDB)/10)
     IT4=0
 726 IT4=IT4+1
     AA4=DISLEV(IT4)
     DO 721 S=1,IS
     A4(S)=10**((XLEQ(S,I,M,3)+MIN+(IT4-1)*IDB)/10)
 721 A6(S)=10*ALOG10(A1(S)+A2(S)+A3(S)+A4(S)+A5(S))
     CALL WWIGHT(ICA,A6,A)
     CALL WE(W,A,ICA)
 714 SAV2=SAV2+W*AA1*AA2*AA3*AA4*AA5
     IF(IT4.LT.IT)GO TO 726
     IF(IT3.LT.IT)GO TO 728
     IF(HSWT(I).GE.3.AND.IT2.LT.IT)GO TO 727
     IF(HSWT(I).EQ.4.AND.IT1.LT.IT)GO TO 725
     IF(IK.EQ.5.AND.IT5.LT.IT)GO TO 724
     PI(IK)=PI(IK)+SEOPLE(I,M)*SAV2
     RETURN
     SUBROUTINE SLEEP
     IF(IK.NE.2.AND.IK.NE.3)RETURN
     DO 37 I=1,3
     DO 42 J=1,JJ
     DO 43 S=1,IS
     IF(IK.EQ.2)A6(S)=SPECTR(S)-NRP(S,4,J,I)
  43 IF(IK.EQ.3)A6(S)=SPECTR(S)-NRS(S,4,J,I)
  42 CALL WWIGHT(1,A6,A1(J))
     X3=0
     DO 36 T=1,IT
     DO 36 N=1,NN
     DO 36 J=1,JJ
     BB=TIM(I,N)*60*RMP9(J,I,N)
C***
C*** TPER(4) CHANGED TO TPER(3) FOR TEST ONLY
C***
     X2=PROBCN(I,J,3,N)*60*TPER(4)
  38 X2=X2-BB
     IF(X2.GT.0)X1=BB
     IF(X2.LE.0)X1=X2+BB
     IF(X1.LE.0)GO TO 36
     IF(X1.GT.120.)X1=120
     AA=A1(J)+MIN+(T-1)*IDB
     SEL=AA+10*ALOG10(X1)
     CALL WE(W,SEL,ICA)
```

```
      X3=X3+XDAYS(N)*W*DISLEV(T)
      IF(X2.GT.0)GO TO 38
   36 CONTINUE
      X4=0
      DO 39 M=1,MM
   39 X4=X4+SEOPLE(I,M)
      AA=1
      IF(IK.EQ.3)AA=HSWT(I)
   37 PI(IK)=PI(IK)+X4*X3*AA
      RETURN
      SUBROUTINE SPEECH
      IF(IK.GT.2)RETURN
      IF(IK.NE.1)GO TO 705
      IF(OPTYP(M).EQ.0.)RETURN
C TO 705 SPEECH INT FOR OPER
      A2(1)=0
      DO 38 T=1,IT
      CC=0
      X1=MIN+(T-1)*IDB+OPDIFF(1)
      IF(X1.LT.50)GO TO 38
      IF(X1.GT.76)X1=75.9
      CC=AITINT(LEV,U,16,X1,2,XT)
      A2(1)=A2(1)+CC*DISLEV(T)
   38 CONTINUE
      X1=0
      DO 718 N=1,NN
  718 X1=X1+ONTIM(I,N)*XDAYS(N)*OPTYP(M)
      PI(1)=PI(1)+A2(1)*X1*SEOPLE(I,M)/900
      RETURN
  705 CONTINUE
      DO 36 T=1,IT
      A2(2)=0
      DO 39 N=1,NN
      SAV2=0
      DO 26 J=1,JJ
      DO 26 K=1,KK
      DO 37 S=1,IS
   37 A6(S)=SPECTR(S)-NRP(S,K,J,I)
      CALL WWIGHT(1,A6,X1)
      X1=X1+MIN+(T-1)*IDB
      CC=0
      IF(X1.LT.50)GO TO 101
      IF(X1.GT.76)X1=75.9
      CC=AITINT(LEV,U,16,X1,2,XT)
  101 CONTINUE
C* EXCLUDE P=4 FOR SPEECH INT
      DO 26 P=1,3
      SAV2=SAV2+SIMEIN(I,K,M,P,N)*PROBON(I,J,P,N)*CC
   26 CONTINUE
   39 A2(2)=A2(2)+XDAYS(N)*SAV2
      A2(2)=A2(2)/900
      PI(2)=PI(2)+SEOPLE(I,M)*A2(2)*DISLEV(T)
   36 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE WE(W,X,ICA)
      IF (ICA.EQ.1) W=10**((X-70)/10)
      IF (ICA.EQ.2) W=.025*(X-70)**2
      IF (ICA.EQ.3.AND.X.GE.70) W=.6*(X-70)**1.2
      IF (ICA.LT.4.OR.ICA.GT.5) GO TO 34
      IF (ICA.EQ.5) X=X+15
      AA=3.36E-6*10**(.103*X)
      BB=.2*10**(.03*X)
      CC=1.43E-4*10**(.08*X)
      W=AA/(BB+CC)
   34 IF (ICA.EQ.6) W=.05*(X-55)
      IF (ICA.EQ.7) W=.01*(10**((X-55)/10)-1)
      IF (ICA.EQ.8) W=(2.**((X-55)/10)-1)/3
      IF (ICA.EQ.9) W=.0125*(X-55)*2**((X-55)/10)
      IF(ICA.EQ.10)W=X
      IF(ICA.EQ.11.OR.ICA.EQ.15.OR.ICA.EQ.17)W=(X-40)/35
      IF(ICA.EQ.12.OR.ICA.EQ.16.OR.ICA.EQ.18)W=(2.**((X-40)/10))/11.31
      IF(ICA.EQ.13)W=(X-32)/43
      IF(ICA.EQ.14)W=(2.**((X-32)/9))/14.81
      IF(ICA.EQ.19)W=.0135*X-.5
      IF(ICA.EQ.20)W=.0110*X-.495
      IF(ICA.EQ.1.AND.X.GT.70)W=1
      IF(ICA.EQ.2.AND.X.LT.70)W=0
      IF(ICA.EQ.3.AND.X.LT.70)W=0
      IF(ICA.GT.5.AND.ICA.LT.10.AND.X.LT.55)W=0
      IF(ICA.GT.10.AND.ICA.LT.13.AND.X.LT.40)W=0
      IF(ICA.GT.13.AND.ICA.LT.15.AND.X.LT.32)W=0
      IF(ICA.GT.14.AND.ICA.LT.19.AND.X.LT.40)W=0
      IF(ICA.GT.18.AND.W.GT.1)W=1
      IF(W.LT.0)W=0
      RETURN
      END
```

```
      SUBROUTINE WWIGHT(ICA,SPECTR,Y)
      REAL SPL(24),NS(240),LT(28),SPECTR(8)
C ALL RCUTINES INPUT 24 FREQ FROM 50 TO 10K HZ
C CCNVERT OCTAVE BANDS TO 1/3 CCTAVE BANDS
      DO 20 I=1,8
      DO 20 J=1,3
      K=3*(I-1)+J
   20 SPL(K)=SPECTR(I)-4.77
      IF(ICA.LT.11)CALL WT(SPL,24,Y,1)
      IF(ICA.EQ.11.OR.ICA.EQ.12)CALL SONE6(SPL,24,Y,IF)
      IF(ICA.EQ.13.OR.ICA.EQ.14)CALL SONE7(SPL,24,Y)
      IF(ICA.NE.15.AND.ICA.NE.16)GO TO 101
      DO 10 I=1,3
   10 LT(I)=0
      DO 11 I=4,27
   11 LT(I)=SPL(I-3)
                    CALL ZWICK(1,LT,27,NS,Y)
  101 IF(ICA.EQ.17.OR.ICA.EQ.18)CALL PNL3(SPL,24,Y,IF)
      IF(ICA.EQ.19.OR.ICA.EQ.20)CALL WT(SPL,24,Y,1)
      RETURN
      END
```

```
      SUBROUTINE WT(SPL,NF,A,I)
C**STANDARD WEIGHTING FOR A(I=1).B(I=2).C(I=3).D(I=4).E(I=5).LIN(I=0)
C**NF 1/3 OCT BANDS FROM 50 TO 10K HZ(NF=24)
C**SPL=VECTOR WITH DB LEVELS FOR EACH BAND
C**NEG SPL MEANS MISSING BAND
C**A=ANSWER IN DB(A),OR(B) OR(C)OR(LIN)
      DIMENSICN SPL(30),W(30,6)
      DATA(W(J,1),J=1,3)/-44.7,-39.4,-34.6/
      DATA(W(J,1),J=4,30)/-30.2,-26.2,-22.5,-19.1,-16.1,-13.4,-10.9,-8.6
     U,-6.6,-4.8,-3.2,-1.9,-.8,0.,.6,1.,1.2,1.3,1.2,1.,.5,-.1,-1.1,-2.5,
     U-4.3,-6.6,-9.3/
      DATA(W(J,2),J=1,3)/-20.4,-17.1,-14.2/
      DATA(W(J,2),J=4,30)/-11.6,-9.3,-7.4,-5.6,-4.2,-3.,-2.,-1.3,-.8,
     U-.5,-.3,-.1,4*0.,-.1,-.2,-.4,-.7,-1.2,-1.9,-2.9,-4.3,-6.1,-8.4,
     U-11.1/
      DATA(W(J,3),J=1,3)/-4.4,-3.,-2./
      DATA(W(J,3),J=4,30)/-1.3,-.8,-.5,-.3,-.2,-.1,9*0.,-.1,-.2,-.3,-.5,
     U-.8,-1.3,-2.,-3.,-4.4,-6.2,-8.5,-11.2/
      DATA(W(J,4),J=1,30)/-18.7,-16.7,-14.7,-12.8,-10.9,-9.,-7.2,-5.5,
     U-4.,-2.6,-1.6,-.8,-.4,-.3,-.5,-.6,0.,2.,4.9,7.9,10.4,11.6,11.1,
     U9.6,7.6,5.5,3.4,1.4,-.7,-2.7/
      DATA(W(J,5),J=1,30)/-27.6,-24.05,-20.68,-17.54,-14.65,-12.,-9.6
     U,-7.44,-5.5,-3.79,-2.36,-1.24,-.48,-.09,-.04,-.18,-.16,.48,1.92
     U,3.80,5.73,7.39,8.55,8.89,8.14,6.29,3.61,.39,-3.12,-6./
      DATA(W(J,6),J=1,30)/30*0./
      A=0
      IF(I.EQ.0)I=6
      DO 20 J=1,NF
      K=J+3
      A=A+10.**((SPL(J)+W(K,I))/10.)
   20 CONTINUE
      IF(A.LE.0)A=1
      A=10.*ALOG10(A)
      RETURN
      END
```

```
      SUBROUTINE SONE6 (SPL,NF,PHON,IFLAG)
C     *** STEVENS' SONES, MARK VI
C     *** NF THIRD OCTAVE BANDS FROM 50 TO 10000 HZ (NF=24)OR 20K HZ(NF=27)
C     *** SPL = VECTOR WITH DB LEVELS FOR EACH BAND
C     *** PHON = ANSWER
C     *** IFLAG = 2 IF ANY BAND WOULD HAVE LOUDNESS INDEX GREATER THAN
C     *** 298 SONES, 1 OTHERWISE
C     *** FOR LEVELS BEYOND 298 SONES THE TABLE IS EXTRAPOLATED
C     *** LINEARLY, 20 SONES/DB
      DIMENSION SONE(103),SPL(27),DBMAX(27)
      DATA DBMAX/133.,132.,131.,130.,129.,128.,127.,126.,125.,124.,
     U  123.,122.,121.,120.,119.,118..117.,116.,115..114.,113.,112.,
     U  111.,112.45,112.5,112.5,112.5/
      DATA SONE/.1,.14,.18,.22,.26,.3,.35,.4,.45,.5,.55,.61,.67,.73,
     U  .8,.87,.94,1.02,1.1,1.18.1.27,1.35,1.44,1.54,1.64,1.75,1.87,
     U  1.99,2.11,2.24,2.38,2.53,2.68,2.84,3.,3.2,3.4,3.6,3.8,4.1,4.3,
     U  4.6,4.9,5.2,5.5,5.8,6.2,6.6,7.,7.4,7.8,8.3,8.8,9.3,9.9,10.5,
     U  11.1,11.8,12.6,13.5,14.4,15.3,16.4,17.5,18.7,20.,21.4,23.,24.7,
     U  26.5,28.5,30.5,33.,35.3,38.,41.,44.,48.,52.,56.,61.,66.,71.,
     U  77.,83.,90.,97.,105.,113.,121.,130.,139.,149.,160.,171.,184.,
     U  197.,211.,226.,242.,260.,278.,298./
      IFLAG=1
      PHON=0
      SUM=0.
      SMAX=0.
      DO 20 I=1,NF
      IF(SPL(I).LE.0)GO TO 20
      IF(SPL(I).GT.DBMAX(I)) IFLAG=2
      IF(I.GE.14) GO TO 31
      IF(SPL(I).GE.108.-7*I) GO TO 31
      X=1.2*SPL(I)+2.4*I-35.6
      GO TO 33
   31 IF(I.GE.24) GO TO 32
      X=SPL(I)+I-14
      GO TO 33
   32 X=SPL(I)+9.5097-4*(I-23.5097)
   33 IF(X.LT.18) GO TO 20
      IF(X.GE.120) GO TO 34
      NX=X
      X=SONE(NX-17)+(X-NX)*(SONE(NX-16)-SONE(NX-17))
      GO TO 35
   34 X=298+20*(X-120)
   35 IF(X.GT.SMAX) SMAX=X
      SUM=SUM+X
   20 CONTINUE
      X=SMAX+.15*(SUM-SMAX)
      IF(X.LE.0)RETURN
      PHON=40+10.*ALOG10(X)/ALOG10(2.)
      RETURN
      END
```

```
      SUBROUTINE SONE7(LL,NF,PL)
C****INPUT NF 1/3 OCTAVE BANDS FROM 50 TO 10K HZ
C *** TO CALCULATE STEVENS MARK7 PLDB
      REAL L(30),S(140),LEQ,SO(95),F(95),LL(30)
      DATA(S(I),I=1,140)/.079,.087,.097,.107,.118,.129,.141,.153,.166,
     1.181,.196,.212,.23,.248,.269,.29,.314,.339,.367,.396,.428,.463,
     1.5,.54,.583,.63,.68,.735,.794,.857,.926,1.,1.08,1.17,1.26,1.36,
     11.47,1.59,1.71,1.85,2.,2.16,2.33,2.52,2.72,2.94,3.18,3.43,3.7,4.,
     14.32,4.67,5.04,5.44,5.88,6.35,6.86,7.41,8.,8.64,9.33,10.1,10.9,
     111.8,12.7,13.7,14.8,16.0,17.3,18.7,20.2,21.8,23.5,25.4,27.4,29.6,
     132.,34.6,37.3,40.3,43.5,47.,50.8,54.9,59.3,64.,69.1,74.7,80.6,
     187.1,94.1,102.,110.,119.,128.,138.,149.,161.,174.,188.,203.,219.,
     1237.,256.,276.,299.,323.,348.,376.,406.,439.,474.,512.,553.,597.,
     1645.,697.,752.,813.,878.,948.,1024.,1106.,1194.,1290.,1393.,
     11505.,1625.,1756.,1896.,2048.,2212.,2389.,2580.,2787.,3010.,3251.,
     13511.,3792.,4096./
      DATA(SO(I),I=1,95)/.181,.196,.212,.23,.248,.269,.29,.314,.339,
     1.367,.396,.428,.463,.5,.54,.583,.63,.68,.735,.794,.857,.926,1.,
     11.08,1.17,1.26,1.36,1.47,1.59,1.72,1.85,2.,2.16,2.33,2.52,2.72,
     12.94,3.18,3.43,3.7,4.,4.32,4.67,5.04,5.44,5.88,6.35,6.86,7.41,
     18.,8.64,9.33,10.1,10.9,11.8,12.7,13.7,14.8,16.,17.3,18.7,20.2,
     121.8,23.5,25.4,27.4,29.6,32.,34.6,37.3,40.3,43.5,47.,50.8,54.9,
     159.3,64.,69.1,74.7,80.6,87.1,94.1,102.,110.,119.,128.,138.,149.,
     1161.,174.,188.,203.,219.,237.,4000./
      DATA(F(I),I=1,95)/.1,.122,.14,.158,.174,.187,.2,.212,.222,.232,
     1.241,.25,.259,.267,.274,.281,.287,.293,.298,.303,.308,.312,.316,
     1.319,.32,.322,.322,.32,.319,.317,.314,.311,.308,.304,.3,.296,
     1.292,.288,.284,.279,.275,.27,.266,.262,.258,.253,.248,.244,.24,
     1.235,.23,.226,.222,.217,.212,.208,.204,.2,.197,.195,.194,.193,
     1.192,.191,.19,.19,.19,.19,.19,.19,.191,.191,.192,.193,.194,.195,
     1.197,.199,.201,.203,.205,.208,.210,.212,.215,.217,.219,.221,.223,
     1.224,.225,.226,.227,.227,.227/
      PL=0
      DO 100 I=1,NF
  100 L(I)=LL(I)
      SUM=0
      SM=0
      N1=17
      N2=NF+16
      DO 110 I=N1,N2
      J=I-N1+1
      IF(LL(J).LE.0)GO TO 110
      N=I
      IF(I.GT.18)GO TO 101
      L(J)=160-19.*(160-LL(J))/I
      N=19
  101 IF(I.GT.25)GO TO 102
      DBL=85.5-1.5*(N-19)
      DBH=DBL+45
      IF(L(J).LT.DBL)LEQ=107-26.*(115-L(J))/N
      IF(L(J).GE.DBL.AND.L(J).LE.DBH)LEQ=L(J)-8-1.5*(26-N)
      IF(L(J).GT.DBH)LEQ=152-26.*(160-L(J))/N
      GO TO 108
  102 IF(I.LE.31)LEQ=L(J)-8
      IF(I.GE.32.AND.I.LE.34)LEQ=L(J)-2*(35-N)
      IF(I.GE.35.AND.I.LE.39)LEQ=L(J)
      IF(I.GT.39)LEQ=L(J)+4*(39-N)
```

```
  108 IF(LEQ.LT.1.)LEQ=1
      I1=LEQ
C *** INTERPOLATE THE SONE TABLE
      S1=(S(I1+1)-S(I1))*(LEQ-I1)+S(I1)
      SUM=SUM+S1
      IF(S1.GT.SM)SM=S1
  110 CONTINUE
C *** FIND THE F FACTOR IN SONE TABLE
      DO 120 I=2,95
  120 IF(SM.LT.SO(I))GO TO 121
  121 N=I
C *** INTERPOLATE THE F TABLE
      F1=F(N-1)+(F(N)-F(N-1))*(SM-SO(N-1))/(SO(N)-SO(N-1))
      STOT=SM+F1*(SUM-SM)
      IF(STOT.LE.0)RETURN
      PL=32+9*ALOG10(STOT)/ALOG10(2)
      RETURN
      END
```

```
      SUBROUTINE ZWICK(MOD,LT,NF,NS,N)
C  ZWICKER PHONS
C**** LT  NF THIRD OCT LEVS FROM 50 TO 10K HZ
C*** PROG ADDS LT(28)=0
C  MOD  PLANE(0),DIFFUSE(1) FIELD
C   OUTPUT
C  N  LOUDNESS IN SONES
C  NS  HAS TO DO WITH BARKS
      REAL LT(28),NS(240),N,N1,N2
      REAL LE,LEHS(20),LG(3),KERN(21)
      REAL LHS(3),NI
      DIMENSICN A0(20),DLTG(20),DLED(20),ZG(21),GRENZ   (16),TANG(8,16)
      DIMENSION TI(11)
      DATA LHS/63.0,54.0,47.0/
      DATA LEHS/36.,21.,12.5,9.,7.3,6.,5.,4.4,12*4./
      DATA A0/     10*0.00,-0.50,-1.6,-3.20,-5.40,-5.60,
     A         -4.00, -1.50, 2.00,5.00,12.00/
      DATA DLED/0.00, 0.00, 0.50,0.90,1.20, 1.60, 2.30,
     A          2.80, 3.00, 2.00,0.00,-1.40,-2.00,-1.90,
     A         -1.00, 0.50, 3.00,4.00, 4.30, 4.00/
      DATA DLTG/-0.25,-0.60,-0.80,-0.80,-0.50,0.00,0.50,
     A            1.10, 1.50, 1.70, 1.80, 1.80,1.70,1.60,
     A            1.40, 1.20, 0.80, 0.50, 0.00,-0.50/
      DATA ZG/   0.90, 1.80, 2.80, 3.50, 4.40,5.40,6.60,
     A           7.90, 9.20,10.60,12.30,13.80,15.20,16.70,
     A          18.10,19.30,20.60,21.80,22.70,23.60,24.0/
      DATA GRENZ /    23.50,19.00,15.10,11.90, 9.00, 6.60,
     A            4.60, 3.20, 2.13, 1.36, 0.82, 0.43, 0.21,
     A            0.08, 0.03, 0.00/
```

```
      DATA TANG/13.00, 8.20, 5.70,     5*5.00,
     2          9.00, 7.50, 6.00, 5.10,     4*4.50,
     3          7.80, 6.70, 5.60, 4.90, 4.40,     3*3.90,
     4          6.40, 5.50, 4.70, 4.10, 3.60,     3*3.20,
     5          5.60, 5.00, 4.50, 4.30, 3.50,     3*2.90,
     6          4.20, 3.90, 3.70, 3.30, 2.90,     3*2.42,
     7          3.20, 2.80, 2.50, 2.30, 2.20, 2.20, 2.20, 2.02,
     8          2.80, 2.10, 1.90, 1.80, 1.70, 1.60, 1.60, 1.41,
     9          1.60, 1.50, 1.40, 1.30, 1.20, 1.10, 1.10, 1.02,
     A          1.50, 1.20, 0.94,     5*0.77,
     B          0.72, 0.66, 0.61,     5*0.54,
     C          0.44, 0.41, 0.40,     5*0.39,
     D          0.29, 0.25,     6*0.22,
     E          0.15,     7*0.13,
     F          0.06,     7*0.05,
     G              8*0.04/
      C63=0.064*(10.**(0.025*LEHS(1)))
      DO 1 I=1,3
      LG(I)=LEHS(I)
      HSF=0.064*(10.**(0.025*LHS(I)))
      NI=HSF*((1.+0.25*10.**(0.1*(LT(I)-LHS(I))))**0.25-1.)
      GI=4.*((NI/C63+1.)**4-1.)
      TI(I)=0.
      IF (GI.LE.0.)GO TO 1
      XP=ALOG10(GI)+0.1*LEHS(I)
      TI(I)=10.**XP
    1 CONTINUE
      DO 2I=4,11
    2 TI(I)=10.**(0.1*LT(I))
      GI=TI(1)+TI(2)+TI(3)+TI(4)+TI(5)+TI(6)
      IF(GI.GT.0.) LG(1)=10.*ALOG10(GI)
      GI=TI(7)+TI(8)+TI(9)
      IF (GI.GT.0.) LG(2)=10.*ALOG10(GI)
      GI=TI(10)+TI(11)
      IF (GI.GT.0.) LG(3)=10*ALOG10(GI)
      DO 3 I=1,20
      LE=LT(I+8)
      IF(I.LE.3) LE=LG(I)
      LE=LE-A0(I)
      KERN(I)=0.
      IF(MOD.EQ.1) LE=LE+DLED(I)
      IF (LE.LE.LEHS(I)) GO TO 3
      LE=LE-DLTG(I)
      HSF=0.064*(10.**(0.025*LEHS(I)))
      KERN(I)=HSF*((1.+0.25*10.**(0.1*(LE-LEHS(I))))**0.25-1.)
    3 CONTINUE
      KERN(21)=0.
      N=0.2
      Z1=0.
      N1=0.
      J=16
      IZ=1
      Z=0.1
      DO13 I=1,21
      IG=I-1
      IF (IG.GT.8)IG=8
    4 IF (N1-KERN(I)) 5,7,9
    5 DO6J=1,16
      IF(GRENZ (J).LT.KERN(I))GO TO 7
    6 CONTINUE
    7 Z2=ZG(I)
      N2=KERN(I)
```

```
      N=N+N2*(Z2-Z1)
    8 IF(Z.GT.Z2) GO TO 12
      NS(IZ)=N2
      IZ=IZ+1
      Z=Z+0.1
      GO TO 8
    9 N2=GRENZ (J)
      IF (N2.LT.KERN(I)) N2=KERN(I)
      DZ=(N1-N2)/TANG(IG,J)
      Z2=Z1+DZ
      IF (Z2.LE.ZG(I)) GO TO 10
      Z2=ZG(I)
      DZ=Z2-Z1
      N2=N1-DZ*TANG(IG,J)
   10 N=N+((N1+N2)/2.)*DZ
   11 IF (Z.GT.Z2) GO TO 12
      NS(IZ)=N1-(Z-Z1)*TANG(IG,J)
      IZ=IZ+1
      Z=Z+0.1
      GO TO 11
   12 IF (N2.EQ.GRENZ (J)) J=J+1
      IF (J.GT.16) J=16
      N1=N2
      Z1=Z2
      IF (Z1.LT.ZG(I)) GO TO 4
   13 CONTINUE
      IF(N.LE.0)N=1
      N=40.+10*ALOG10(N)/.301
      RETURN
      END
```

```
      SUBROUTINE PNL3(SPL,NF,PNDB,IFLAG)
C     *** STANDARD PERCEIVED NOISE LEVEL
C     *** 24 THIRD OCTAVE BANDS FROM 50 TO 10000 HZ
C     *** SPL = VECTOR WITH DB LEVELS FOR EACH BAND
C     *** PNDB = ANSWER
C     *** IFLAG = 2 IF ANY BAND HAS NOY VALUE OFF THE UPPER END OF THE
C     *** TABLE, 1 OTHERWISE
C     *** FOR HIGH VALUES THE TABLE IS EXTRAPOLATED ALONG THE LAST
C     *** STRAIGHT LINE SEGMENT
      DIMENSION AL1(24),AL2(24),AL3(24),AL4(24),ALC(24),AM1(24),AM2(24)
      DIMENSION AM3(24),AM4(24),SPL(24),DBMAX(24)
      DATA AL1/49.,44.,39.,34.,30.,27.,24.,21.,18.,16.,16.,16.,16.,16.,
     U 15.,12.,9.,5.,4.,5.,6.,10.,17.,21./
      DATA AL2/55.,51.,46.,42.,39.,36.,33.,30.,27.,25.,25.,25.,25.,25.,
     U 23.,21.,18.,15.,14.,14.,15.,17.,23.,29./
      DATA AL3/64.,60.,56.,53.,51.,48.,46.,44.,42.,40.,40.,40.,40.,40.,
     U 38.,34.,32.,30.,29.,29.,30.,31.,37.,41./
      DATA AL4/52.,51.,49.,47.,46.,45.,43.,42.,41.,40.,40.,40.,40.,40.,
     U 38.,34.,32.,30.,29.,29.,30.,31.,34.,37./
      DATA ALC/91.01,85.88,87.32,79.85,79.76,75.96,73.96,74.91,94.63,
     U 13*100.,44.29,50.72/
      DATA AM1/.07952,2*.06816,.05964,10*.053013,.05964,2*.053013,
     U 2*.047712,2*.053013,.06816,.079520,.0596401/
      DATA AM2/2*.058098,.052288,.047534,2*.043573,.040221,.037349,
     U 7*.034859,.040221,.037349,4*.034859,.037349,.037349,.043573/
      DATA AM3/.043478,.040572,2*.036831,.035336,2*.033333,.032051,
     U .030675,6*.030103,7*.02996,2*.042285/
      DATA AM4/15*.030103,9*.02996/
      DATA DBMAX/14*150.,148.,144.,142.,140.,2*139.,140.,141.,144.,147./
```

```
      IFLAG=1
      SUM=0.
      PNDB=0
      SMAX=0.
      DO 20 I=1,NF
      IF(SPL(I).LE.0)GO TO 20
      IF(SPL(I).GT.DBMAX(I)) IFLAG=2
      IF(SPL(I).LT.AL1(I)) GO TO 20
      IF(SPL(I).GE.AL2(I)) GO TO 31
      X=AM1(I)*(SPL(I)-AL1(I))
      X=.1*10.**X
      GO TO 35
   31 IF(SPL(I).GE.AL3(I)) GO TO 32
      X=AM2(I)*(SPL(I)-AL3(I))
      GO TO 34
   32 IF(SPL(I).GE.ALC(I)) GO TO 33
      X=AM3(I)*(SPL(I)-AL3(I))
      GO TO 34
   33 X=AM4(I)*(SPL(I)-AL4(I))
   34 X=10.**X
   35 IF(X.GT.SMAX) SMAX=X
      SUM=SUM+X
   20 CONTINUE
      X=SMAX+.15*(SUM-SMAX)
      IF(X.LE.0)RETURN
      PNDB=40.+33.22*ALOG10(X)
      RETURN
      END
```

```
      FUNCTION AITINT(X,Y,N,XB,K,P)
C-----------------------------------------------------------------------
C-----------------------------------------------------------------------
      DIMENSION X(N),Y(N),P(K)
      DO2J=1,N
C         ---------------------------------------------------------
C     TRY TO USE AN EQUAL NUMBER OF GIVEN POINTS TO
C     THE LEFT AND RIGHT OF THE INTERPOLATION POINT, XP
C         ---------------------------------------------------------
      IF(X(J)-XB)2,1,3
C         ---------------------------------------------------------
C     IF THE INTERPOLATION POINT IS A GIVEN POINT, USE .
C     THE GIVEN FUNCTION VALUE AND EXIT
C         ---------------------------------------------------------
    1 AITINT=Y(J)
      RETURN
    2 CONTINUE
      J=N
    3 J=MINO(MAXO(1,J-(K+1)/2),N-K+1)
      IF(J+K.LE.N.AND.X(J+K)-XB.LT.XB-X(J))J=J+MOD(K,2)
      P(1)=Y(J)
C         ---------------------------------------------------------
C     AITKIN'S PROCEDURE, USING THE CLOSEST OF THE GIVEN POINTS.
C         ---------------------------------------------------------
      DO4I=2,K
      P(I)=Y(J+I-1)
      DO4L=2,I
    4 P(I)=(P(L-1)*(X(J+I-1)-XB)-P(I)*(X(J+L-2)-XB))/((X(J+I-1)-XB)-(X(J
     1+L-2)-XB))
      AITINT=P(K)
      RETURN
      END
```

APPENDIX D
SAMPLE CALCULATION

In order to demonstrate the use of the FORTRAN program, a test case computation for vacuum cleaners was made. The input data and their sources and the outputs of the FORTRAN program are presented in this appendix.

Note: the estimated data used for this sample calculation are not sufficiently accurate for use in actual impact assessments! Thus, the data presented at the end of this appendix do not reflect an actual assessment of vacuum cleaner noise impact.

The sources of the input data were:

For data independent of the product -

- XDAYS, the fraction of different day types for a year, was determined from a 1977 calendar.
- LEV and U, the fraction of speech unintelligibility as a function of A-weighted sound level, was determined from Figure 9 of Section 5.3.
- TPER, the number of hours in each time period, was obtained from the values of P given in Section 6.3.
- TIMEIN, the length of time spent in different rooms was arrived at through the the use of tables summarizing the time spent in certain activities by employed men, employed women, and housewives given in [1]*. The rooms in which these activities were conducted were estimated based on the nature of each activity. There were no data concerning unemployed men, preschool children at home, and school-age children or day care children. Thus, unemployed men were assumed to spend their time similarly to housewives, except more time would be spent in the living room/family room and bedroom areas than a housewife, and more time away from home. Preschool children were assumed to spend their time much like a housewife, except more time would be spent in the bedroom for all time periods. The school-age/day care children were assumed to spend their time most like the employed women, except more time is spent outdoors during the day and more time in bed for the period 1700-2200.
- PEOPLE, the number of people of each type in the country was obtained from data in [2].
- NPR, the room-to-room noise reductions within the primary dwelling, were estimated on the basis of typical floor plans and construction practices.

---

* Numbers in square brackets refer to the references listed at the end of this appendix.

- NRS, the noise reductions between rooms in the primary dwelling and rooms in the secondary dwelling were estimated on the basis of typical construction plans and practices.

For data dependent on the product -

- OPTYR, the distribution of operators among person types was estimated from personal observations by the authors.

- PERC, the fraction of dwellings that have the product, was estimated from data in [2,5,6].

- ONTIM, the length of time the product is operated, was estimated from two sources. The times per week that a vacuum cleaner is used (three times/week) was found in [4]. The number of minutes per use was estimated from a survey of personnel in the NBS Sound Building. The length of time taken to vacuum a dwelling was obtained from this limited survey, which included people living in all three dwelling types considered in the present model. Using this information, the length of time to vacuum each of the three dwelling types was estimated. The total time spend per week vacuuming a particular dwelling was the product of the number of minutes per day of operation, was calculated assuming each day equally likely.

- TIM, the length of time of a single operation, was obtained as described in the description of ONTIM.

- TP9, the probability that the appliance is operated in a given time period, was obtained by assigning to each time period a probability that the vaccum cleaner would be on. The probabilities, based on personal observations, were:

  0700-0900 - .05
  0900-1700 - .75
  1700-2200 - .20
  2200-0700 - 0

- RMP9, the probability that the appliance is operated in a given room was obtained, for each of the living areas for each dwelling type, by assigning a probability based on the (estimated from personal observations) amount of time the vacuum cleaner would be used in each area:

Area	Single-Family	Townhouse	Apartment
Kitchen	.08	.11	.17
Living/Dining/Family Room	.50	.56	.50
Bedroom	.34	.33	.33
Bathroom	0	0	0
Basement/Garage/Utility Room	.08	0	0
Outdoors	0	0	0

- SPECTR, the relative octave band spectrum for vacuum cleaners, was obtained from sound power measurements made at NBS.

- DISLEV, the distribution of the A-weighted sound power levels of vacuum cleaners, was obtained from data in [6].

Using the sources of information described above, the numerical inputs to the program are indicated on the following pages.

D.1 Listing of Input Data for Sample Calculation

NOTE

These data are not sufficiently accurate for use in actual population impact studies.

****

```
TITCAL    1   HEARING,FRACTIONAL EXPOSURE(CRITERION LEVEL=70 DB)
          2   HEARING,4 FREQUENCY AVERAGE(CORRESP TO PHL FROM CHABA WG69)
          3   HEARING.AVERAGE NIPTS AT 4 KHZ
          4   GENERAL ADVERSE RESPONSE,CHABA WG69  LWP(LDN)
          5   GENERAL ADVERSE RESPONSE,CHABA WG69  LWP(LDN+15)
          6   GENERAL ADVERSE RESPONSE,POPULATION EQUIVALENT(FRACTIONAL IMPACT)
          7   GENERAL ADVERSE RESPONSE.ALEXANDRE ENERGY INDICATOR(LDN)
          8   GENERAL ADVERSE RESPONSE.ALEXANDRE LOUDNESS INDICATOR(LDN)
          9   GENERAL ADVERSE RESPONSE.ALEXANDRE SYNTHETIC INDICATOR(LDN)
         10   SPEECH INTEFERENCE,FRACTIONAL UNINTELLIGIBILITY BASED ON A-LEVEL
         11   GENERAL ADVERSE RESPONSE.STEVENS MARK6 LOUDNESS LEVEL
         12   GENERAL ADVERSE RESPONSE.STEVENS MARK6 LOUDNESS
         13   GENERAL ADVERSE RESPONSE.STEVENS MARK7 LOUDNESS LEVEL
         14   GENERAL ADVERSE RESPONSE.STEVENS MARK7 LOUDNESS
         15   GENERAL ADVERSE RESPONSE.ZWICKER LOUDNESS LEVEL
         16   GENERAL ADVERSE RESPONSE.ZWICKER LOUDNESS
         17   GENERAL ADVERSE RESPONSE,PERCEIVED NOISE LEVEL(FAR 36)
         18   GENERAL ADVERSE RESPONSE.NOISINESS(FAR 36)
         19   SLEEP INTERFERENCE.DISRUPTION(FROM A-WEIGHTED SOUND EXPOSURE LEVEL)
         20   SLEEP INTERFERENCE, AWAKENING(FROM A-WEIGHTED SOUND EXPOSURE LEVEL)
TIMEIN   21   15.315.315.331. 36. 41. 15.115.115.148. 48. 48. 6.  5.  0.  0.  0.  0.
         22   10.210.210.2 5.35.3 5.3 10.110.110.121.221.221.20.  0.  0.  0.  0.  0.
         23   25.325.325.331. 31. 31. 15.115.115.148. 48. 48. 0.  0.  0.  0.  0.  0.
         24   18.621.721.715.318.518.515. 15. 15. 31.231.231.26.3 0.  0.  0.  0.  0.
         25   18.621.721.718.418.518.515. 15. 15. 31.231.231.20.  0.  0.  0.  0.  0.
         26   25.325.325.336. 31. 31. 10. 15.115.148. 48. 48. 0.  0.  0.  0.  0.  0.
         27   33.130. 30. 143.167.173.30. 23.723.745.130. 45.157.335. 7.2 43. 41.525.
         28   11.511.511.523.127. 34.910. 10. 10. 13.913.913.9 7.9 4. 0.   7.9 7.94.
         29   72.382.339.3133.147.153.43.743.743.745.145.145.128.714.37.2 43. 22. 10.
         30   31.431.431.438.242.242.215.915.915.939.739.739.715.97.9 7.9 0.  0.  0.
         31   15.415.415. 35. 10. 30. 5.  5.  10. 35. 39.739.710.67.9 0.  40.139.121.
         32   53.353. 53. 72.361.655.615. 15. 15. 165.165.165.0.  0.  0.  60. 60. 60.
         33   15. 20. 30. 97. 109.109.16.216.216.267.867.867.830. 14.55.  15. 14.59.
         34   33. 33. 33. 79.690. 97.820. 20. 20. 39. 39. 39. 10.4 5.20.  10.4 5.22.6
         35   35. 39. 39. 107.109.109.16.216.216.267.867.867.810. 5.  5.  10. 5.  5.
         36   64. 64.264.275.679.679.618.318.318.321. 21. 21. 14.57.3 7.3 0.  0.  0.
         37   30. 35. 35. 102.86.9106.18.318.318.390. 110.110.10. 0.  0.  30. 30. 0.
         38   36. 35. 39. 66. 55.966.815. 15. 16.2120.120.120.0.  0.  0.  10. 10. 0.
         39   6.3 10.912.955.452.952.912.512.512.5441.441.441.0.  2.  0.  0.  0.  0.
         40   7.1  7.17.1 53.453.453.415.315.315.3417.417.471.0.  0.  0.  0.  0.  0.
         41   12.912.912.952.952.952.912.512.512.5441.441.441.0.  0.  0.  0.  0.  0.
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46   10.210.210.2 5.35.3 5.3 10.110.110.121.221.221.20.  0.  0.  0.  0.  0.
47   25.325.325.331. 31. 31. 15.115.115.148. 48. 48. 0.  0.  0.  0.  0.  0.
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49   18.621.715.118.418.539.115. 15. 7.2 31.231.258.00.  0.  0.  0.  0.  0.
50   25.325.325.336. 31. 31. 10. 15.115.148. 48. 48. 0.  0.  0.  0.  0.  0.
51   33.130. 30. 143.167.173.30. 23.723.745.130. 45.157.335. 7.2 43. 41.525.
52   11.511.511.523.127. 34.910. 10. 10. 13.913.913.9 7.9 7. 0.   7.9 7.94.
53   72.382.389.3133.147.153.43.743.743.745.145.145.128.714.37.2 43. 22. 10.
54   31.431.431.438.242.242.215.915.915.939.739.739.715.97.9 7.9 0.  0.  0.
55   15.415.435.035. 10. 205.5.  5.  20.035. 39.750.210.67.9 0.  40.139.160.
56   53.353. 53. 72.361.655.615. 15. 15. 165.165.165.0.  0.  0.  60. 60. 60.
57   15. 20. 30. 97. 109.109.16.216.216.267.867.867.830. 14.55.  15. 14.59.
58   33. 33. 33. 79.690. 97.820. 20. 20. 39. 39. 39. 10.4 5.20.  10.4 5.22.6
59   36. 39. 39. 107.109.109.16.216.216.267.867.867.810. 5.  5.  10. 5.  5.
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61   30. 35. 35. 102.86.9129.18.318.315.890. 110.90. 10. 0.  0.  30. 30. 0.
62   36. 35. 39. 66. 55.966.815. 15. 16.2120.120.120.0.  0.  0.  10. 10. 0.
63   6.3 10.912.955.452.952.912.512.512.5441.441.441.0.  2.  0.  0.  0.  0.
64   7.1  7.17.1 53.453.453.415.315.315.3417.417.471.0.  0.  0.  0.  0.  0.
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67   10. 10. 10. 35.635.635. 5.  5.  5.  489.489.470.0.  0.  0.  0.  0.  0.
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69   19.515. 19.538. 38. 38. 15. 15. 15. 46.346.346.30.  4.5 0.  0.  0.  0.
70   14.214.214.27.4 7.4 7.4 5.2 5.2 5.2 64.364.364.30.  0.  0.  0.  0.  0.
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81   15. 20. 25. 87.782.792.715. 15. 15. 88.288.288.220. 20. 5.  5.  0.  0.
82   35.235.235.278.689. 94.220.420.420.458.558.558.510.45.2 0.  10.45.2 5.2
83   45. 45. 45. 82.782.782.715. 15. 15. 88.288.288.25.  5.  5.  0.  0.  0.
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85   30. 35. 35. 102.86.9129.18.318.315.890. 110.90. 10. 0.  0.  30. 30. 0.
86   35. 35. 35. 55.955.972. 15. 15. 15. 120.120.120.0.  0.  0.  10. 10. 0.
87   22. 10. 10. 16. 20. 22. 7.  10. 7.  477.477.477.0.  0.  0.  0.  0.  0.
88   12.912.912.985.485.485.419.819.319.8368.368.368.0.  0.  0.  0.  0.  0.
89   22. 22. 22. 16. 16. 16. 7.  7.  7.  477.477.477.0.  0.  0.  0.  0.  0.
90   36.436.436.456.856.856.821.421.421.4357.357.357.0.  0.  0.  0.  0.  0.
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	91	10. 10. 10. 35.635.635. 5. 5. 5. 489.489.470.0. 0. 0. 0. 0. 0.															
	92	0. 0. 0. 0. 0. 0. 5. 5. 5. 535.535.535.0. 0. 0. 0. 0. 0.															
PEOPLE	93	7.4 2.2 5.225.9 7.818.121.4 6.415.015.6 4.710.924.6 7.317.210.0 3.0 7.0															
	94	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	10.4	11.0	11.6	11.6	11.6	11.6	11.6	11.6
	95	11.7	14.2	19.4	20.8	21.0	21.0	21.0	21.0	14.2	16.8	22.0	23.3	23.5	23.6	23.6	23.6
	96	15.2	17.7	22.9	24.2	24.4	24.5	24.5	24.5	20.2	22.7	27.9	29.2	29.4	29.5	29.5	29.5
	97	6.0	6.6	7.1	7.2	7.2	7.2	7.2	7.2	6.7	6.7	6.7	6.7	6.7	6.7	6.7	6.7
	98	15.4	17.4	20.3	20.8	20.9	20.9	20.9	20.9	18.0	19.9	22.9	23.4	23.4	23.5	23.5	23.5
	99	19.7	22.3	27.5	28.8	29.0	29.0	29.0	29.0	23.9	25.9	28.8	29.3	29.4	29.4	29.4	29.4
	100	10.7	13.3	18.5	19.8	20.0	20.1	20.1	20.1	12.2	14.1	17.1	17.6	17.7	17.7	17.7	17.7
	101	-.3	-.3	-.3	-.3	-.3	-.3	-.3	-.3	10.3	11.9	13.9	14.2	14.3	14.3	14.3	14.3
	102	12.7	15.3	20.5	21.8	22.0	22.1	22.1	22.1	17.7	20.3	25.5	26.8	27.0	27.1	27.1	27.1
	103	10.7	13.3	18.5	19.8	20.0	20.1	20.1	20.1	12.2	14.1	17.1	17.6	17.7	17.7	17.7	17.7
	104	3.0	9.6	11.6	11.9	12.0	12.0	12.0	12.0	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8
	105	17.9	20.4	25.6	26.9	27.1	27.2	27.2	27.2	22.0	24.0	26.9	27.4	27.5	27.5	27.5	27.5
	106	10.7	13.3	18.5	19.8	20.0	20.1	20.1	20.1	13.0	15.6	20.8	22.1	22.3	22.3	22.3	22.3
	107	9.5	12.1	17.3	18.6	18.8	18.8	18.8	18.8	12.1	14.6	19.8	21.2	21.4	21.4	21.4	21.4
	108	6.7	6.7	6.7	6.7	6.7	6.7	6.7	6.7	23.9	25.9	28.8	29.3	29.4	29.4	29.4	29.4
	109	10.7	13.3	18.5	19.8	20.0	20.1	20.1	20.1	12.2	14.1	17.1	17.6	17.7	17.7	17.7	17.7
	110	9.5	12.1	17.3	18.6	18.8	18.8	18.8	18.8	11.3	13.2	16.1	16.7	16.7	16.7	16.7	16.7
	111	12.2	14.1	17.1	17.6	17.7	17.7	17.7	17.7	16.7	16.7	16.7	16.7	16.7	16.7	16.7	16.7
	112	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	10.4	11.0	11.6	11.6	11.6	11.6	11.6	11.6
	113	11.7	14.2	19.4	20.8	21.0	21.0	21.0	21.0	14.2	16.8	22.0	23.3	23.5	23.6	23.6	23.6
	114	15.2	17.7	22.9	24.2	24.4	24.5	24.5	24.5	20.2	22.7	27.9	29.2	29.4	29.5	29.5	29.5
	115	6.0	6.6	7.1	7.2	7.2	7.2	7.2	7.2	6.7	6.7	6.7	6.7	6.7	6.7	6.7	6.7
	116	15.4	17.4	20.3	20.8	20.9	20.9	20.9	20.9	18.0	19.9	22.9	23.4	23.4	23.5	23.5	23.5
	117	19.7	22.3	27.5	28.8	29.0	29.0	29.0	29.0	23.9	25.9	28.8	29.3	29.4	29.4	29.4	29.4
	118	10.7	13.3	18.5	19.8	20.0	20.1	20.1	20.1	12.2	14.1	17.1	17.6	17.7	17.7	17.7	17.7
	119	-.3	-.3	-.3	-.3	-.3	-.3	-.3	-.3	10.3	11.9	13.9	14.2	14.3	14.3	14.3	14.3
	120	12.7	15.3	20.5	21.8	22.0	22.1	22.1	22.1	17.7	20.3	25.5	26.8	27.0	27.1	27.1	27.1
	121	10.7	13.3	18.5	19.8	20.0	20.1	20.1	20.1	12.2	14.1	17.1	17.6	17.7	17.7	17.7	17.7
	122	3.0	9.6	11.6	11.9	12.0	12.0	12.0	12.0	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8
	123	17.9	20.4	25.6	26.9	27.1	27.2	27.2	27.2	22.0	24.0	26.9	27.4	27.5	27.5	27.5	27.5
	124	10.7	13.3	18.5	19.8	20.0	20.1	20.1	20.1	13.0	15.6	20.8	22.1	22.3	22.3	22.3	22.3
	125	9.5	12.1	17.3	18.6	18.8	18.8	18.8	18.8	12.1	14.6	19.8	21.2	21.4	21.4	21.4	21.4
	126	6.7	6.7	6.7	6.7	6.7	6.7	6.7	6.7	23.9	25.9	28.8	29.3	29.4	29.4	29.4	29.4
	127	10.7	13.3	18.5	19.8	20.0	20.1	20.1	20.1	12.2	14.1	17.1	17.6	17.7	17.7	17.7	17.7
	128	9.5	12.1	17.3	18.6	18.8	18.8	18.8	18.8	11.3	13.2	16.1	16.7	16.7	16.7	16.7	16.7
	129	12.2	14.1	17.1	17.6	17.7	17.7	17.7	17.7	16.7	16.7	16.7	16.7	16.7	16.7	16.7	16.7
	130	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	10.4	11.0	11.6	11.6	11.6	11.6	11.6	11.6
	131	11.7	14.2	19.4	20.8	21.0	21.0	21.0	21.0	14.2	16.8	22.0	23.3	23.5	23.6	23.6	23.6
	132	15.2	17.7	22.9	24.2	24.4	24.5	24.5	24.5	20.2	22.7	27.9	29.2	29.4	29.5	29.5	29.5
	133	6.0	6.6	7.1	7.2	7.2	7.2	7.2	7.2	6.7	6.7	6.7	6.7	6.7	6.7	6.7	6.7
	134	15.4	17.4	20.3	20.8	20.9	20.9	20.9	20.9	18.0	19.9	22.9	23.4	23.4	23.5	23.5	23.5
	135	19.7	22.3	27.5	28.8	29.0	29.0	29.0	29.0	23.9	25.9	28.8	29.3	29.4	29.4	29.4	29.4

136	10.7	13.3	18.5	19.8	20.0	20.1	20.1	20.1	12.2	14.1	17.1	17.6	17.7	17.7	17.7	17.7
137	-.3	-.3	-.3	-.3	-.3	-.3	-.3	-.3	10.3	11.9	13.9	14.2	14.3	14.3	14.3	14.3
138	12.7	15.3	20.5	21.8	22.0	22.1	22.1	22.1	17.7	20.3	25.5	26.8	27.0	27.1	27.1	27.1
139	10.7	13.3	18.5	19.8	20.0	20.1	20.1	20.1	12.2	14.1	17.1	17.6	17.7	17.7	17.7	17.7
140	8.0	9.6	11.6	11.9	12.0	12.0	12.0	12.0	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8
141	17.9	20.4	25.6	26.9	27.1	27.2	27.2	27.2	22.0	24.0	26.9	27.4	27.5	27.5	27.5	27.5
142	10.7	13.3	18.5	19.8	20.0	20.1	20.1	20.1	13.0	15.6	20.8	22.1	22.3	22.3	22.3	22.3
143	9.5	12.1	17.3	18.6	18.8	18.8	18.8	18.8	12.1	14.6	19.8	21.2	21.4	21.4	21.4	21.4
144	6.7	6.7	6.7	6.7	6.7	6.7	6.7	6.7	23.9	25.9	28.8	29.3	29.4	29.4	29.4	29.4
145	10.7	13.3	18.5	19.8	20.0	20.1	20.1	20.1	12.2	14.1	17.1	17.6	17.7	17.7	17.7	17.7
146	9.5	12.1	17.3	18.6	18.8	18.8	18.8	18.8	11.3	13.2	16.1	16.7	16.7	16.7	16.7	16.7
147	12.2	14.1	17.1	17.6	17.7	17.7	17.7	17.7	16.7	16.7	16.7	16.7	16.7	16.7	16.7	16.7
148	33.4	36.4	45.4	52.4	55.4	56.4	56.4	56.4	35.7	38.7	47.7	54.7	57.7	58.7	58.7	58.7
149	32.2	35.2	44.2	51.2	54.2	55.2	55.2	55.2	34.7	37.7	46.7	53.7	56.7	57.7	57.7	57.7
150	35.7	38.7	47.7	54.7	57.7	58.7	58.7	58.7	20.7	23.7	32.7	39.7	42.7	43.7	43.7	43.7
151	37.9	40.9	49.9	56.9	59.9	60.9	60.9	60.9	40.2	43.2	52.2	59.2	62.2	63.2	63.2	63.2
152	36.7	39.7	48.7	55.7	58.7	59.7	59.7	59.7	39.3	42.3	51.3	58.3	61.3	62.3	62.3	62.3
153	40.2	43.2	52.2	59.2	62.2	63.2	63.2	63.2	25.2	28.2	37.2	44.2	47.2	48.2	48.2	48.2
154	30.9	33.9	42.9	49.9	52.9	53.9	53.9	53.9	33.2	36.2	45.2	52.2	55.2	56.2	56.2	56.2
155	29.7	32.7	41.7	48.7	51.7	52.7	52.7	52.7	32.3	35.3	44.3	51.3	54.3	55.3	55.3	55.3
156	33.2	36.2	45.2	52.2	55.2	56.2	56.2	56.2	18.2	21.2	30.2	37.2	40.2	41.2	41.2	41.2
157	36.1	39.1	48.1	55.1	58.1	59.1	59.1	59.1	38.3	41.3	50.3	57.3	60.3	61.3	61.3	61.3
158	34.8	37.8	46.8	53.8	56.8	57.8	57.8	57.8	37.4	40.4	49.4	56.4	59.4	60.4	60.4	60.4
159	38.3	41.3	50.3	57.3	60.3	61.3	61.3	61.3	23.3	26.3	35.3	42.3	45.3	46.3	46.3	46.3
160	37.9	40.9	49.9	56.9	59.9	60.9	60.9	60.9	40.2	43.2	52.2	59.2	62.2	63.2	63.2	63.2
161	36.7	39.7	48.7	55.7	58.7	59.7	59.7	59.7	39.3	42.3	51.3	58.3	61.3	62.3	62.3	62.3
162	40.2	43.2	52.2	59.2	62.2	63.2	63.2	63.2	25.2	28.2	37.2	44.2	47.2	48.2	48.2	48.2
163	27.9	30.9	39.9	46.9	49.9	50.9	50.9	50.9	30.2	33.2	42.2	49.2	52.2	53.2	53.2	53.2
164	26.7	29.7	38.7	45.7	48.7	49.7	49.7	49.7	29.3	32.3	41.3	48.3	51.3	52.3	52.3	52.3
165	30.2	33.2	42.2	49.2	52.2	53.2	53.2	53.2	24.2	24.2	24.2	24.2	27.2	28.2	28.2	28.2
166	23.4	26.4	35.4	42.4	45.4	46.4	46.4	46.4	25.7	28.7	37.7	44.7	47.7	48.7	48.7	48.7
167	22.2	25.2	34.2	41.2	44.2	45.2	45.2	45.2	24.7	27.7	36.7	43.7	46.7	47.7	47.7	47.7
168	25.7	28.7	37.7	44.7	47.7	48.7	48.7	48.7	20.7	23.7	32.7	39.7	42.7	43.7	43.7	43.7
169	27.9	30.9	39.9	46.9	49.9	50.9	50.9	50.9	30.2	33.2	42.2	49.2	52.2	53.2	53.2	53.2
170	26.7	29.7	38.7	45.7	48.7	49.7	49.7	49.7	29.3	32.3	41.3	48.3	51.3	52.3	52.3	52.3
171	30.2	33.2	42.2	49.2	52.2	53.2	53.2	53.2	25.2	28.2	37.2	44.2	47.2	48.2	48.2	48.2
172	20.9	23.9	32.9	39.9	42.9	43.9	43.9	43.9	23.2	26.2	35.2	42.2	45.2	46.2	46.2	46.2
173	19.7	22.7	31.7	38.7	41.7	42.7	42.7	42.7	22.3	25.3	34.3	41.3	44.3	45.3	45.3	45.3
174	23.2	26.2	35.2	42.2	45.2	46.2	46.2	46.2	18.2	21.2	30.2	37.2	40.2	41.2	41.2	41.2
175	26.1	29.1	38.1	45.1	48.1	49.1	49.1	49.1	28.3	31.3	40.3	47.3	50.3	51.3	51.3	51.3
176	24.8	27.8	36.8	43.8	46.8	47.8	47.8	47.8	27.4	30.4	39.4	46.4	49.4	50.4	50.4	50.4
177	28.3	31.3	40.3	47.3	50.3	51.3	51.3	51.3	23.3	26.3	35.3	42.3	45.3	46.3	46.3	46.3
178	27.9	30.9	39.9	46.9	49.9	50.9	50.9	50.9	30.2	33.2	42.2	49.2	52.2	53.2	53.2	53.2
179	26.7	29.7	38.7	45.7	48.7	49.7	49.7	49.7	29.3	32.3	41.3	48.3	51.3	52.3	52.3	52.3
180	30.2	33.2	42.2	49.2	52.2	53.2	53.2	53.2	25.2	28.2	37.2	44.2	47.2	48.2	48.2	48.2

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          181      27.9 30.9 39.9 46.9 49.9 50.9 50.9 50.9 30.2 33.2 42.2 49.2 52.2 53.2 53.2 53.2
          182      26.7 29.7 38.7 45.7 48.7 49.7 49.7 49.7 29.3 32.3 41.3 48.3 51.3 52.3 52.3 52.3
          183      30.2 33.2 42.2 49.2 52.2 53.2 53.2 53.2 24.2 24.2 24.2 24.2 27.2 28.2 28.2 28.2
          184      23.4 26.4 35.4 42.4 45.4 46.4 46.4 46.4 25.7 28.7 37.7 44.7 47.7 48.7 48.7 48.7
          185      22.2 25.2 34.2 41.2 44.2 45.2 45.2 45.2 24.7 27.7 36.7 43.7 46.7 47.7 47.7 47.7
          186      25.7 28.7 37.7 44.7 47.7 48.7 48.7 48.7 20.7 23.7 32.7 39.7 42.7 43.7 43.7 43.7
          187      27.9 30.9 39.9 46.9 49.9 50.9 50.9 50.9 30.2 33.2 42.2 49.2 52.2 53.2 53.2 53.2
          188      26.7 29.7 38.7 45.7 48.7 49.7 49.7 49.7 29.3 32.3 41.3 48.3 51.3 52.3 52.3 52.3
          189      30.2 33.2 42.2 49.2 52.2 53.2 53.2 53.2 25.2 28.2 37.2 44.2 47.2 48.2 48.2 48.2
          190      20.9 23.9 32.9 39.9 42.9 43.9 43.9 43.9 23.2 26.2 35.2 42.2 45.2 46.2 46.2 46.2
          191      19.7 22.7 31.7 38.7 41.7 42.7 42.7 42.7 22.3 25.3 34.3 41.3 44.3 45.3 45.3 45.3
          192      23.2 26.2 35.2 42.2 45.2 46.2 46.2 46.2 18.2 21.2 30.2 37.2 40.2 41.2 41.2 41.2
          193      26.1 29.1 38.1 45.1 48.1 49.1 49.1 49.1 28.3 31.3 40.3 47.3 50.3 51.3 51.3 51.3
          194      24.8 27.8 36.8 43.8 46.8 47.8 47.8 47.8 27.4 30.4 39.4 46.4 49.4 50.4 50.4 50.4
          195      28.3 31.3 40.3 47.3 50.3 51.3 51.3 51.3 23.3 26.3 35.3 42.3 45.3 46.3 46.3 46.3
          196      27.9 30.9 39.9 46.9 49.9 50.9 50.9 50.9 30.2 33.2 42.2 49.2 52.2 53.2 53.2 53.2
          197      26.7 29.7 38.7 45.7 48.7 49.7 49.7 49.7 29.3 32.3 41.3 48.3 51.3 52.3 52.3 52.3
          198      30.2 33.2 42.2 49.2 52.2 53.2 53.2 53.2 25.2 28.2 37.2 44.2 47.2 48.2 48.2 48.2
          199      27.9 30.9 39.9 46.9 49.9 50.9 50.9 50.9 30.2 33.2 42.2 49.2 52.2 53.2 53.2 53.2
          200      26.7 29.7 38.7 45.7 48.7 49.7 49.7 49.7 29.3 32.3 41.3 48.3 51.3 52.3 52.3 52.3
          201      30.2 33.2 42.2 49.2 52.2 53.2 53.2 53.2 24.2 24.2 24.2 24.2 27.2 28.2 28.2 28.2
---------------------------------------------------------------------------------------------------------
TITLE     202        VACUUM CLEANER 1 CYCLE ONLY OPERATOR REQUIRED EUREKA CANISTER
NCANUM    203      1,1,1,2,2,2,2,2,2,3,1,1,1,1,1,1,1,1,4,4
OPTYP     204      .1     .05    .5     .25    .1     0.
PERC      205      .992   .992   .992
ONTIM     206      25.7   19.3   12.8
TIM       207      60.    45.    30.
NT,MT     208      1,1
TP9       209      .05    .75    .2     .0
RMP9      210      .08 .50 .00 .34 .08 .00 .11 .56 .00 .33 .00 .00 .17 .50 .00 .33 .00 .00
SPECTR    211      62.2   69.5   71.5   71.0   71.1   64.2   56.8   44.5
   ┌────→ 212      5,70,90,-12
   │DISLEV 213      .19 .33 .19 .15 .14
   │
   └─IDB, MIN, MAX, OPDIFF
```

D.2 Computer Output for Sample Calculation

VACUUM CLEANER 1 CYCLE ONLY OPERATOR REQUIRED EUREKA CANIS
POPULATICN IMPACTS FOR CPERATOR, PRIMARY , SECONDARY DWELLINGS
EXPOSED PERSONS= .2080+09 TOTAL POPULATION= .2097+09

1 HEARING,FRACTIONAL EXPOSURE(CRITERION LEVEL=70 DB)

	OPERATOR	PRIMARY	SECONDARY	PRI+OP
WEIGHTED POPULATION	.7343+06	.3606+07	.1908+04	.4340+07
NOISE IMPACT INDEX	.3530-02	.1733-01	.9173-05	.2086-01

2 HEARING,4 FREQUENCY AVERAGE(CORRESP TO PHL FROM CHABA WG69)

	OPERATOR	PRIMARY	SECONDARY	PRI+OP
WEIGHTED POPULATICN	.0000	.0000	.0000	.0000
NOISE IMPACT INDEX	.0000	.0000	.0000	.0000

3 HEARING,AVERAGE NIPTS AT 4 KHZ

	OPERATOR	PRIMARY	SECONDARY	PRI+OP
WEIGHTEC PCPULATION	.0000	.0000	.0000	.0000
NOISE IMPACT INDEX	.0000	.0000	.0000	.0000

4 GENERAL ADVERSE RESPCNSE,CHABA WG69 LWP(LDN)

	OPERATOR	PRIMARY	SECONDARY	PRI+OP
WEIGHTED POPULATION	.4395+07	.1335+08	.8256+05	.1478+08
NOISE IMPACT INDEX	.2113-01	.6415-01	.3969-03	.7103-01

5 GENERAL ADVERSE RESPCNSE,CHABA WG69 LWP(LDN+15)

	OPERATOR	PRIMARY	SECONDARY	PRI+OP
WEIGHTED POPULATICN	.3176+08	.7731+08	.9868+06	.8304+08
NOISE IMPACT INDEX	.1527+00	.3716+00	.4744-02	.3992+00

6 GENERAL ADVERSE RESPCNSE,POPULATION EQUIVALENT(FRACTIONAL IMPACT)

	OPERATOR	PRIMARY	SECONDARY	PRI+OP
WEIGHTED PCPULATION	.4284+06	.5764+07	.0000	.7231+07
NOISE IMPACT INDEX	.2059-02	.2771-01	.0000	.3476-01

7 GENERAL ADVERSE RESPCNSE,ALEXANDRE ENERGY INDICATOR(LDN)

	OPERATOR	PRIMARY	SECONDARY	PRI+OP
WEIGHTED POPULATICN	.2619+05	.4607+06	.0000	.6380+06
NOISE IMPACT INDEX	.1259-03	.2215-02	.0000	.3067-02

8 GENERAL ADVERSE RESPCNSE,ALEXANDRE LOUDNESS INDICATOR(LDN)

	OPERATOR	PRIMARY	SECONDARY	PRI+OP
WEIGHTED PCPULATION	.2150+06	.3097+07	.0000	.3980+07
NOISE IMPACT INDEX	.1033-02	.1489-01	.0000	.1913-01

9 GENERAL ADVERSE RESPCNSE,ALEXANDRE SYNTHETIC INDICATOR(LDN)

	OPERATOR	PRIMARY	SECONDARY	PRI+OP
WEIGHTED PCPULATION	.1260+06	.1938+07	.0000	.2548+07
NOISE IMPACT INDEX	.6058-03	.9318-02	.0000	.1225-01

10 SPEECH INTEFERENCE,FRACTIONAL UNINTELLIGIBILITY BASED ON A-LEVEL
*** NO SECCNDARY CALC FCR SPEECH INT***

	OPERATOR	PRIMARY	SECONDARY	PRI+OP
WEIGHTED PCPULATICN	.2669+06	.6631+06	.0000	.9300+06
NOISE IMPACT INDEX	.1283-02	.3188-02	.0000	.4471-02

11 GENERAL ADVERSE RESPONSE,STEVENS MARK6 LOUDNESS LEVEL

	OPERATOR	PRIMARY	SECONDARY	PRI+OP
WEIGHTED POPULATION	.4931+08	.1099+09	.0000	.1149+09
NOISE IMPACT INDEX	.2370+00	.5282+00	.0000	.5522+00

12 GENERAL ADVERSE RESPONSE,STEVENS MARK6 LOUDNESS

	OPERATOR	PRIMARY	SECONDARY	PRI+OP
WEIGHTED POPULATION	.3386+08	.7700+08	.0000	.8138+08
NOISE IMPACT INDEX	.1628+00	.3701+00	.0000	.3912+00

13 GENERAL ADVERSE RESPONSE,STEVENS MARK7 LOUDNESS LEVEL

	OPERATOR	PRIMARY	SECONDARY	PRI+OP
WEIGHTED POPULATION	.4791+08	.9677+08	.0000	.1005+09
NOISE IMPACT INDEX	.2303+00	.4652+00	.0000	.4830+00

14 GENERAL ADVERSE RESPONSE,STEVENS MARK7 LOUDNESS

	OPERATOR	PRIMARY	SECONDARY	PRI+OP
WEIGHTED POPULATION	.3513+08	.7693+08	.0000	.8150+08
NOISE IMPACT INDEX	.1689+00	.3698+00	.0000	.3918+00

15 GENERAL ADVERSE RESPONSE,ZWICKER LOUDNESS LEVEL

	OPERATOR	PRIMARY	SECONDARY	PRI+OP
WEIGHTED POPULATION	.8435+08	.1495+09	.4935+05	.1540+09
NOISE IMPACT INDEX	.4055+00	.7186+00	.2372-03	.7403+00

16 GENERAL ADVERSE RESPONSE,ZWICKER LOUDNESS

	OPERATOR	PRIMARY	SECONDARY	PRI+OP
WEIGHTED POPULATION	.5981+08	.1198+09	.1608+06	.1263+09
NOISE IMPACT INDEX	.2875+00	.5761+00	.7731-03	.6074+00

17 GENERAL ADVERSE RESPONSE,PERCEIVED NOISE LEVEL(FAR 36)

	OPERATOR	PRIMARY	SECONDARY	PRI+OP
WEIGHTED POPULATION	.4294+08	.9698+08	.0000	.1017+09
NOISE IMPACT INDEX	.2064+00	.4662+00	.0000	.4891+00

18 GENERAL ADVERSE RESPONSE,NOISINESS(FAR 36)

	OPERATOR	PRIMARY	SECONDARY	PRI+OP
WEIGHTED POPULATION	.2961+08	.6573+08	.0000	.6952+08
NOISE IMPACT INDEX	.1423+00	.3160+00	.0000	.3342+00

19 SLEEP INTERFERENCE,DISRUPTION(FROM A-WEIGHTED SOUND EXPOSURE LEVEL)
NO OPERATOR CALC FOR SLEEP INT
***NO NIGHT OPER FOR VACUUM USE TPER(3) FOR TEST

	OPERATOR	PRIMARY	SECONDARY	PRI+OP
WEIGHTED POPULATION	.0000	.4203+09	.2929+09	.0000
NOISE IMPACT INDEX	.0000	.2020+01	.1408+01	.0000

20 SLEEP INTERFERENCE, AWAKENING(FROM A-WEIGHTED SOUND EXPOSURE LEVEL)
NO OPERATOR CALC FOR SLEEP INT
***NO NIGHT OPER FOR VACUUM USE TPER(3) FOR TEST

	OPERATOR	PRIMARY	SECONDARY	PRI+OP
WEIGHTED POPULATION	.0000	.2787+09	.1099+09	.0000
NOISE IMPACT INDEX	.0000	.1340+01	.5283+00	.0000

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References for Appendix D

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Simone L. Yaniv, Daniel R. Flynn, Daniel M. Corley and Marilyn A. Cadoff

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Final

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15. SUPPLEMENTARY NOTES

☐ Document describes a computer program; SF-185, FIPS Software Summary, is attached.

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

This report documents the development of a conceptual model, and a computer program for its implementation, for assessing the aggregate impact of noise from household and consumer products on the health and welfare of the national population. The computer program requires input data on population, time utilization, dwelling type, noise isolation in dwellings, product noise emission, and product utilization. From the input data, the "weighted population," corresponding to each of a number of different noise descriptors, is computed. The report describes the assumptions involved in the model, reviews available input data, and documents the computer program.

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

Acoustics; consumer products; environmental impact; human response criteria; noise; sound

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