N-96-01
II-A-282

GUIDELINES

FOR

THE PREPARATION OF PROCEDURES

FOR

THE MEASUREMENT OF SOUND SOURCE EMISSION

DECEMBER 1978

PRELIMINARY

GUIDELINES FOR THE PREPARATION OF PROCEDURES FOR THE MEASUREMENT OF SOUND SOURCE EMISSION

DECEMBER 1978

PREPARED FOR

U. S. ENVIRONMENTAL PROTECTION AGENCY

WASHINGTON, D.C. 20460

by

ACOUSTICAL SOCIETY OF AMERICA

FROM

WORKSHOP ON DEVELOPMENT OF STANDARDS ON ENVIRONMENTAL SOUND

STANDARDS PLANNING PANEL ON NOISE ABATEMENT AND CONTROL

AMERICAN NATIONAL STANDARDS INSTITUTE

PRELIMINARY

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Section 1

INTRODUCTION

1.1 Background

Recent efforts by the Federal Government and several state and local governments to control environmental noise in an effort to reduce noise exposure of the population brought out the need for uniform, standardized sound measurement methods, human response evaluation and analysis of noise control effectiveness. Although the voluntary standards system coordinated by the American National Standards Institute (ANSI) has been and is presently providing, through its various committees concerned with sound, a broad spectrum of standards on physical acoustics, bioacoustics and noise emission by various sources and its control, it became obvious that the various legislative and regulatory needs required additional, sometimes slightly different, standards from those available. Frequently, regulatory agencies are committed to mandatory time schedules and require standards reflecting the present state of knowledge. These standards often are not available and cannot be produced as voluntary consensus standards without adequate lead time. Since these regulatory efforts are rapidly increasing, it can clearly be foreseen that the need for additional and/or updated standards also will increase.

To anticipate these needs and to provide for a coordinated program of standards development of the voluntary system to satisfy government requirements, the ANSI Executive Standards Council established in 1976 the ANSI Standards Planning Panel on Noise Abatement and Control. This panel, composed of representatives from the various societies with an interest in noise standards and from regulatory agencies, issued a report ("Assessment and Recommendation: Report of ANSI Standards Planning Panel on Noise Abatement and Control")[1] carrying out the Planning Panel's mission to: (1) identify standards needs and their priorities and scheduling requirements, (2) determine if there are standards projects covering the scope of the needs, (3) identify the standards developing organization most capable of carrying out the mission and (4) endeavor to have the project initiated in a standards developing organization. One of the critical action items recommended in the Planning Panel's report is the convening of a conference workshop on "Development of Standards for Environmental Sound" to prepare (1) "a detailed, integrated development plan for voluntary standards, including priorities and research requirements, for measurement and evaluation of sound in communities, rooms and industry, and for basic standards necessary to support measurement and evaluation of source sound emission and its control and (2) guidelines for the use of writing groups in the federated voluntary standards system, which are endeavoring to develop standards for the measurement of source sound emission, with particular emphasis on relating the intent of the measurement standard with the ease of use, accuracy and appropriateness for its purpose."

[1]Available from the American National Standards Institute, 1430 Broadway, New York, N. Y. 10018 and from the Acoustical Society of America, 335 E. 45 St., New York, N. Y. 10017.

In response to this recommendation such a workshop was organized and managed by the Acoustical Society of America under the auspices of the ANSI Standards Planning Panel on Noise Abatement and Control and was sponsored by the U.S. Environmental Protection Agency in cooperation with the National Bureau of Standards. It was held Dec. 7-9, 1977, at Deerfield Beach, Florida, with the administrative support of Florida Atlantic University. Participants came from many voluntary standards organizations including the Acoustical Society of America, ANSI, the American Society for Testing and Materials, and the Society of Automotive Engineers, and from several federal agencies including, in addition to EPA and NBS, the Department of Labor, the Department of Transportation, the Department of Health, Education and Welfare, the Department of Housing and Urban Development, the U. S. Air Force, the U. S. Navy and the General Services Administration. Additional participants came from state governments, industry, universities and acoustical consulting organizations (for List of Participants see Appendix A1). The participants contributed to the workshop as individuals, not as representatives of their organizations.

The results of the workshop are presented in two separate documents according to the two goals listed above: the report on "Plan for the Development of Voluntary Standards on Environmental Sound in Response to Federal Agencies' Needs" and the present report on "Guidelines for the Preparation of Procedures for Measurement of Source Sound Emission".

1.2 Operation of the Workshop

Sixty-eight people attended the workshop. Thirty-two were assigned to the "guidelines", thirty-three to the "planning" division according to expertise and organizational background and the three staff people were involved with both divisions. Care was taken to have balanced representation on all groups. Most participants had received assignments ahead of time and after opening presentations and agreement on purpose and goals, detailed discussion and collection of material took place in small working groups. The results of the working groups' analyses and recommendations were presented to all workshop participants to benefit from broad discussion and all possible inputs. The final accumulation and editing of the reports took place after the workshop and all participants were given another chance for review and comments. An attempt was made to incorporate all opinions and suggestions. When conflicting opinions existed they were resolved by the working group chairpersons, the division chairpersons or the editor. Although an attempt was made to achieve a consensus document, final responsibility for the guidelines report rests with the five persons who chaired the guidelines division and with the editor.

1.3 Introduction to the Guidelines

This report contains guidelines for the preparation of procedures (standards, test codes, recommended practices, etc.) for measurement of source sound emission. These guidelines are intended to provide the framework for the thought processes to be followed in developing measurement procedures. They do not contain a catalogue of existing procedures nor do they contain a collection of specific requirements. Rather, they outline the general questions and issues which need to be considered by the working group (writing group, subcommittee, etc.) during the development of a measurement procedure.

This report is organized in eight sections and two appendices. Section 2 contains a summary check-list for the guidelines. Section 3 discusses considerations for the purpose and scope and other necessary material preceding the procedure. Sections 4, 5, and 6 cover measurement conditions, operations during tests, and measurements and data reduction, respectively. Section 7 considers the test report and section 8, the various possible needs for supplemental information. Appendix A1 lists the Workshop participants and Appendix A2 provides guidelines for selection of descriptors related to human response.

Section 2

GUIDELINE SUMMARY CHECKLIST

The following sections of this report provide a structure for items to be considered by a working group during the development of a procedure for the measurement of source sound emission. Each such procedure is of course unique and thus not all of the factors may be applicable.

This section contains a checklist which is intended to ensure that a working group addresses all the elements which should be considered in developing a standardized procedure for measurement of sound source emission. The key item for consideration is the purpose. All other items must be considered in relation to the purpose, consistent with ease of use and accuracy required to meet the purpose.

Prefatory Material

- Purpose - sound source and descriptor, uses and users, consequences
- Scope - source and operating mode(s)
- Compatibility with other procedures and standards
- Sound descriptor(s) to be measured
- Measurement accuracy intended
- Definitions unique to the document

Measurement Conditions

- Instrumentation specifications, tolerances and calibration
- Support equipment
- Test environment required
- Physical site
- Ambient conditions - acoustic and atmospheric

Test Operations

- Source configuration and installation
- Source operating mode(s) during test
- Repeatability of operations, results
- Relative complexity of the procedure

Measurements and Data Reduction

- Specification of preferred sound descriptor
- Replications necessary
- Variability, confidence criteria
- Corrections to measured data

Test Report

- Documentation of source type, installation and operations; site condition, configuration and environmental conditions; measurement equipment etc.
- Report of final sound data and any adjustments made

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Supplemental Information

- Rationale for test procedure requirements
- Explanation of compromises made
- Determination of measurement uncertainty
- Supportive test data
- Overall assessment of the measurement procedure

Section 3

PREFATORY MATERIAL IN A MEASUREMENT PROCEDURE

This section enumerates and discusses these items that should be considered for inclusion in the prefatory sections of a measurement procedure.

3.1 Purpose

The first section following a general introduction of a procedure for the measurement of sound source emission should contain a concise and complete statement of purpose. This generally entails five main factors:

- Sound source
- Sound descriptor
- Intended uses of the measurement data
- Intended users of the procedure
- Possible consequences of the sound from the source when in use which procedure is intended to address

3.1.1 Statement of Purpose

One can begin with a simple statement that the purpose of the document is to describe a standardized procedure for defining sound emissions of a specific stationary or mobile source under specified operating conditions for certain uses by defined user groups and with respect to specific consequences of the sound emissions.[1] (An example of a statement of purpose is given in the footnote below.)

3.1.2 Uses

The statement of purpose should identify intended uses. Following is a partial list of uses:

- Determining compliance with purchase specifications and certification
- Determining compliance with regulations
- Rating
- Labeling
- Quality assurance
- Performance verification
- Engineering information
- Monitoring (by enforcement agencies and others)
- Degradation assessment
- Contracts between buyer and seller

[1] An example of a statement of purpose is the following: The purpose of this standard is to describe a procedure for defining the sound emissions of widgets when used in the high-speed mode during the manufacturing cycle of gadgets. This procedure is intended for use by regulatory enforcement agencies and for production verification to establish compliance with noise regulations and specifications for widgets. The primary concern is the risk of hearing damage to widget operators and gadget production line workers. Special purpose widgets are not covered by this standard.

3.1.3 User Groups

The statement of purpose should identify expected users of the procedure. Typical users may include:

- Regulators (federal, state, or local)
- Legislators (federal, state, or local)
- Manufacturers
- Operators
- Owners/contractors
- Enforcement agencies or officials
- Public interest groups
- Consumers

3.1.4 Consequences

Data developed through application of this procedure may be expected to be used for estimating potential effects on people such as operators, passengers and others in the vicinity. Possible effects include, but are not limited to:

- Task interference
- Hearing loss
- Communication interference
- Annoyance (or aversiveness)
- Sleep interference
- Interference with the detection and recognition of signals

More details on human response can be found in Appendix A2.

3.2 Scope

The statement of the scope of a procedure should be a clear, concise description of the source, or class of sources, including a description of operating cycles or modes of concern. When appropriate, the scope should state exclusions in terms of applications of the data to situations beyond the purpose of the procedure.

3.3 Compatibility

The working group should consider existing, proposed and draft documents dealing with similar sources and basic acoustical measurement procedures. Where applicable, the working group should consider incorporating, or including as references, appropriate national and international consensus standards and governmental regulations. Typical documents to be considered may include:

- Standards for measurement of similar acoustical quantities (e.g. sound level, sound pressure level, and sound power level)
- Standards concerned with similar types of sources
- Standards related to the application of the procedure

3.4 Sound Descriptors

3.4.1 Definition

One of the objectives included in the statement of purpose is to define the sound emission of a source. In order to do that exactly, many acoustical parameters have to be measured. However, not all of them may be relevant to the purpose. Therefore, one must choose those parameters, or combination of parameters, that are appropriate to the purpose. The chosen quantity(ies) is called a sound descriptor(s) and may be based on one acoustical parameter or a set of such parameters. The descriptor(s) may be obtained by direct measurement or may be based on calculations from measured acoustical parameters.

Descriptors which are appropriate to the intended use of the standard should be defined and identified. Sound descriptors may evaluate one or more properties of the sound, including the following:

- Amplitude
- Frequency (for weighting purposes or for identification of tonal quantities, etc.)
- Temporal characteristics
- Directionality

3.4.2 Some Applications of Descriptors

There are many descriptors which have been devised to relate the physical magnitude of sound with its effects on people. The A-weighted sound pressure level (sound level) has the most common use. Loudness level and perceived noise level are also used for specific types of sources and applications.

The descriptor should be specified either as a quantity to be measured directly or a quantity to be calculated from frequency band measurements, and should be appropriate for the temporal variations of the noise to be measured and the effects considered. For time varying noise emissions, a time-averaged sound level such as equivalent sound level (L_{eq}) is in most common use. However, other descriptors, such as time varying octave or one-third octave band levels or sound power levels etc., may be required when the data are needed for differing purposes, such as sound abatement, computing the source efficiency in sound emission or choosing a site in a land use planning study.

More detailed guidelines for descriptors related to human response can be found in Appendix A2.

3.5 Measurement Accuracy: Environment and Instrumentation

3.5.1 Background

There are three levels of accuracy requirements for procedures which have been generally used in measuring source sound emission. They are:

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- Precision test method (also called primary or basic test method)
- Engineering test method (also often called regulation or performance verification test method)
- Survey test method (also often called in-use compliance or screening test method

These methods are characterized by the environment in which the test is performed and by the type of instrumentation used. In general, the more highly controlled the environment, the closer the tolerances of the instrumentation, and the greater the training and skill of test personnel, the more precise the test.

The accuracy of the test should be appropriate to the purpose and be cost-effective. As used here, the precision test method provides the engineer, designer and manufacturer with the most reliable information possible about the sound emission of a source. One of its uses is for design development, validation, etc. The engineering test method can be used for testing for compliance with regulations or quality control at a manufacturer's plant. The survey test method can be used to measure the sound output of a source while in use and to monitor changes in performance with time. However the choice amongst these three levels of accuracy should be made after weighing all consequences of the choice (including cost and practicality) with respect to the purpose.

Further discussions on measurement accuracy can be found in sections 5.2 and 8.4.

3.5.2 Information for Inclusion with the Prefatory Material

The measurement accuracy should be stated. A concise description of the environment where the tests are to be made should be given. The description should include acoustic field properties, i.e. reverberant, free field, etc., and ambient noise level. These environments may be:

- Special test facilities such as a highly controlled outdoor site or indoor room. The ambient noise is also controlled so that it does not impair the precision significantly.
- On the production line, or in a manufacturer's plant. This can be a well defined site with limits on the ambient noise.
- In situ, or at the place where the source or product is used. Here the procedure must cope with the ambient noise as found.

The class of instrumentation should be described. This may be precision, general purpose or survey.

3.6 Definitions

New or unfamiliar terminology must be defined, and references to existing standards should be given for common terminology.

Section 4

MEASUREMENT CONDITIONS

This section discusses instrumentation, support equipment, and environmental requirements as they relate to the purpose of the test procedure and its associated accuracy requirements.

Acoustical characterization of a source is the objective of the acoustic measurement procedures being considered. However, the support equipment and the environment in which a source is operated usually affect its sound emission. The environment includes the physical site and environmental conditions. These factors should either be controlled, limited, or monitored to the extent consistent with the purpose of the test procedure. That is, if a high degree of acoustical accuracy is desired, extremely close attention must be paid to the measurement tolerance and control of the support equipment and any environmental factor that may affect the measurement. On the other hand, if a lesser degree of accuracy is acceptable, little or no control of these factors may be required. Accordingly, attention should be given to two classes of measurement:

- Measurement of sound output of source, such as sound level, frequency, etc.
- Measurement of environmental factors such as temperature, wind speed and length (for location of reflecting surfaces), surface impedance, etc.

These involve both acoustical and non-acoustical measurements.

Each environmental factor needs to be identified and evaluated in terms of its potential effect on the sound output measurement. Whenever possible the degree of measurement accuracy for the environmental factors should be determined by the sensitivity of the acoustical measurement to these influencing factors. If that relationship cannot be defined, a judgment should be made as to how accurately the factor needs to be measured based on practicality and available test instrumentation.

For example, assume the measurement of sound from a given device is influenced by ambient temperature. If a sound level versus temperature relationship exists, e.g., X dB/°C, this would define the needed accuracy for measurement of the ambient temperature. If such a relationship cannot be defined, it might be determined that a temperature change of ± 1°C can easily be measured with readily available equipment. Therefore, judgment would dictate measurement to this accuracy.

4.1 Instrumentation

Instruments required to perform both acoustical and non-acoustical measurements need to be specified. The precision and calibration of the instrumentation used can greatly affect the results obtained, and the instrumentation should be chosen to match the measurement needs of the test.

4.1.1 Specification

Specifications should be included for all instruments. Factors to consider are:

- Frequency response and frequency weighting
- Dynamic range requirements
- Meter characteristics (e.g. fast, slow etc.)
- Whenever possible the instruments should be required to conform to existing standards.
- For instruments for which standards do not exist, or when existing standards are not sufficient, specific criteria for evaluating the performance of such devices should be included. For example, if one wishes to measure the transient acoustic output of a noise source, the response of the instrumentation to one or more well defined and relevant transient signals should be specified.

4.1.2 Tolerances

The allowable tolerances which the instruments are required to meet should be clearly stated. The following items should be included or considered:

- The measurement range for each parameter should be defined and the tolerance established for that range.
- The defined range for each instrument should be established such that the highest expected readings are close to full scale.
- Unnecessarily restrictive tolerances should be avoided. As an example, if it is required that the wind speed be no more than X kilometers per hour, the tolerance for the instrument measuring wind speed should be specified for the vicinity of the limiting windspeed and not over the entire range of possible wind speeds. (This recognizes that typical anemometers have a threshold wind speed for indication, and an overall tolerance may mandate unnecessarily complex or expensive instrumentation.)

Instrument specifications should be applied not only to the specific components but to the overall system. The tolerance of the total system is the critical parameter to be defined. Caution must be exercised to account for the buildup of tolerances of the individual components that comprise the system. For example, combining several instruments which individually meet a specific tolerance specification does not guarantee that the overall system will meet the same specific tolerance specification.

4.1.3 Calibration

The measurement procedures should specify the minimum calibration procedures that are required for normal testing, as well as the more detailed calibration procedures which are required to ensure proper functioning of an entire instrumentation system. Factors to consider include the following:

- Frequency of calibration: The frequency with which these procedures will have to be repeated depends on the stability of the instrumentation.
- Use of an outside laboratory: The complete calibration may be beyond the capability of the laboratory or organization performing the test (e.g. calibration of the random incidence response of a sound level meter by a local regulatory enforcement agency). If so, requirements for periodic calibrations by an outside laboratory with the necessary capability should be stated.
- Primary standards: Traceability of the calibration to primary standards such as those maintained at the National Bureau of Standards should be considered when applicable.
- Performance check: Some procedure for checking the system performance at each time of use should be included.
- Complexity: The complexity of calibration should be consistent with the purpose of the standard. For example, a single point single frequency field calibration may be adequate for measuring overall sound level, but a wide range frequency and amplitude calibration may be required if extreme accuracy is desired. Calibrator accuracy is dictated by the desired accuracy of measurement.

4.2 Support Equipment

Often support equipment is required to make acoustical measurements. Examples are the internal combustion engine used in the acoustical evaluation of exhaust mufflers or the portable air compressor used to power a pavement breaker under test. This support equipment must be controlled, monitored, or limited to ensure that it is operated at appropriate conditions and the proper input is provided for the desired test conditions. Additionally, the acoustical influence of the support equipment must be considered. Complete elimination of sound emission from support equipment is desirable but may not always be feasible in which case corrections to the test data may be necessary.

4.3 Test Environment

Environment of the test is defined by the physical site and ambient conditions. Each of these parameters must be considered in terms of the purpose of the intended procedure as described in Sections 3.1 and 3.5.

4.3.1 Physical Site

Site specifications should be developed to optimize repeatability of test results. The availability of test sites as specified should be considered so that the test can be performed in as many different locations as are desired.

Sites may be characterized in two ways:

- By controlled specifications (such as "semi-polished Portland cement concrete" indicating grade of aggregate and surface roughness)
- By acoustical qualification procedures (such as "surface impedance limitations")

For example, a reverberation chamber may be qualified on the basis of a well defined calibration procedure with standard equipment. On the other hand, a passby test site is specified in terms of surface conditions and absence of nearby reflecting surfaces.

Specifications and restrictions must be carefully considered to avoid unnecessary site constraints. For example, for some purposes a ten meter distance to a reflecting surface might be adequate and should be specified rather than specifying the typical thirty meter requirement. In order to ascertain the adequacy of a less stringent requirement, experimentation is often necessary.

Some of the site parameters that should be considered may include:

- Cutoff frequency (e.g., anechoic and semi-anechoic rooms)
- Impedance and flatness of reflecting planes (e.g., passby and stationary sites)
- Room absorption and diffuser effects (e.g., reverberation rooms)

An example is the inconsistency encountered between outdoor measurements conducted over ground surfaces with differing acoustical properties, such as sealed and unsealed open-graded asphalt surfaces or concrete and dirt. For other test procedures, it may be desirable to specify specialized sites (for example, measurements inside ducts which have specific dimensions and acoustical properties).

4.3.2 Ambient Conditions

Ambient conditions can affect the sound generation and radiation characteristics of a source, the propagation of the noise between source and receiver, and the measurement accuracy. Those factors which are significant should be measured and controlled within appropriate limits, or taken into account by corrections. These factors may include:

- Ambient noise
- Air speed and wind gradient
- Temperature and temperature gradient
- Relative humidity (air absorption)
- Barometric pressure

For example, temperature, air speed and background noise level may be controlled in an anechoic chamber. However, for outdoor measurements, background noise level, together with temperature, wind speed and their gradients often need to be monitored and the test should be conducted only if these parameters fall within predetermined limits, or if appropriate corrections can be applied.

The effect of ambient conditions on sound propagation should also be addressed. Temperature gradients, wind gradients and air absorption are factors that can critically affect sound propagation. In general, propagation effects become more critical as measurement distance increases.

Section 5

MEASUREMENT OPERATIONS

This section considers source configuration, installation and operation; repeatibility; and simplicity vs complexity of the test procedure.

5.1 Source Configuration, Installation and Operation

The configuration, installation, and operation of the source should be such that it will produce results consistent with the intended objective of the procedure. Measurements representing operator exposure and bystander exposure to the same source may require different test configurations and/or operating modes.

All source operating parameters that could have a significant effect on the test results should be identified and dealt with. An objective evaluation must be made to decide if a parameter should be controlled within a close limit, allowed to vary over a wide range or taken into consideration by correction techniques. Some parameters may be left uncontrolled if it is decided that they do not significantly influence the test results or if control is so difficult that it is more reasonable to accept the resulting variability; in these instances comments should be made within the document and/or in the rationale documentation (see Section 8).

5.1.1 Environmental Conditions

Environmental factors which significantly affect the sound output of the source should be measured and controlled within appropriate limits or taken into account by corrections to the extent practical and consistent with the purpose of the standard. These factors have been discussed in Section 4.

5.1.2 Source Condition

Operational conditions which significantly affect the sound output of the source should also be appropriately measured and controlled or varied. These conditions may include:

- Electrical supply voltage and frequency
- Quantity and state of fluids supplied by support equipment
- Operating speeds
- Temperatures
- Pressures
- Load

Physical conditions of the source should be specified and/or recorded. Where appropriate, provisions should be specified relative to suitable break-in periods for new sources, and time required to attain equilibrium conditions, etc.

5.1.3 Configuration and Installation of a Source in a Sound Measurement Field

The sound value(s) reported through the use of a sound measurement procedure depends on, among other factors:

- The configuration and installation of the source
- The configuration and installation of auxiliary equipment
- The spatial environment in which the source is located
- The microphone field (arrangement and orientation of microphones) used to measure the radiated sound.

Thus, in the development of a procedure, these factors must be properly considered.

5.1.3.1 Specifying the Configuration and Installation

The configuration and installation of the source may be a critical factor in its generation and radiation of sound. In the preparation of a procedure, decisions must be made on whether the source should be measured in a typical use environment or a highly controlled environment. If the purpose of a procedure is to determine the sound emission under typical use conditions, the various ways in which a source might be configured and installed may dictate that several configurations and installations be tested. The procedure should specify the configuration and installation of the source.

5.1.3.2 Specifying Auxiliary Equipment

Sources may normally be used with standard components, accessories and/or auxiliary equipment. Such equipment may be necessary or incidental to the operation of the source as in the case of accessories. This equipment may act as an additional source of sound, as in the case of the surface of the sink which is set into vibration by the operation of the garbage disposal. The equipment may also act as an attenuator. To insure a meaningful test, these components may have to be specified.

5.1.3.3 Specifying Spatial Environment

Examples of applications of configuration, installation and operation might range from attempting to reproduce typical use environments (e.g., for determining operator exposure) to identifying differences in like sources (e.g., for labeling or design purposes). In the former instance, there is interest only in the sound that reaches the operator, while in the latter case, a more complete measurement of the radiated sound field is often of concern (e.g., sound levels at specific distances and directions from the source or sound power and directivity of the source).

The spatial environment in which a source is located can amplify or attenuate the measured sound level. The development of the measurement procedure should evaluate which spatial environmental factors must be limited or established to provide results in harmony with the purpose of the measurement procedure.

5.1.3.4 Specifying the Microphone Field

The microphone field can affect the result obtained from a measurement of source emission depending on the directivity characteristics of the source. The chosen microphone field must be in harmony with the purpose of the measurement procedure. The number and location of the microphones will usually affect the reported result or the utility of the information.

For example, if the purpose of the procedure is to measure operator sound exposure, the location of the microphone(s) should be representative of the position of the operator with respect to the source. If the purpose is for the general description of source sound emission characteristics, a number of microphone locations may be required depending on source directivity, range of distances of interest, size of the source, repeatability, simplicity and intended use of the results. There may be tradeoffs between measurement distance and the number of microphone positions. The size of the source and its radiation area, the spatial environment and the desired measurement accuracy of the procedure must all be considered in arriving at the desired microphone field. Where sound power values are the desired output, the number of microphone positions must be evaluated against the directivity of the source. In this case, an adequate number of microphone positions must be used to characterize the sound field.

5.1.4 Operational Mode or Cycle

5.1.4.1 General

In general, products have a range of operating modes. The sound level of these devices at any instant in time often depends dramatically on the operational mode being measured. An operational mode consists of:

- The operating condition (e.g., rinse cycle in the case of a dish or clothes washer, or engine and vehicle speed in the case of a motor vehicle)
- The load (e.g., type of food matter and water flow in the case of a garbage disposal, or vehicle weight (actual load) and acceleration (inertial load) in the case of a motor vehicle).

5.1.4.2 Choosing the Mode of Operation

The choice of operating mode(s) for measurement is directly related to the purpose of the measurement. The key to deciding upon the mode or modes of operation that should be specified for measurement purposes hinges on knowledge of how the device is normally operated and how the sound from its operation affects people. From this information one can determine the significance relative to the purpose of the procedure of each of the possible modes of operation to the noise associated with the device. The operating mode(s) with the greatest significance should be chosen for the measurement procedure. The measurement procedure should also include a description of the precise procedure for obtaining the operational modes. This would include the manner of application of the load to the source under test.

5.1.4.3 Cyclical Modes

Devices such as dishwashers and clothes washers operate according to a prescribed cycle and the sound levels generated vary depending on the particular portion of the cycle (e.g., rinse operations, water filling operation, etc.) as well as the type of load in the dishwasher or clothes washer. For some measurement purposes, a use study may be needed to define the operating mode, including parameters such as:

- The length of the various portions of the operation cycle
- The normal load
- The sound emission generated during each portion of the total cycle

With this information, it can be decided whether the sound emission during one or more specific portions of an operating cycle should be measured or whether the average over a complete operating cycle is appropriate. The decision depends on the sound and use characteristics of the devices as well as the purpose of the measurement procedure.

5.2 Repeatability

In developing a measurement procedure, a working group has to consider the uncertainty with respect to how well the results represent the desired measured quantity. The uncertainty of the procedure depends upon its precision or repeatability (variability of successive independent measurements following this procedure) and its accuracy (deviation from the true value characteristic of such measurements).

The repeatability of a test procedure may depend, to a great extent, on the variability inherent in the configuration, installation, and operation of the source.

In the development of the test procedure, considerations should be given to the repeatability obtained under the following multiple test situations as appropriate:

- Tests run sequentially on the same device
- Tests run on the same device at different times (e.g., different times of the day, different days, or different months)
- Tests run on the same device at a different but presumably equivalent site
- Tests run on the same device by a different operator
- Tests run on the same device using a different observer

An estimate of the accuracy of the procedure can be obtained by measuring the device using a different procedure, but one whose objective is to measure the same descriptor. For example, a survey type procedure for measuring the sound power level of a source may be compared with the measurement of the sound power level of the same source using the reverberation room procedure.

When the resulting sound descriptor is used to compare the performance of a product with the requirements of a regulation or with the performance of a competitive product, and if the repeatability of the measurement procedure is low, difficulties in enforcement, inequities in trade, and excessive costs may be incurred. When used for product development, low repeatability may inhibit or delay the development process.

Permissible variation in the measurement procedure is a function of its sensitivity to variations in test parameters and the degree of control maintained over those parameters. Therefore, a satisfactory degree of repeatability can only be obtained by adequate specification of the configuration, installation, and operation of the source as well as the acoustical elements involved. Published data, knowledge of experts and new experimental test data should be used as a basis for establishing the expected repeatability. It is essential that the procedure be designed to yield results sufficiently repeatable to meet the requirements implicit in the purpose(s) of the measurement.

5.3 Simplicity/Complexity

A measurement procedure should be as simple as possible provided that the accuracy and repeatability requirements can be met. If the test is intended for use by persons who have limited training or if test cost becomes a constraint, simplicity may become a guiding factor in the design of the procedure.

General factors which should be considered include:

- Availability and/or cost of the required test facility and instrumentation
- Time required by the test procedure both for preparation of the source and set up and calibration of the instrumentation and for conducting the measurement

- For tests conducted outdoors, the number of days per year and hours per day of acceptable environmental conditions available to the potential users of the procedure
- Number of persons required to conduct the tests
- Training and relative skill level requirements for personnel conducting the test.

Section 6

MEASUREMENTS AND DATA REDUCTION

This section discusses the factors to be considered during the test related to measurements and during or after the test related to data reduction.

6.1 Measurement

Considerations of the sound descriptors to be obtained from the measurements were discussed in Section 3 and the instrumentation specifications, tolerances and calibration were discussed in Section 4. Additional details to consider in designing the specific procedure to follow during the test include the following items.

6.1.1 Preliminary Observations and Measurements

Appropriate observations and measurements should be made to ascertain that the test environment, source configuration and installation (including microphone placement), and source operating modes are as specified in Sections 4 and 5. This may involve a complicated qualification test, such as for a reverberation room. If so, the exact procedure should be specified.

The procedure should also specify methods for determining ambient sound level and special precautions appropriate to determining the existence of conditions which might lead to erroneous data; (e.g., conditions such as ground loops, hum pickup, wind gusts, and electromagnetic and other interferences).

6.1.2 Required Observations and Replications

The procedure should state the minimum number of observations or test runs necessary to obtain the required confidence level or statistical accuracy as determined during preparation of the procedure (see Section 5.2). The value of the minimum number of observations will depend on the time varying characteristics of the signal and the influence of other random test variables (e.g., changes in environmental conditions) that cannot be controlled within limits which will not affect the magnitude of the signal. Additional factors are:

- The averaging time for each sound level measured to obtain the confidence level desired
- The order in which the data are to be taken, if significant
- Measurement of those environmental factors that will be used as the basis for applying corrections to the raw data

6.1.3 Record Keeping

At the time the test is performed, all pertinent information, observations and data obtained should be recorded. These will be the basis for the test report described in Section 7.

6.2 Data Reduction

The recommendations of Section 4 for instrument calibration and use also apply to the instrumentation system used for data reduction in the laboratory after the test. In addition, the laboratory data reduction may include procedures for corrections of many types, including instrument system response, presence of background noise, normalization of environmental conditions and deviations from specified test conditions. Whenever corrections are contemplated, an explicit procedure should be defined. Further items should be specified, such as:

- The procedure for calculating the desired sound descriptor.
- Requirements for averaging the data and obtaining statistical information (such as standard deviation and confidence criteria) calculated in a prescribed manner.

Section 7

TEST REPORT

The test report is intended to document the measurement of sound emission, presenting the results and conclusions together with the relevant supporting data. These data are included to show whether the test complied with the specified measurement procedure (for instrumentation, environment, source operation, measurement conditions, data reduction, etc.), and to provide a basis for judging the validity of the test results and conclusions.

The following items, plus any other pertinent tables, photographs, drawings, etc. should be considered for the requirements for the test report.

7.1 General Information

The general information required in the test report should be specified and may include appropriate items such as the following:

- Date and place of test, client, and equipment user (if different than client)
- Citation of the measurement procedure or standard(s) used
- Summary of the test objective, results, and conclusions
- Statement of who authorized the test, and why, and any contractual obligations, guarantees or stipulated agreements between the parties concerned
- Description of any unavoidable deviations from the prescribed test procedures
- Estimation of the magnitude of the effects of such deviations on the reported results

7.2 Description of the Sound Source

The description of the sound source should be specified after consideration of factors such as the following:

- Identification of the sound source(s) by manufacturer, model and serial number
- Statement of the physical size of the equipment
- Description of the equipment set-up, including any optional parts and attachments
- List of auxiliary and other equipment in the vicinity of the sound source, including existing acoustical treatment
- Specification of the operating conditions for the sound source including such variables as input wattage/horsepower, volume flow rates, operating pressures and temperatures, rotation rate, acceleration, and any other factors as appropriate
- Description of how the equipment was mounted and identification of any isolation mount(s) used

7.3 Acoustical Environment

The test report should require a statement to verify that the test was conducted in the required acoustical environment considering such factors as the following:

- Definition of the acoustical environment in which the test was conducted, including any procedures used to calibrate or validate the environment for the test (with results), and a description of the use of any special techniques or equipment to modify the environment, such as rotating diffusers
- Location of the sound source within the test environment giving the actual dimensions, including the location and description of other equipment that could influence the measurement(s)
- Statement of the nature and levels of any background noise, and a list of any auxiliary equipment in operation during the test
- Statement of atmospheric pressure, temperature, relative humidity, wind speed and direction when relevant
- Statement of physical and topographical description of test site as required

7.4 Instrumentation

The following factors should be considered in specifying the instrumentation used for the test report.

- Identification of the specific instrumentation used. List the type, make, model, serial number, date of last calibration, and where calibration was performed. Traceability of calibration devices to primary standards should be stated where required. Verify that the complete instrumentation system meets the test requirements for accuracy, frequency response and dynamic range.
- Identification of the acoustic calibrator and the level and frequency of the signal generated for the acoustic calibration.
- Statement of the dynamic response characteristic (e.g., slow/fast) of the sound level meter. If a different type of instrument is used, the averaging or integration time for the readout device should be given.
- Statement of the bandwidth and also the weighting network of the data acquisition and/or reduction system used. Variable settings on the instrumentation system which could have an influence on the data should be noted (such as gain setting on a measuring amplifier, voltage and writing speed settings on recorders, etc.)

7.5 Acoustical Data to be Recorded and Reported

The following items should be considered in specifying the data to be reported in the test report:

- Identification of location and orientation of all microphone locations

- Statement of the measured sound pressure levels. Record whether these levels are linear, weighted, averaged, integrated or band levels as specified in the test procedure. In addition, sound pressure levels averaged on an energy or time basis shall be shown, if required. The data shall be given for each microphone location.
- Statement of background sound pressure levels at key microphone locations
- Statement of correction factors used (such as those based on background noise, temperature, barometric pressure, etc.) to obtain "true" sound pressure levels for each microphone location. Corrected and calculated levels should be clearly separated from the measured raw data.
- Indication, when required, of time averages or time intervals during which measurements were taken
- Calculations of derived units or descriptors (e.g. sound power level, average sound level, perceived noise level, etc.) from sound pressure level measurement
- Calculations of mean and standard deviation determined from sound pressure levels when measurements are repeated under nominally identical conditions
- Names of personnel who performed and observed the measurements
- Directivity of sound source, if appropriate

7.6 Special Considerations

The test report specification should also include a description of any special procedures used to convert the experimental data to some other physical quantity (e.g., converting voltage readings to sound pressure level readings); and the procedure used to calculate any derived unit, or to estimate statistical uncertainty of the measurements.

Section 8

SUPPLEMENTAL INFORMATION

8.1 Introduction

The purpose of this section is to provide guidelines for documentation of the background information supporting the development of a procedure for the measurement of source sound emission. In the past many procedures were published with minimum, and in some cases, no explanation of their rationale. However, documentation of the rationale, issues and data involved in the development of a measurement procedure may be critical to its potential use at some future date for purposes other than its original intended use. It will be helpful also in facilitating the review and approval of the procedure, and have utility to regulatory agencies who might desire to use it. Further, it will be useful in understanding the differences among different procedures for purposes which may appear similar and for comparison of national and international procedures.

In determining the supplemental documentation for a particular measurement procedure, all the elements identified in this section should be considered, but only those applicable to the specific procedure under development should be included. To obtain maximum utilization, documentation of the background information should be widely available. In this regard, working groups are encouraged to publish in the open technical literature the background and basis for the measurement procedure. This encouragement is not intended to hinder the timely development of standards, and the lack of this background information should not delay adoption of new standards. However, when possible, publication of material such as that discussed in the following should be accomplished when publishable material relevant to potential users exists.

8.2 Rationale for the Requirements of the Sound Measurement Procedure

For any given source there is a range of possible alternatives that may be specified for the measurement and description of its sound emission characteristics. In preparing a particular procedure, decisions are made as to which one of the alternatives is most appropriate, taking into account the purpose(s) of the document. The principal alternatives considered should be described and the rationale given for selecting the chosen one as well as for discarding the others. Some of these decisions will be major determinants in the formulation of the particular noise measurement and should be documented in detail. Others may be of minor importance, and this should be reflected in the rationale statement. The rationale statement does not have to be highly detailed or lengthy, but should be informative as to the general considerations relative to the choices. Typical choices to be explained include:

8.2.1 Sound Descriptor

Reasons for the selection of the particular descriptor specified and its relationship to human response and expected exposure (e.g., compatibility with descriptors for other sources); suitability for further assessment (community impact, engineering modifications, etc.) (See also section 3.4 and Appendix A2)

8.2.2 Source Operation and Installation

Reasons for choice of specified operating parameters and positioning of the source; for example, relationship to human exposure, operator, others closely associated with the operation, general community, and mounting conditions (See also Section 5.1 and Appendix A2.)

8.2.3 Test Environment

Reasons for choice of controlled laboratory environment, semicontrolled outdoor environment, or in-situ environment depending on source operating requirements and the purpose of the measurement, tolerable deviations, costs (See also Sections 3.1, 4 and 4.3.)

8.2.4 Instrumentation Requirements

Reasons for choice of accuracy type and sophistication of instrumentation system specified for acoustical and other measurements; calibration and checking of system performance specified (See also Sections 4 and 4.1.)

8.2.5 Data Acquisition and Reduction

Reasons for choice of number and placement of microphones; number of tests required; method of data reduction specified - all related to the stated purpose of the procedure (See also Sections 3.1 and 6.)

8.2.6 Compatibility With Other Standards

Discussion of existing standards, national and international, if any, dealing with the same or similar sources, rationale for differences, and compromises made in the interests of harmonization and international commerce. (See also Section 3.3)

8.3 Explanation of Compromises

Before a measurement procedure is published, choices generally have been made between contending alternatives, and conflicting viewpoints have been resolved. It is possible that it has been necessary to compromise in some areas. Since the problems resolved by compromise may not have general applicability for all purposes, or uses of the standard, it is useful to provide a statement of any major issues involved together with the opposing positions and the bases for the final resolutions.

Examples of some of the areas that may be addressed include:

8.3.1 Simplicity of Measurement/Instrumentation

The choice between a type 1 or type 2 sound level meter exemplifies a choice between a high precision, but less available and more expensive instrument and a more readily available, less costly, but less precise piece of equipment. The choice between a Type 1 sound level meter or integrating sound level meter and a Type 1 instrumentation system with an on-line computer exemplifies the choice between two degrees of sophistication and the possibility of using a more complex descriptor for greater cost, both with the same normal degree of precision.

8.3.2 Cost - Time Requirements

Cost and time difference between the number and duration of tests and number of samples required for high statistical confidence versus that required for reasonable reproducibility

8.3.3 Site Availability

Physical availability of desired facilities which may not comply with all desired conditions, for example geographical and seasonal conditions

8.3.4 Personnel Requirements - Training

Availability of technically/professionally qualified personnel, related to purpose of test; lead time - costs of training

8.3.5 Source Operating Requirements

Necessity for auxillary equipment, mounting systems, services for source operation; relative mobility of source; stationary measurements of mobile sources; duration of tests; costs

8.3.6 Accuracy

Statement of the accuracy implications resulting from the compromises for other factors

8.4 Determination of Measurement Uncertainty

8.4.1 Source

A quantitative discussion should be given where possible of the uncertainty introduced by those factors that have been considered to significantly affect the sound generation and radiation of the source. Particular attention should be given to those factors which are peculiar to the source or class of sources addressed by the measurement procedure. The discussion should present any experimental results which indicate the expected sensitivity of the source emission with fluctuations of the parameter in question. If theoretical methods were used to assess uncertainty, the formulation of the theoretical model should be presented along with the assumptions used in its development. If empirical data have been used to assess uncertainty or to provide information on deciding which parameters may influence the source, references to these data should be given.

Examples of those factors which may be included in the consideration of the uncertainties attributable to the source are:

8.4.1.1 Environmental Factors

This category would include both site and meterological factors. For example, the measurement of sound level from a moving machine while it is in contact with a ground surface may be significantly influenced by the characteristics of the surface. Similarly, the measured sound level from an aerodynamic noise source may be influenced by the density of the surrounding atmosphere.

8.4.1.2 Operational Factors

This category would include those uncertainties arising from variation in operating parameters of the source. These factors may include parameters such as machine loading, motor speed, throttle position, kinematic conditions of velocity and acceleration of moving machines, etc.

8.4.1.3 Physical Condition

This category would encompass any factors which might create uncertainty due to variation in the physical condition of the source. As examples, this category might consider break-in condition of a machine, machine temperature, state of tune for internal combustion engines, belt tension for belt driven machines, etc.

8.4.2 Propagation

A quantitative discussion should be included, when possible, of the uncertainties introduced by those factors which were considered in regard to the propagation of sound from the source to the microphones. In many measurement situations, the state-of-the-art is not sufficiently developed to allow quantitative assessment of the uncertainties attributable to environmental factors. In the absence of such quantification, bounds may have to be set on environmental conditions based on published empirical data, available conceptual models, or data taken during the course of the development of the test procedure. Any such information used in determining environmental bounds for the purpose of reducing measurement uncertainty due to sound propagation should be presented or references given.

Two primary examples of factors which may significantly affect the uncertainty due to propagation are:

8.4.2.1 Atmospheric effects

This category would include the uncertainty due to effects such as temperature gradients, wind velocity and gradient, atmospheric turbulence, atmospheric sound absorption, etc.

8.4.2.2 Site Effects

This category would include both the overall specification of the site and those conditions which may vary from test-to-test. As examples of overall specifications, it may be required to specify surface impedance, surface flatness and slope for machines tested on a ground plane. Further it may be necessary to specify in detail the characteristics of a reverberation room, or an anechoic or semi-anechoic chamber. As examples of varying test site conditions, it may be required to specify dry, dirt-free surfaces for measurement over a reflecting plane, or allowable positions of observers, temporary obstacles, etc.

8.4.3 Measurement System

A quantitative discussion should be given where possible of the uncertainties involved with the detection, processing, and ultimate presentation of the measured value. This discussion should include both the uncertainties of the physical measurement of sound pressure level at specific locations and the uncertainty of relating such measurements to the quantity which directly relates to the purpose of the measurement. As an example of this latter point, it may be desired to measure the maximum sound level emitted by a source under a particular operating condition. However, the source may be highly directional and hence one or more microphone positions may not actually measure the maximum but rather approximate it. Or if it is desired to determine the sound power emitted by such a source, the power level determined in a semi-anechoic space can only approximate the actual emitted power. The discussion of these uncertainties should include reference to applicable instrumentation standards for determination of uncertainties and present any appropriate results obtained in the development of the measurement procedure such as source directivity.

More specifically, it may be necessary to consider in the discussion of measurement uncertainty factors such as the following:

8.4.3.1 Number of Microphones

For example, the uncertainty due to using a limited number of microphones instead of a continuum or very large array of microphones

8.4.3.2 Location of Microphones

For example, the uncertainty due to locating a microphone in a given position or positions in a reverberation room in the determination of sound power

8.4.3.3 Orientation of Microphones

For example, the uncertainty due to the directivity response of a microphone for a source which is tested by passby methods, or when more than one propagation path exists between source and receiver

8.4.3.4 Instrumentation Type

This may include a discussion of the uncertainties introduced by using one class of instrumentation as opposed to another, or introduced by the cumulative effect of several instruments used in series each of which individually satisfy a class standard.

8.4.3.5 Frequency and Tolerance of Calibration

This may include a discussion of the uncertainty introduced by the specification of one method of calibration as opposed to another. Further, the uncertainty involved with the allowed time lapse between calibrations (both absolute and relative to a calibrator) may be included.

8.5 Supporting Data

When possible, relevant data used in the development of a sound measurement procedure should be available for review. Examples of data which may be included in a supporting data report are:

- Data used to determine expected accuracy of the measurements
- Data used to determine sample size, or number of test runs
- Data base for determination of the number of microphones specified

Information in the supporting data report is not limited to acoustic performance data. Depending on the specific sound test it may include:

- Test product make, model, size, type of power unit etc.
- Meterological conditions
- Site conditions

There are several options for publication of the supporting data information. Included, are:

- Publication as a part of the supplemental information report
- As a professional paper or other publically available publication, and given as a reference in the supplemental information report.

If subsequent reports containing supporting data and analysis related to the development of the sound measurement procedures are published, the reference section of the supplemental information report should be revised to include these reports. A routine review/revision cycle for supplemental information reports may be appropriate for some sound emission procedures.

8.6 Overall Assessment of Measurement Procedure

The writers of a sound emission measurement procedure are in a unique situation with respect to their knowledge of its major strengths and weaknesses. They have taken part in the evaluation of data and the formulation and resolution of problems and they should know which parts of the code are based on well-accepted scientific or engineering knowledge, and which parts are less well established. These aspects should be included in the supplemental report. In some cases the test procedure may be the first procedure developed for a particular measurement purpose and may be subject to considerable revision after a period of trial and study. When this is the case it should be clearly stated so that users less familiar with its development are aware of its potential change. Additionally, of particular interest would be the recommendations of the writers for future improvements in the method, and identification of areas in which feed-back data are required for future revisions.

Appendix A1

PARTICIPANTS IN WORKSHOP

ON

DEVELOPMENT OF STANDARDS FOR ENVIRONMENTAL SOUND

December 7-9, 1977

Deerfield Beach, Florida

Organized and managed by the Acoustical Society of America under the auspices of the ANSI Standards Planning Panel on Noise Abatement and Control.

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APPENDIX A2

GUIDELINES FOR DESCRIPTORS RELATED TO HUMAN RESPONSE

A2-1 Introduction

The primary objective of a procedure for the measurement of sound emission of stationary and moving sources is to quantify the sound emission characteristics of the source of interest. This requires the identification of the relevant physical acoustical parameters. When the purpose of the measurement is to assess the effects of noise on people, these data, in turn, must be related to measures of human response.

A2-2 Definition of a Sound Descriptor

To specify the human response to sound, measurements should be relatable to currently available information on the effects of noise on people. A sound descriptor for human response is a number which can be used to relate sound emission data to physiological or behavioral effects of noise. A sound descriptor may be measured directly, as is generally done with an A-weighted sound level; or may be derived from other measurements, as is the case with perceived noise level or loudness level which are generally calculated from spectral data.

A2-3 Considerations Regarding Test Procedures

The specification of the appropriate test procedure depends upon the nature of the sound, the receiver, and the response of interest. These are described below:

A2-3.1 Nature of the Sound

The fundamental acoustical parameters of interest are:

(1) amplitude of the sound
(2) spectral characteristics;
(3) temporal characteristics
(4) under certain conditions, directional characteristics

Descriptors may be classified as scaled or composite. The former (e.g. A-weighted sound level, loudness level and perceived noise level) are based entirely upon acoustical measurements. The latter (e.g. composite noise rating, noise exposure forecast) are derived from scaled descriptors when additional information, such as the number of events or the time of day, is available.

A2-3.2 Nature of Receiver

The sound descriptor should be relevant to the receiver of interest such as the operator, passenger, bystander, and/or neighbor. Measurements should be obtained so that the acoustical data can be transformed for the appropriate receiver location. In some cases the directivity of the sound source may need to be considered.

A2-3.3 Human Responses of Interest

Current scientific data regarding human response to noise are sufficient to warrant consideration of: (1) hearing loss, (2) speech interference; (3) aversiveness/annoyance; (4) sleep interference; and (5) signal detectability and audibility. Quantitative noise-effect relationships have not been sufficiently well established for other effects such as stress-related physiological effects or task performance effects. As new scientific evidence becomes available, the guidelines should be extended to these and other human response effects.

A2-4 Descriptors and Human Responses

Table A2-1 shows the types of sound level measurements commonly used to predict the effects of sound on people.

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TABLE A2-1

DESCRIPTORS FOR THE EFFECTS OF SOUND ON PEOPLE

Effect	Simple Descriptor	Complex Descriptor
1. Hearing loss	A-weighted sound level[1] and duration[2] Equivalent continuous sound level (L_{eq})	CHABA[3] band level criteria and duration
2. Speech interference	A-weighted sound level[1] and duration Equivalent continuous sound level (L_{eq})	Speech interference level[1] Articulation index[1]
3. Aversiveness (Annoyance)	A-weighted sound level[1] and duration[2] Equivalent continuous sound level (L_{eq}) Day-night average sound level (L_{dn}) for cumulative noises	Loudness[1], loudness level, Perceived noise level (PNL), Effective PNL (EPNL), Tone-corrected EPNL for aircraft certification[1], Noise exposure forecast (NEF) for community response to aircraft noise
4. Sleep interference	A-weighted sound level[1] and duration	Temporal structure is relevant but quantitative relations not established
5. Signal detection		1/3 octave band spectrum and duration

[1]American National Standard available (S3 series)
[2]A simple descriptor which combines A-weighted sound level and duration is sound exposure level (L_e). It is generally measured with an integrating sound level meter.
[3]Committee on Hearing and Bioacoustics, National Academy of Sciences, National Research Council.

Experience has shown that many advantages accrue to the use of the simple descriptor. Its broad applicability to the four principal effects helps to accure its utility in the frequent situations where future applications are not fully known. Even in cases where the more complex descriptor is warranted, inclusion of the measurement and reporting of the values of the simple descriptor should be considered as well.