Measurement of Industrial Sound

Performance Test Codes

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ASME PTC 36-2004

Measurement of Industrial Sound

Performance Test Codes

AN AMERICAN NATIONAL STANDARD

The American Society of Mechanical Engineers

Three Park Avenue • New York, NY 10016

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This Code will be revised when the Society approves the issuance of a new edition. There will be no addenda issued to ASME PTC 36-2004.

ASME issues written replies to inquiries as code cases and interpretations of technical aspects of this document. Code cases and interpretations are published on the ASME Web site under the Committee Pages at http://www.asme.org/codes/ as they are issued.

The American Society of Mechanical Engineers
Three Park Avenue, New York, NY 10016-5990

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NOTICE

All Performance Test Codes must adhere to the requirements of ASME PTC 1, General Instructions. The following information is based on that document and is included here for emphasis and for the convenience of the user of the Code. It is expected that the Code user is fully cognizant of Sections 1 and 3 of ASME PTC 1 and has read them prior to applying this Code.

ASME Performance Test Codes provide test procedures that yield results of the highest level of accuracy consistent with the best engineering knowledge and practice currently available. They were developed by balanced committees representing all concerned interests and specify procedures, instrumentation, equipment-operating requirements, calculation methods, and uncertainty analysis.

When tests are run in accordance with a Code, the test results themselves, without adjustment for uncertainty, yield the best available indication of the actual performance of the tested equipment. ASME Performance Test Codes do not specify means to compare those results to contractual guarantees. Therefore, it is recommended that the parties to a commercial test agree before starting the test and preferably before signing the contract on the method to be used for comparing the test results to the contractual guarantees. It is beyond the scope of any Code to determine or interpret how such comparisons shall be made.

FOREWORD

In October 1967 the Board on Performance Test Codes recognized the need for procedures and measuring techniques to provide reliable and accurate sound measurement analysis. This action was taken in view of the growing environmental concern that lengthy, unprotected exposure to high industrial noise levels is detrimental to human health. This concern has also resulted in government-sponsored noise level criteria. Accordingly, the Board on Performance Test Codes authorized the organization of Performance Test Codes Committee No. 36 on Measurement of Industrial Sound. The new PTC 36 was published as an American National Standard in 1985.

In May 1992 at the request of the Board on Performance Test Codes a committee was convened to consider revisions to PTC 36-1985. There were three principal reasons for undertaking the revision. First, the technology of digital sound data acquisition and processing had evolved dramatically since the development of the first edition of the Code, resulting in more widespread use of sound intensity methods. Second, extending the Scope of the Code to encompass far field measurements was considered likely to make the Code more useful to a broader range of potential users. Third, a considerable enlargement of uncertainty considerations, included as an integral part of the procedure, was believed to enhance its applicability.

This revision of the Code was approved by the Board on Performance Test Codes on September 21, 2004. It was approved as an American National Standard by the American National Standards Institute on December 28, 2004.

PERSONNEL OF PERFORMANCE TEST CODE COMMITTEE NO. 36 ON MEASUREMENT OF INDUSTRIAL SOUND

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General. ASME Codes are developed and maintained with the intent to represent the consensus of concerned interests. As such, users of this Code may interact with the Committee by requesting interpretations, proposing revisions, and attending Committee meetings. Correspondence should be addressed to:

Secretary, PTC 36 Standards Committee
The American Society of Mechanical Engineers
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Proposing Revisions. Revisions are made periodically to the Code to incorporate changes that appear necessary or desirable, as demonstrated by the experience gained from the application of the Code. Approved revisions will be published periodically.

The Committee welcomes proposals for revisions to this Code. Such proposals should be as specific as possible, citing the paragraph number(s), the proposed wording, and a detailed description of the reasons for the proposal, including any pertinent documentation.

Interpretations. Upon request, the PTC 36 Committee will render an interpretation of any requirement of the Code. Interpretations can only be rendered in response to a written request sent to the Secretary of the PTC 36 Standards Committee.

The request for interpretation should be clear and unambiguous. It is further recommended that the inquirer submit his/her request in the following format:

Subject:	Cite the applicable paragraph number(s) and the topic of the inquiry.
Edition:	Cite the applicable edition of the Code for which the interpretation is being requested.
Question:	Phrase the question as a request for an interpretation of a specific requirement suitable for general understanding and use, not as a request for an approval of a proprietary design or situation. The inquirer may also include any plans or drawings which are necessary to explain the question; however, they should not contain proprietary names or information.

Requests that are not in this format will be rewritten in this format by the Committee prior to being answered, which may inadvertently change the intent of the original request.

ASME procedures provide for reconsideration of any interpretation when or if additional information that might affect an interpretation is available. Further, persons aggrieved by an interpretation may appeal to the cognizant ASME Committee or Subcommittee. ASME does not "approve," "certify," "rate," or "endorse" any item, construction, proprietary device, or activity.

Attending Committee Meetings. The PTC 36 Standards Committee regularly holds meetings, which are open to the public. Persons wishing to attend any meeting should contact the Secretary of the PTC 36 Standards Committee.

MEASUREMENT OF INDUSTRIAL SOUND

Section 1
Object and Scope

1-1 OBJECT

The object of this Code is to describe procedures for measuring and reporting airborne sound emission from stationary sound sources and equipment, or from facilities composed of multiple stationary sound sources.

1-2 SCOPE

The scope of this Code includes measurement procedures in a variety of acoustical environments, including outdoor settings influenced by background noise. Generally, sound pressure levels and/or sound power levels in prescribed frequency bands are used to quantify the sound emission of industrial equipment and facilities. Sound pressure level measurements or sound intensity measurements obtained using the procedures of this Code may be used to calculate sound power level.

1-3 UNCERTAINTY

The uncertainty associated with this Code is a function not only of the procedures described here, and the instrumentation prescribed, but also the circumstances and variables of the individual tests. The uncertainties are defined and described in Mandatory Appendix I. Any departure from the Code requirements could introduce additional uncertainty.

Section 2
Definitions and Description of Terms

absorption: the process of dissipating or removing sound energy.

acoustical: relating to the science of sound, its production, transmission, and effects.

airborne sound: sound that arrives at the point of interest by propagation through air.

ambient noise: all encompassing sound or noise associated with a given environment, being usually a composite of sounds from many sources near and far, and usually regarded as including the contribution of inherent electrical noise within the measuring instruments.

A-weighted sound level: a sound level to which an A-weighting electrical filter has been applied which conforms with ANSI S1.4. This filter attenuates low frequency sound.

decibel (dB): one-tenth of a bel; thus, the decibel is a unit of level when the base of the logarithm is the tenth root of ten, and the quantities concerned are proportional to power. It is defined as 10 $\log_{10}$ (a ratio).

background noise: noise from all sources unrelated to a particular sound that is the object of interest. Background noise may include airborne, structureborne, and instrument noise.

discrete frequency: a sound wave, the instantaneous sound pressure of which is a simple sinusoidal function of time.

far field: the region where the sound pressure level decreases 6 dB for each doubling of distance from the source. This region will exist if the sound source is in the free field or if the absorption in an enclosure is great enough that the reverberant field has not been reached first.

filter: a device for separating components of a signal on the basis of their frequency. It allows components in one or more frequency bands to pass relatively unattenuated, and it attenuates components in other frequency bands.

free field: a homogeneous, isotopic medium free from boundaries. Generally regarded to imply an environment permitting hemispherical diffusion over relatively flat, unobstructed, outdoor terrain.

frequency: the frequency of a function periodic in time is the reciprocal of the period. The unit is hertz (Hz).

hertz (Hz): unit of frequency equal to one cycle per second.

level: in acoustics, the level of a quantity is the logarithm of the ratio of that quantity to a reference quantity of the same kind. The base of the logarithm, the reference quantity, and the kind of level must be specified.

microphone: a transducer that responds to a pressure wave in air and delivers an electrical signal proportional to the incident pressure.

near field: a sound field near to the source in which the sound pressure does not decrease 6 dB for each doubling of distance from the source.

octave: the interval between two sounds whose frequency ratio is 2:1.

octave band: the segment of a frequency spectrum where the highest frequency is twice the lowest frequency.

oscillator calibrator: an electronic microphone-calibrating device which generates a known sound pressure level in a closed cavity at a specified frequency.

pistonphone: a microphone calibrating device equipped with a reciprocating piston of measurable displacement that permits the establishment of a known sound pressure in a closed cavity.

reflecting surface: an acoustically nonabsorptive (acoustically hard) surface, as opposed to an acoustically absorptive (acoustically soft) surface.

reverberant field: the sound in an enclosed or partially enclosed space that has been reflected repeatedly or continuously from the boundaries.

sound absorption: the process by which sound energy is dissipated or removed. The property possessed by materials, objects, and structures such as rooms of absorbing sound energy.

sound level: measured in decibels, a sound pressure level obtained by the use of a sound level meter whose weighting characteristics are specified in ANSI S1.4.

sound level meter: a device which is used to measure sound pressure level, functioning in accordance with the standard specifications for sound level meters established by ANSI S1.4, IEC 60651, and ANSI S1.11 (see References).

sound power level (L_w): ten times the logarithm to the base ten of the ratio of the sound power produced by the sound source to the reference power of 10^{-12} watts.

sound pressure level (L_p): ten times the logarithm to the base ten of the ratio of the square of the sound pressure of the sound under consideration to the square of the standard reference pressure. The standard reference pressure is 20 micropascals (μPa) , or equivalently, 2×10^{-5} N/m^2.

tone: a sound wave capable of exciting an auditory sensation of pitch.

Section 3
Guiding Principles

3-1 CHOICE OF METHODS

It is the intent of this Code to provide the user with a choice of methods for the measurement and characterization of sound emissions from operating industrial equipment. Equipment could consist of a component or an entire set of components comprising all or part of an industrial facility. The equipment may be located indoors or outdoors and may include the enclosure building(s) as a source of noise. This Code utilizes, by reference, existing standards and provides additional nonmandatory guidance in the application of those methodologies.

3-2 CONFIGURATIONS

A wide range of potential equipment configurations is addressed. For those cases in which the sound power level of indoor equipment is the objective, either the sound intensity method or the Two-Surface Method may be used, according to the availability of measurement systems. For those cases where outdoor sources must be characterized, whether in terms of sound power level, or in terms of receiver sound levels, the methods of either of the other referenced standard methodologies may be employed.

3-3 TEST UNCERTAINTY

The Code presents a mandatory appendix on the subject of uncertainty in sound level measurements. The user is encouraged to review the appendix and to make appropriate use of the information contained therein in the preparation of the test report. Each of the referenced standards cited in this Code carries statements addressing the accuracy, precision, bias, or uncertainty of measurements obtained using the respective methods, and shall be used for the primary treatment of test uncertainty.

3-4 AGREEMENTS PRIOR TO TEST

The parties to a test conducted under this Code should reach agreement on the following items prior to the test. In many cases it will only be necessary to agree upon one of the referenced standards in order to agree upon certain of these items.

3-4.1

The objective(s) of the test shall be defined as one or more of the following:

(*a*) near field sound pressure level
(*b*) sound intensity for sound power level
(*c*) Two-Surface method for sound power level
(*d*) far field sound pressure level

3-4.2

Survey particulars shall be defined in terms of the following:

(*a*) acoustical instrumentation
(*b*) microphone locations and orientation
(*c*) data retrieval and archiving, such as direct readout, data storage, tape recording, etc.
(*d*) data reduction required
(*e*) expected measurement uncertainty
(*f*) corrections to be used

3-4.3

The acoustical environment in which the equipment components are to be tested shall be defined. Variables that shall be considered are

(*a*) free, semi-reverberant, or reverberant field
(*b*) reflecting surfaces
(*c*) contribution of auxiliary noise sources
(*d*) background noise
(*e*) atmospheric conditions

3-4.4

Equipment components to be tested shall be operated at conditions as stipulated. A record of the operating conditions shall be maintained. Additional parameters that shall be considered are

(*a*) location and mounting of equipment
(*b*) starting time of each acoustical test
(*c*) duration and number of tests
(*d*) frequency of observations
(*e*) duration of operation at test conditions before measurements are made
(*f*) criteria for determining when test conditions are attained
(*g*) responsibility for control of operating conditions during test

3-4.5

Equipment to be tested shall be classified in terms of the following:

(*a*) size (physical dimensions). A controlled drawing, to be included in the report, may suffice.
(*b*) type of operation
(*c*) installation and mobility
(*d*) acoustical characteristics

3-4.6

The general format of the report shall be defined. Refer to Section 6 for further guidance.

3-5 SOUND SURVEY

Sound surveys shall be conducted by an engineer, technician, or acoustical consultant qualified by experience or training.

Section 4
Instruments and Methods of Measurement

4-1 PROCEDURES

Acceptable procedures for making sound pressure level (L_p) measurements, Sound Intensity measurements (L_i), and sound power level calculations (L_w) are described in the following sections. Procedures are given for sound power level determination of specific equipment components using either the Two-Surface Method or sound intensity measurements. Far field sound pressure level measurement procedures are given for application to either specific equipment components, or industrial installations comprised of a number of separate components.

4-2 SOUND PRESSURE LEVEL MEASUREMENTS — GENERAL

4-2.1 Sound Pressure Level Measurement

The procedures presented herein shall be used to obtain a compilation of near field or far field sound pressure level measurements for specific equipment components or for a specific installation. Measurements using this Code shall conform to the provisions of ANSI S1.13.

4-2.2 Instrumentation

The instrumentation required for the measurements outlined in this Code is as follows.

(*a*) Sound level meter and microphone system. The sound level meter and microphone system shall comply with the latest revision of IEC 60651 or ANSI S1.4, Type 1 or better (see References).

(*b*) Octave band and one-third octave band analyzer. The octave band or one-third octave band analyzer shall comply with the latest revision of ANSI S1.11.

(*c*) Data recording equipment.

(*d*) Narrow band spectrum analyzer, where applicable.

(*e*) Wind Screen for microphone.

(*f*) Means of determining wind speed, wind direction, dry bulb temperature, and relative humidity.

4-2.3 Acoustical Calibration

The microphone frequency response shall be calibrated in accordance with the procedures of ANSI S1.10. The complete instrumentation system including the microphone and connecting cables shall be calibrated with a pistonphone or oscillator calibrator before and after each test series. The instrumentation shall have been calibrated to applicable standards within 12 months prior to the test.

4-2.4 Operation of the Sound Source

The source shall be mounted and operated under conditions closely duplicating its actual configuration(s) and use(s). When the normal operating condition cannot be obtained, the tests shall be made at some other agreed-upon condition and this condition shall be clearly described in the test report.

4-2.5 Test Environment

Measurements should be conducted in an environment which approximates, as nearly as possible, a free field above a reflecting plane and not influenced by reflections from walls and nearby projects. When this is not possible, the corrections of ANSI B133.8 for nearby reflective surfaces, shall apply, as appropriate.

If large reflective surfaces or atmospheric inhomogeneities are present, and strong discrete frequency components above 500 Hz are suspected, a test shall be conducted for standing waves by moving the microphone vertically or horizontally approximately ± 0.3 m from each prescribed location. If the sound level over such a distance differs from the prescribed position's level by more than 3 dB in any frequency band of interest, test locations shall be expanded to include the maximum value of the standing wave sound pressure level and shall be noted in the report.

For far field measurements, regardless of whether strong discrete frequency components are present, whenever reflective buildings, fences, walls, or other large structures are located within a distance of 5λ of the microphone location, where λ is the wavelength of the center frequency of the lowest band of interest, they shall be noted in the report. For A-weighted levels, the presence of reflective buildings, fences, walls, or other large structures within a distance of 15 m (50 ft) of the microphone location shall be noted in the report.

4-2.6 Background Sound Pressure Level

The background sound pressure level with the test machine not operating shall be determined for all of the test microphone locations, for all octave bands or one-third octave bands of interest. The sound pressure level at each location with the machine running should ideally exceed the background sound pressure level by at least 10 dB for each octave band.

If the total measured operational sound pressure level does not exceed the background sound pressure level by 10 dB or more, the background sound pressure level shall be used to correct the measured operational sound level data obtained with the test machinery operating, as described in Nonmandatory Appendix A. If the total measured operational sound pressure level exceeds the background sound pressure level by 10 dB or more, no background sound pressure level correction is necessary, but the background sound pressure level correction of Nonmandatory Appendix A may be used.

When the measured operational sound pressure level is less than 3 dB above background sound pressure level, a corrected machine sound pressure level may be reported, but must be qualified in the report as having been determined using a difference of less than 3 dB.

4-2.7 Microphone Positions

For near field sound pressure level measurements, it is usually sufficient to select locations 1 m from the major vertical surfaces of the machine at a height of 1.5 m above the floor or walk level. Measurement locations shall be established relative to an imaginary parallelepiped, which will just enclose the source, omitting minor projections.

4-2.8 Measurement Technique

The measurement techniques prescribed in the respective standards shall govern. Where unique test conditions require departures from prescribed techniques, an explanation of the reasons for the departures shall be given in the final report.

In any measurement, the observer shall remain at least 0.5 m from the microphone. The observer shall in no event be between the microphone and the sound source. The microphone should be oriented as recommended by the manufacturer.

Large sound pressure level fluctuations may occur when strong discrete frequency components are present because of the interference between direct sound waves and those from reflective surfaces such as the floor, the ground, or nearby walls or buildings. Atmospheric inhomogeneities exhibit similar influences on far field measurements.

4-2.9 Test Conditions

The operation of the machinery under test shall be as required. For the measurement of background sound pressure level, all normally operating equipment not a part of the tested equipment scope of supply shall be operating to the maximum practical extent. However, it is not always feasible to continue to operate all equipment components not a part of the test equipment scope of supply when the test equipment is turned off. In this event, the test report shall describe the conditions.

Reasonable care should be taken to obtain background sound pressure level measurements and operational test measurements under the same general atmospheric conditions.

4-3 SPECIFIC MEASUREMENTS

4-3.1 Pressure Measurement

4-3.1.1 Sound pressure level measurements of airborne sound are subject to the same general guidelines and restrictions given in para. 4.2, whether the purpose of the test is to determine the sound power level of the source or sources, or whether the purpose is simply to catalog the sound pressure levels at particular positions. The procedures of ANSI S1.13 and ANSI S12.18 shall be followed when obtaining near field or far field airborne sound pressure level measurements under any conditions.

4-3.1.2 The data forms of the standards referenced in this Code may be used to prepare test reports for the measurements obtained using the procedures of this Code. The data obtained using the procedures of this Code may be used to define the sound pressure levels in general, at particular positions, for purposes other than the determination of sound power level, or the determination of far field sound pressure levels at prescribed positions.

4-3.1.3 Refer to Nonmandatory Appendix B of this Code for guidelines regarding the application of the referenced procedures to expected industrial sound measurement situations.

4-3.2 Sound Measurement by the Sound Intensity Method

4-3.2.1 The procedure for conducting sound intensity measurements shall comply with the latest revision of ANSI S12.12. The procedures given under this para. are used to obtain sound intensity levels for a specific piece of equipment. Sound intensity is the average rate of sound energy transmitted in a specified direction through a unit area normal to this direction at the point of measurement. Sound intensity levels are used in the determination of equipment sound power levels. In general, the procedure consists of measuring the sound intensity level normal to one or more measurement surfaces enclosing the equipment item under test, computing the sound power level for each surface based on the area of that surface, and then summing (on an energy basis) the sound power level for all of the surfaces to obtain the total sound power level.

4-3.2.2 Sound intensity is used for determining the contributions of individual components to the total sound power of a multicomponent source.

4-3.2.3 Sound intensity measurements may be A-weighted or, if frequency distribution is desired, conducted in octave or one-third octave bands.

4-3.2.4 Sound intensity differs from sound pressure level in that sound intensity can distinguish both the amplitude and direction of the acoustical energy transmission.

4-3.2.5 Sound intensity measurements are intended to mitigate or eliminate errors associated with using sound pressure level measurements to determine sound power levels. These include errors caused by measurements in the acoustic near field, the influence of the general acoustic environment, background noise from extraneous equipment, and lack of acoustic energy flow directionality. Sound intensity measurements are intended to mitigate or eliminate these errors.

4-3.3 Sound Measurement by the Two-Surface Method

4-3.3.1 To obtain the sound power level emitted from a particular piece of machinery or component using the Two-Surface Method, the procedures of the latest revision of ASTM E 1124, "Standard Test Method for the Field Measurement of Sound Power Level by the Two-Surface Method," shall be followed.

4-3.3.2 The principal distinguishing elements of the ASTM Two-Surface Method are

(*a*) the use of simultaneous averaging of the inner and outer microphone sound pressure levels, usually accomplished by mounting the microphones on the same beam or rod, which maintains a constant and precise spacing of each microphone from one another as well as from the equipment under test.

(*b*) the assumption that the fixed microphone spacing permits the reliable resolution of averaged sound pressure levels to the nearest 0.1 dB, which yields a broader range of usable data and a theoretically more precise result.

4-3.3.3 The key features of the application of the ASTM Two-Surface Method are

(*a*) the use of the fixed mounting for the two microphones as described in 4-3.3.2(a), thereby obtaining simultaneous and exactly corresponding readings.

(*b*) the user-selected option of either a swept-area coverage or a discrete position coverage, as depicted in Figs. 4 and 5 of ASTM E 1124.

(*c*) the need for the user to divide the total measurement surface into smaller areas over which the sound pressure levels are to be averaged.

(*d*) the need for the user to calculate the effective surface areas, both for the constituent areas and for the total area surveyed, over which each of the microphones is to be moved.

4-3.4 Sound Measurement in the Far Field From Machinery or Facilities

4-3.4.1 To obtain the far field sound pressure levels from a particular piece of machinery, component, or group of components, the procedures of the latest revision of ANSI S12.18, "Procedures for Outdoor Measurement of Sound Pressure Level," shall be followed. Also, the latest revision of ANSI B133.8, "Gas Turbine Installation Sound Emissions," may be used as an informative reference, and in the absence of otherwise prescribed measurement positions, ANSI B133.8 shall be used to establish the far field measurement positions. On matters where there is a conflict between ANSI S12.18 and ANSI B133.8, then ANSI S12.18 shall take precedence.

The objective of ANSI S12.18 is to obtain sound pressure measurements that are individually reproducible from a specific source or sources outdoors. The measurements take into account the source height, receiver height, the type of ground, and the local atmospheric conditions. The measurements obtained using the recommended procedures can be used to calculate sound pressure levels at other distances from the source or extrapolated to other environmental or ground conditions.

4-3.4.2 Distinguishing elements of the ANSI S12.18 procedure are

(*a*) ANSI S12.18 defines two methods for measuring sound pressure levels outdoors.

(*1*) *Method 1:* The general method outlines conditions for routine measurements and is utilized if meteorological variables fall within broad but predetermined limits. No effort is made to control the acoustical environment; that is, the environment is accepted "as is". This method usually will utilize a hand-held sound level meter to provide a frequency-weighted and time-averaged sound level, but it does not preclude instruments for frequency band analysis.

(*2*) *Method 2:* This method describes strict conditions for precise measurements for more reproducible measured sound pressure levels if the meteorological and ground conditions fall within strict limits. The acoustical environment may be "as is" or guidelines are given to modify or find a controlled acoustical environment for better accuracy. Procedures are suggested to adjust the measured sound pressure levels to reference conditions. This precision method is suited for frequency band analysis but also provides more accurate frequency-weighted sound pressure levels if required.

(*b*) Standardized receiver locations are not prescribed in ANSI S12.18.

4-3.4.3 Distinguishing elements of the ANSI B133.8 procedure are

(*a*) Far field sound measurement locations are described in para. 3.6.3 of ANSI B133.8 in terms of a "sound source envelope," which is defined as the smallest rectangular perimeter that just encloses the source component, or multiple components, of interest. The ANSI

B133.8 method prescribes measurement locations at the eight cardinal positions, 45 deg apart, at a distance of 400 ft from the source envelope.

(*b*) The ANSI B133.8 also suggests procedures for test data averaging, and corrections based on environmental and operational factors.

4-3.4.4 The key features of the application of the far field sound pressure level test method are

(*a*) *Determination of the purpose of the measurements.* For example, whether the test data will be used for the verification of compliance with regulatory or equipment specification requirements, or for use in engineering design calculations. This will provide guidance as to whether the general or precision measurement method is used.

(*b*) *Determination of the location of the receivers of interest.* The receivers may be at a fixed distance and direction from the source equipment under test, or the receiver may be at another location of interest, such as the boundary line of a receiving property.

(*c*) Determination of the operating condition for which the component under test will be measured.

4-3.4.5 Far-field receiver positions shall be selected such that they conform to the definitions of the acoustic far field, as described in ANSI S12.18 and ANSI B133.8. This definition signifies that the receiver location be at such a distance from the source that the source sound pressure level decreases at a rate of 6 dB for each doubling of the distance between the receiver and the acoustic center of the source. For locations close to the sound source envelope, measurements may not indicate true far field sound levels. In general, the acoustic far field may be determined to begin at the lesser of two distances:

(*a*) at least 5 times the greatest dimension of the sound source envelope, or

(*b*) at least 5 times the wavelength of the lowest acoustic frequency of interest.

4-3.4.6 Far field measurements of the component under test shall be made for conditions in which the component is operated at its full, normal load or at other mutually agreed upon operating conditions. The background noise shall be measured with the component not operating. These two measurements shall be made in a period during which the representative ambient conditions are reasonably similar. The representative ambient conditions may be determined using the guidance of Nonmandatory Appendix A of this Code.

Section 5
Computation of Results

5-1 GUIDELINES

In all cases the computation of results shall conform to the requirements of the applicable method referenced in this Code.

Mandatory Appendix I herein provides guidance on the computation of the uncertainty of measurements. In the absence of prescribed methods for the determination of uncertainty in the applicable method referenced in this Code, the uncertainty obtained from Mandatory Appendix I, either as calculated or as estimated from Table I-1, may be used in the report of test results.

Nonmandatory Appendix A herein provides formulas for calculating background noise corrections and distance corrections for use in conjunction with the applicable methods referenced in this Code. In the absence of prescribed methods for corrections for background noise or distance in the applicable method referenced in this Code, the guidance and mathematical expressions of Nonmandatory Appendix A shall be used.

Section 6
Report of Results

6-1 TEST REPORT INFORMATION

When tests are made according to any of the methods referenced in this Code, the following information shall be included in the test report.

6-2 GENERAL INFORMATION REQUIRED

6-2.1

A summary of the test objective, the results, and conclusions.

6-2.2

A statement of individual(s) authorizing the test, the objective, any contractual obligations, guarantees, or stipulated agreements between or among the parties to the test.

6-2.3

The data reporting requirements of the respective referenced test procedures cited in this Code shall be met.

6-3 DESCRIPTION OF THE SOURCE OF SOUND

6-3.1

The sound source or sources shall be described in appropriate detail including, as applicable, manufacturer, model, and description of the physical size of the equipment and relevant noise control measures to be noted.

6-3.2

Auxiliary equipment shall be described, including relevant acoustical measurements.

6-3.3

The operating conditions for the noise source(s), as well as the operating conditions of any equipment not included in the test objective but which has potentially affected the measurements, shall be stated in appropriately specific terms.

6-3.4

Appropriate notations shall be made of equipment mounting conditions, such as vibration isolators, if relevant.

6-3.5

In the event that vibration tolerances have been specified for the equipment under test, which constitute acceptable operating conditions, then such specifications shall be met during testing.

6-4 ACOUSTICAL ENVIRONMENT

6-4.1

The test environment, especially if indoors, should be described as to size and location of surfaces and types of, or acoustical characteristics of, surface finishes, wherever relevant.

6-4.2

The source location within the test environment shall be described, preferably graphically.

6-4.3

If indoors, then the test room shall be described in terms of suitability for acoustical measurements.

6-4.4

Any auxiliary equipment, extraneous structures, or other equipment not among the test objective equipment, in the vicinity of the source(s) or potentially affecting the measurements, shall be described, including relevant acoustical measurements.

6-4.5

Atmospheric conditions shall be described. Required information for indoor measurements are temperature, relative humidity, and time of day. Required information for outdoor measurements are temperature, relative humidity, wind speed, wind direction, and time of day. For any test site at an altitude of 300 m or more above sea level, or in the event the tested equipment is known to be intended for later installation at altitudes above 300 m, the atmospheric pressure shall also be recorded. For outdoor measurements, the sky conditions, or cloud cover, should be recorded.

6-5 INSTRUMENTATION

6-5.1

The instrumentation used shall be described by make, model, type, serial number, and date of last calibration.

6-5.2

A description of the relevant bandwidth limitations of the instrumentation shall be provided, if any.

6-5.3

Relevant notations regarding the averaging time, or dynamic meter response, as applicable, shall be provided.

6-5.4

The method of field calibration of the measurement system shall be described.

6-6 ACOUSTICAL DATA TO BE RECORDED AND REPORTED

6-6.1

The location of all measurement positions and microphone orientation shall be described.

6-6.2

All measured sound pressure levels, weighted sound pressure levels, band sound pressure levels, or sound intensity levels, shall be recorded. All measured background ambient levels shall be recorded, in appropriate terms. All measured data required to be taken on other equipment not within the scope of the test, or to characterize the acoustical behavior of reflective surfaces or structures, shall be recorded. The data may be summarized or reported completely in the test report, as agreed to by the parties to the test.

6-6.3

All adjustments and corrections for microphone and/or system, shall be reported.

6-6.4

Any derived average sound pressure levels shall be averaged on an energy basis unless otherwise agreed to by the parties to the test, and in any event, such averaging shall be shown in the report.

6-6.5

All calculations shall be shown, for instance, whenever sound power is calculated from sound pressure level, or whenever corrections are made to recorded data for distance, background noise contributions, or any other reason.

Section 7
References

ANSI B133.8, Gas Turbine Installation Sound Emissions
ANSI S1.1, Acoustical Terminology
ANSI S1.4, Sound Level Meters
ANSI S1.11, Specifications for Octave, Half-Octave, and Third-Octave Band Filter Sets
ANSI S1.13, Methods of Measurement of Sound Pressure Levels
ANSI S12.12, Engineering Method for the Determination of Sound Power Levels of Noise Sources Using Sound Intensity
ANSI S12.18, Procedures for Outdoor Measurement of Sound Pressure Levels
ANSI S12.36, Survey Methods for the Determination of the Sound Power Levels of Noise Sources

Publisher: American National Standards Institute (ANSI), 25 West 43rd Street, New York, NY 10036

ASTM E 1124, Standard Test Method for Field Measurement of Sound Power Level by the Two-Surface Method

Publisher: American Society for Testing and Materials (ASTM), 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959

IEC 60651, Sound Level Meters

Publisher: International Electrotechnical Commission (IEC), 3 rue de Varembé, Case Postale 131, CH-1211, Genève 20, Switzerland/Suisse

ISO/TAG4/WG3, Guide to the Expression of Uncertainty in Measurement

Publisher: International Organization for Standardization (ISO), 1 rue de Varembé, Case Postale 56, CH-1211, Genève 20, Switzerland/Suisse

MANDATORY APPENDIX I
Evaluation of Measurement Uncertainty

I-1 INTRODUCTION

The measurement results from the use of this Code may be compared with similar measurement results, design goals, or criteria. For such a comparison to be valid, the uncertainty of the measurement results must be stated. It is the responsibility of the experienced acoustician making the measurements to determine their measure of uncertainty, based upon measurement results, observations during the measurements, and general knowledge. This Appendix gives guidance on how to make this determination.

I-2 UNCERTAINTY COMPONENTS OF TYPE A AND TYPE B

The measurement uncertainty of each of the reported acoustic quantities shall be derived and reported as the combined standard uncertainty in the manner defined in this Appendix.[1] Additional guidance on applying the methods is contained in the latest revision of ISO "Guide to the expression of uncertainty in measurement." In this Appendix a distinction is made between Type A uncertainty components which are evaluated by using statistical methods on a series of repeated determinations, and Type B uncertainty components which are evaluated by judgment using different kinds of relevant information including experience from similar situations. Uncertainty components of both Type A and B are expressed as standard deviations and are combined by the combination of variances method to form the combined standard uncertainty.

I-3 SITE EFFECTS

When the uncertainty of the measurement results is evaluated, it is important to take into account the influence that the actual measurement site can have upon the acoustic conditions of the microphone mounting. The site effects are Type B uncertainty components.

[1] The guidance provided in this Appendix has been adapted from a Draft document to revise ASME Performance Test Code 19.1 (PTC 19.1) Supplement which has since been published as PTC 19.1-1998, "Test Uncertainty." PTC 19.1-1998 has in turn been substantially harmonized with the ISO "Guide to the Expression of Uncertainty in Measurement."

I-3.1 Uncertainty on Acoustic Parameters

I-3.1.1 Apparent Sound Power Level. This para. describes the uncertainty components that, based upon current knowledge, are the most important with respect to the apparent sound power level.

I-3.1.1.1 The parameter describing the Type A uncertainty is the standard error of the estimated L_{Aeq}. This is found from a standard analysis of variance and designated as U_A.

I-3.1.1.2 The following are considered uncertainty components of Type B:

U_{B1} = calibration of the acoustic instruments
U_{B2} = tolerances on the chain of acoustic instrumentation
U_{B3} = uncertainty on the acoustic conditions for microphone mounting
U_{B4} = uncertainty on the distance from microphone to source
U_{B5} = uncertainty on the acoustic impedance of air
U_{B6} = uncertainty on the acoustic emission of source due to changing weather conditions, if measured outdoors
U_{B7} = unaccounted for background noise correction

For all of the Type B uncertainties mentioned here, a rectangular distribution of possible values is assumed for simplicity with a range described as $\pm a$. The standard deviation for such a distribution is

$$U = \frac{a}{\sqrt{3}}$$

I-3.1.1.3 In Table I-1, possible values of the standard uncertainty components are given as examples. They can be used as guidance for evaluations to be made in actual cases.

The combined standard uncertainty is found as the root sum of the squared components

$$U_C = \sqrt{U_A^2 + U_{B1}^2 + U_{B2}^2 + \ldots}$$

Taking an example where the standard error on the estimated L_{Aeq} (U_A) is 0.5 dB (typical) or 1.5 dB (worst), the combined standard uncertainties can be found as U_C = 0.8 dB (typical) and U_C = 2.2 dB (worst). In cases with pronounced source or site effects, a larger uncertainty is to be expected.

Table I-1 Examples of Possible Values of Type B Uncertainty Components Relevant for Apparent Sound Power Level

Component	Possible Typical Range (±a)	Possible Typical Standard Uncertainty	Possible "Worst Case" Standard Uncertainty
U_{B1} calibration	±0.3 dB	0.2 dB	0.3 dB
U_{B2} instrument	±0.3 dB	0.2 dB	0.4 dB
U_{B3} mount	±0.5 dB	0.3 dB	0.9 dB
U_{B4} distance	±0.1 dB	0.1 dB	0.2 dB
U_{B5} impedance	±0.2 dB	0.1 dB	0.3 dB
U_{B6} weather	±0.7 dB	0.4 dB	0.9 dB
U_{B7} background	equals the applied correction	e.g., 0.1 dB	0.8 dB

I-3.1.2 Directivity. As an example of the standard uncertainty on the directivity, $\sqrt{2}$ times the combined standard uncertainty of the apparent sound power can be used in cases where a more detailed uncertainty analysis is not made.

I-3.1.3 Octave or One-Third Octave Band Spectra. For the octave or one-third octave band, the U_A for each band is the standard error on the averaged band level, computed as the standard deviation divided by $\sqrt{N-1}$, where N is the number of measured spectra (at least 5).

The value U_{B3} in octave bands or one-third octave bands must be considered to be much larger than for A-weighted sound level; estimated typical values are 1.2 dB and 1.7 dB for octave band and one-third octave bands, respectively.

I-3.1.4 Tonality. For tonality, U_A for each tone is the standard error on the averaged maximum tone level. The value of U_{B3} can be estimated to be 1.7 dB.

I-3.2 Range of Expected Uncertainty

The source standards used in the development of this Code, and the guidelines of the preceding discussion on uncertainty, have been used to develop a table of the estimated range of uncertainty when using this Code, in the event rigorous uncertainty analysis is not performed. These uncertainties may be used to evaluate the results of surveys conducted using this Code.

Table I-2 Expected Uncertainty for Various Parameters

Parameter		Near Field(1)	Far Field(2)
Sound Pressure	Band Level(3)	2	3
	dB(*A*)(4)	3	4
Sound Power	Band Level	3	4
	dB(*A*)	4	5
Sound Intensity(5)		3	n/a

NOTES:
(1) Near field measurements would be those obtained using either of the standard methods ANSI S1.13, ANSI S12.18, or ASTM E 1124 when used to obtain sound pressure levels directly.
(2) Far field measurements would be those obtained using either of the standard methods ANSI S1.13 or ANSI S12.18 when used to obtain sound power levels.
(3) Band level refers to either one-third octave band levels, or full octave band levels.
(4) dB(A) – A-weighted sound level, or A-weighted sound power level.
(5) Sound intensity does not apply to far field sound surveys.

NONMANDATORY APPENDIX A
Background Noise and Distance Corrections for Far Field Measurements

A-1 INTRODUCTION

Whenever far field measurements are to be performed, either for the purpose of characterizing a source, or for the purpose of comparison to an agreed upon criterion, it will often be necessary to correct for the influence of background noise or to correct for the necessity of measuring at a distance other than that prescribed by the applicable standard.

A-2 BACKGROUND NOISE CORRECTION

A background noise correction shall be applied to the measured data obtained with the sound source operating. For example if the background sound pressure level is 79 dB and the total sound pressure level with the machine operating is 84 dB, then the corrected sound pressure level is 82.4 dB, in accordance with the following expression.

$$L_c = 10 \log_{10} (10^{(0.1L_t)} - 10^{(0.1L_b)})$$

where:

L_c = background corrected sound pressure level
L_t = total measured operational sound pressure level
L_b = measured background sound pressure level

Corrections for background sound pressure level do not eliminate extraneous sounds from associated system components, which are not part of the test equipment, such as piping, intercoolers, accessories, etc. Correcting for the influence of these sound sources requires supplementary measurement techniques, which should be determined beforehand.

A-2.1

In determining the background noise to be subtracted from the total measured sound level, it will also be usual to measure the total background noise at each position of interest when the source is not operating. The potential problem with such a procedure is the possibility of the background noise changing between the time of the background only measurement and the total operational measurement. The unknown magnitudes of such background noise changes are a source of error in far field measurements. There are a number of ways to minimize this error; two are given here.

A-2.2 Long Term Monitoring at Each Measurement Position

In anticipation of the time of day during which the total operational measurement will be performed at each monitoring position (the "survey"), a series of short duration, average background noise measurements would be obtained at each position (the "background"). The time window during which the background measurements are obtained should bracket the expected survey measurement time for each position. The number of individual background measurements obtained should be sufficient to enable a determination of the average trend of the background noise. It should be noted that variations from day to day will introduce an additional variable, so that the accuracy of the average background noise will be improved with additional surveys on successive days, remembering that background noise trends during weekend days tend to be different in most environments, from that during weekdays. The use of the L90 level, that level exceeded 90 percent of the time during the measurement period, is encouraged as a means of defining the background level.

A-2.3 Control Position Monitoring

A "control" microphone position is used in those cases where it is reasonable to expect that the variations in background noise will be approximately the same at the entire set of far field measurement positions as well as the control position, and the control position is distant enough that the source in question will be essentially inaudible. In this case, the background readings are obtained at each measurement position as well as at the control position. Then the background noise is measured, at discrete intervals, continuously for the duration of the survey at the far field measurement positions. All measurements should consist of the same averaging time. In this case, any differences between the background noise at the control positions without the source operating, relative the level with the source operating, may be applied to the background noise measured at each position of interest, before the corrections are made.

A-3 DISTANCE CORRECTION

A distance correction shall be applied to the measured data obtained with the sound source operating, in the event site-specific constraints require a measurement position to be located at a distance from the source other than the distance prescribed by the standard method being used.

A-3.1

The distance correction shall be calculated as follows:

$$L_c = L_{ra} - 20 \log_{10} (R_c/R_a)$$

where:

L_c = distance corrected sound level
L_{ra} = actual measured sound level at the measurement position
R_c = distance from the source to the prescribed measurement position
R_a = distance from the source to the actual measurement position

A-3.2

For the purposes of this Code, a distance correction may only be made from an actual measurement position lying closer to the source than the prescribed position.

NONMANDATORY APPENDIX B
Guidance in the Use of Sound Intensity Methodology

B-1 INTRODUCTION

B-1.1

Refer to ANSI S12.12 for a complete detail of precautionary notes and data quality indicators regarding the measurement of sound intensity. The following precautions should be noted:

(*a*) Sound intensity instrumentation is significantly more complicated then sound pressure level instrumentation. This applies to both use and calibration. In addition, the frequency range of the measurement may be limited by the microphone configuration. Therefore multiple measurement sequences may be required, one for each applicable frequency range, in order to cover the total frequency range of interest.

(*b*) The proper use of sound intensity to determine sound power levels requires the judicious selection of the measurement surfaces. The use of concave measurement surfaces should be avoided. Sound absorption material inside the measurement surface (including air absorption), or on a physical surface that terminates the measurement surface, may absorb sound energy, resulting in a net *in situ* sound power level which may vary with ambient noise and installation environment. In addition the proximate location of large reflecting surfaces may affect the uniformity of the sound field, resulting in sound directionality information which may vary with test environment.

(*c*) ANSI S12.12 addresses a limited frequency range. The user should be aware that neither the accuracy nor the precision of the methodology has been established for frequencies below 100 Hz, typically of interest in industrial sound surveys

(*d*) While the proper use of sound intensity can usually mitigate the effect of extraneous background noise, sound intensity measurements will be adversely influenced if the background noise is too high. In addition, the background noise, if significant, must be steady during the measurements.

(*e*) A reverberant environment makes sound intensity measurements more difficult due to the degradation of the instrumentation accuracy. Therefore, highly reverberant environments should be avoided.

NONMANDATORY APPENDIX C
General Guidance for Sound Level Measurements

C-1 INTRODUCTION

C-1.1

The sound pressure level near a source is a function of source characteristics and the environment. Important source characteristics are the directivity and near-field sound pressure levels. For indoor measurements, important considerations are the proximity of reflecting surfaces, acoustical absorption, and room volume. Methods developed in ANSI S1.13, para. 3.4.4, should be followed for all indoor measurements.

C-1.2

Important considerations outdoors are the ambient temperature, wind velocity and direction, relative humidity, nearby reflecting surfaces, and intervening terrain. Measurements of sound pressure levels change with the interference from such test environment variables.

C-1.3

In a laboratory setting environmental factors can be controlled, or accounted for, and more precise measurements can be made. Measurements using this Code are not expected to be made in laboratory settings. The use of Sound Intensity measurements is intended to minimize the effects of such environmental interference.

C-1.4

When measuring sound pressure levels in the vicinity of machinery components in reverberant or semi-reverberant environments, it is common to generate a correction factor to account for the effect of the reverberant field. Such a correction factor is typically subtracted from the sound pressure levels prior to any data manipulation. This correction factor is not necessary when using Sound Intensity or Two-Surface Methods because the effects of the reverberant environment are inherently accounted for and no further corrections are necessary. However, in the use of Sound Intensity measurements, a strong reverberant field can reduce the accuracy of the measurement, and therefore highly reverberant environments should be avoided.

C-1.5

Refer to the ASTM standard E1124 method for precautionary notes regarding the application of the Two-Surface method to industrial facilities.

C-1.6

In planning a series of far field sound pressure measurements using ANSI S12.18, the purpose of the measurements should be kept clearly in mind. Whether General Method 1 or the Precision Method 2 is selected depends upon the required accuracy of the measurements. In many situations, the measurement procedure of the general method may be entirely adequate. The precision method is used when more precise measurements are required or for an analysis of the sound pressure levels in frequency bands from measurements made under prescribed meteorological and ground conditions over an appropriate time interval.

C-1.7

Selection of far-field receiver positions may be difficult if between the source component and the desired receiver location there exists intervening terrain, vegetation, or barriers, or if there are nearby reflecting surfaces. The field data report should indicate all factors which the surveyor judges to be significant, and reasons for any adjustments to far field positions.

C-1.8

If it is not possible to completely shut down the component under test, or if high or variable background noise levels exist at the desired receiver location, the contribution of the component may be indeterminate. In the case of far-field sound pressure level surveys, a “traverse” test may be conducted. This is a series of receiver measurement locations, which traverse the distance between the far field position most proximate to the component and the desired distant receiver position. A sufficient number of traverse test locations should be selected such that a clear trend for sound level with increasing distance can be determined. Also, it is convenient for trend analysis purposes to select locations at distances from the component under test which follow a geometric progression, for example, positions at 50, 100, 200, 400, and 800 ft from the source envelope.

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