ASME B133.8-2011

[Revision of ASME B133.8-1977 (R2001)]

Gas Turbine Installation Sound Emissions

AN AMERICAN NATIONAL STANDARD

The American Society of Mechanical Engineers

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AN AMERICAN NATIONAL STANDARD

The American Society of Mechanical Engineers
Three Park Avenue • New York, NY • 10016 USA

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The next edition of this Standard is scheduled for publication in 2017.

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

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FOREWORD

The purpose of this Standard is to provide format and criteria for the preparation of gas turbine procurement acoustical specifications for industrial, pipeline, and utility applications. This Standard will also be useful for response to such specifications. Field sound measurement guidelines to determine specified sound emissions compliance and to report field data are also presented.

This Standard provides essential information for the procurement of gas turbine power plants involving acoustical requirements. This Standard applies to simple-cycle gas turbines and combined-cycle gas turbines operating in simple-cycle mode with simple-cycle bypass capability, and conventional or advanced low-emissions combustion systems for industrial, marine, and electric power applications. Auxiliaries needed for proper operation are included. Gas turbines applied to earth-moving machines, agricultural and industrial-type tractors, automobiles, trucks, buses, and aeropropulsion units are not included.

For gas turbines using unconventional or special heat sources (such as chemical processes, nuclear reactors, or furnaces for supercharged boilers), this Standard may also be useful; however, appropriate modifications may be necessary.

The intent of this Standard is to cover the normal requirements of the majority of applications as determined by the consensus of the B133 Committee, recognizing that economic tradeoffs and reliability implications may differ in some applications. The user may desire to add, delete, or modify the requirements in this Standard to meet specific needs, and may do so in the procurement specification.

In the 1990s, the B133 Committee decided not to update the B133 standards, but instead to work with the ISO TC 192 Committee to prepare a series of gas turbine standards. These standards would essentially replace the B133 series of standards. As the ISO 3977 series of standards was released, the related B133 standards were withdrawn. In the first decade of this century, the B133 Committee was disbanded and all but one of the B133 standards were withdrawn. The B133.8 Standard, *Gas Turbine Installation Sound Emissions*, was considered of sufficient continuing interest in U.S. industry to merit its retention. Subsequently, it was felt that it should be updated. PTC Committee 36 on Measurement of Industrial Sound was considered to be the closest in subject matter among the ASME Standards and Certification Committees to undertake such a revision. In 2008, several former members of the B133 Committee responsible for the B133.8 Standard agreed to serve on the PTC 36 Committee.

The 2011 edition of B133.8 improves on the 1977 edition in the following aspects:

(a) addition of a near-field measurement specification along a prescribed near-field source envelope contour

(b) clarification of the gas turbine acoustical specification in the case of combined-cycle applications for both near field and far field

(c) clarification of the definition of measurement positions and distance corrections

(d) additional guidance regarding measurement methodology

(e) clarification of the treatment and evaluation of reflective surface effects

(f) additional and updated references, including Nonmandatory Appendix B on low-frequency airborne sound

Suggestions for improvement of this Standard are welcome. They should be stated as specifically as possible, and sent to the Secretary, PTC 36 Committee, The American Society of Mechanical Engineers, Three Park Avenue, New York, NY 10016.

This edition of the B133.8 Standard was approved by the PTC Standards Committee on April 18, 2011, and was approved as an American National Standard by the American National Standards Institute on August 17, 2011.

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Secretary, PTC Standards Committee
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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.

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Interpretations. Upon request, the PTC Standards 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 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 that 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 Standards Committee and PTC Committees hold meetings regularly, which are open to the public. Persons wishing to attend any meeting should contact the Secretary of the PTC Committee.

INTRODUCTION

This Standard is intended to be primarily a sound emissions procurement specification for gas turbines, as opposed to a standardized test procedure. The PTC 36 Committee believes that although there are many test procedures available to users of this Standard, procurement and testing are inextricably and unavoidably connected.

Whether the specification calls for measured airborne sound levels at particular positions, or for source sound power levels from components, a significant degree of measurement methodology is absolutely necessary.

Whenever sound levels at particular positions are called out, requirements are also specified for controlling the operating conditions, the instrumentation, the definition of locations, the averaging methodology, the meteorological constraints, the measurement duration, the test tolerances permitted, the environmental corrections to be applied, and the manner and methodologies used in any such corrections. Without such defined constraints, similar to test procedures, the sound emissions specification will be deficient.

Sound power level specifications require even more explicit details to adapt and apply any of the several possible sound power test procedures for gas turbine installations. Failure to provide detailed qualifications to sufficiently control and limit the range of possible interpretations on the specification or commitments can have adverse effects. These qualifications should be provided at the earliest possible stage in the specification (and by extension, in the contract documents and vendor guarantees) to avoid disagreements regarding the limitations and constraints of any specified sound emissions. Sound emissions must be considered in any gas turbine installation, as they are central to declarations of provisional acceptance, final acceptance, etc. Furthermore, the degree of financial exposure as a result of disagreements as to whether acoustical compliance has been achieved, or the degree to which some shortfall has occurred, is always a function of the precision of the definition of measurement methodology. In turn, any such disagreements affect the cost of both retrofit corrections or liquidated damages involved.

While contractual considerations are beyond the scope of this Standard, an awareness of the context within which the specification will be implemented is needed. This awareness influences the work of PTC 36 on this Standard, since it bears directly on the revisions contained herein.

The gas turbine literature often uses “gas turbine” and “combustion turbine” interchangeably. PTC 36 regards the use of “gas turbine” herein to be synonymous with “combustion turbine.”

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GAS TURBINE INSTALLATION SOUND EMISSIONS

Section 1
Object and Scope

1-1 OBJECT

The object of this Standard is to provide methods and procedures for specifying the sound emissions of gas turbine installations for industrial, pipeline, and utility applications. Included are guidelines for making field sound measurements and for reporting field data. This Standard may be used by users and manufacturers to write specifications and to determine compliance with a specification after installation. Information is included in Nonmandatory Appendices A and B for guidance in estimating expected community reaction to noise.

These methods and procedures are intended to be used by gas turbine users and manufacturers. The procedure may be used to specify sound emissions levels in accordance with local, state, or federal noise control requirements. A methodology is suggested in Nonmandatory Appendices A and B to determine gas turbine installation sound emissions levels that are generally compatible with the sound environment of a neighboring sensitive receiver, such as a residential community.

1-2 SCOPE

This Standard is applicable to land-based, or shoreside, barge-mounted gas turbines in single or multiple arrangements, for indoor or outdoor stationary installations. Applications may include, but are not limited to, gas turbine-driven generators, compressors, or pumps, in simple-cycle gas turbines or combined-cycle gas turbines with simple-cycle bypass capabilities.

Gas turbines used for the primary or auxiliary propulsion source in transportation vehicles (airplanes, automobiles, off-road vehicles, ships, etc.) are excluded from this Standard.

Procedures outlined in Section 2 may be used to specify either the sound emissions from the gas turbine only, or the total sound emissions from the site, including, but not limited to, gas turbine-driven equipment and auxiliary equipment. The user's specification must clearly define the equipment for which the noise specification is applicable, especially for combined-cycle plants, where all equipment may not be furnished by the gas turbine manufacturer on a turnkey basis. Unless otherwise stated, the specified noise emissions limits shall include all equipment at the site provided by the gas turbine manufacturer on a turnkey basis.

This Standard does not include specifications addressing exhaust stack exit sound pressure levels, exhaust stack exit sound power levels, or either the presence or absence of tonal components in the emitted acoustic spectrum.

Section 2
Sound Emissions Specification

2-1 INTRODUCTION

This Section provides standard methods to specify gas turbine installation sound emissions to comply with applicable environmental sound emissions limits[1] or company standards, or to avoid unreasonable sound intrusions into the surrounding neighborhoods, or to conserve employee hearing.

2-2 ENVIRONMENTAL SOUND EMISSIONS SPECIFICATION PROCEDURES

Gas turbine installation environmental sound emissions, at the specified steady-state load condition (up to and including full load as defined by the performance specification), are specified by one of two alternate procedures: specifying the A-weighted and, optionally, the C-weighted sound levels, or specifying the octave-band sound pressure level spectrum at a standard distance of 400 ft (120 m) from the perimeter of the gas turbine(s) sound source envelope. The gas turbine sound emissions level can be estimated for other far-field locations using Fig. 2-2-1 [refer to para. 3-6(c)].

2-2.1 Procedure A

This procedure requires specifying either the maximum[2] or the average[3] A-weighted sound levels. One suggested method to determine gas turbine installation sound emissions that are expected to be acceptable in a neighboring community is presented in Nonmandatory Appendix A. Also, for some installations, such as simple-cycle installations, where sensitive receivers consisting of frame structures occupied by people are nearby, the A-weighted sound level alone does not adequately define permissible low-frequency sound emissions. Thus, when using this procedure, the permissible C-weighted level may also be specified. Suggestions for specifying the C-weighted sound level limit are given in Nonmandatory Appendix B. A specification format is given in Form 2-2.1-1.

[1] Applicable limits may include local, state, or national regulatory requirements.

[2] Maximum sound level in this context means the highest measured sound level at any defined measurement position, nominally 400 ft (120 m) from the gas turbine sound source envelope.

[3] Average sound level is defined in para. 3-9.

2-2.2 Procedure B

This procedure requires specifying the maximum or average sound emissions levels in each of nine specified octave bands. This procedure should be used when local or state regulations or user procedures set octave band sound limits. A specification format is shown in Form 2-2.2-1.

2-3 ENVIRONMENTAL SOUND EMISSIONS SPECIFICATION FORMAT

Where the gas turbine manufacturer or the engineering, procurement, and construction (EPC) contractor provides all the equipment in the gas turbine installation, a typical gas turbine installation environmental sound emissions specification can be stated as follows: "Sound emissions from the total gas turbine site, including auxiliary equipment, when operated at specified megawatt or horsepower load in accordance with the contract specifications and ASME B133.8 procedures, shall not exceed the spatial average[4] or maximum (choose one) A-weighted and C-weighted sound level, or any octave band sound level listed in Form 2-2.1-1 or 2-2.2-1, when measured at a distance of 400 ft (120 m) or other specified positions from the sound source envelope of the nearest gas turbine. If the manufacturer does not provide all of the equipment, the user shall specify the maximum or average permissible sound level emitted from all sources other than the manufacturer's equipment." Note that in the latter circumstance, the owner accepts responsibility for achieving site acoustical goals due to the total operating facility. The requester should ensure that the noise specifications are for environmental conditions (humidity, temperature, cloud cover) that are typical of those in the installation area. The requester may also specify that the noise level requirements are for worst-case conditions.

When specifying sound levels in either the nine specified octave bands or the A-weighted and C-weighted format, the following information should be contained within the purchase specification:

(a) physical description and topographical plots of the ground surface.

(b) dimensioned sketch showing gas turbine, measurement points, and significant building structures, or other sound-reflecting objects [see para. 3-4(b)].

[4] Refer to para. 3-9.6 Footnote (1).

(c) appropriate or typical seasonal average meteorological conditions, including temperature, relative humidity, wind speed, and wind direction. Sound levels may be specified for multiple meteorological conditions at different seasons of the year.

(d) ANSI type specification of all instruments to be used during final evaluation of gas turbine plant (refer to references [2] and [7]). See para. 3-5.

(e) list of major site area sound sources existing at time of bid invitation.

2-4 NEAR-FIELD SOUND EMISSIONS SPECIFICATION

Control of employee exposure to sound emissions from gas turbine(s), auxiliary equipment, and driven devices is necessary to manage long-term employee hearing damage risk, and is the responsibility of the plant owner-operator. Thus, it is not proper to include reference to the Occupational Safety and Health Act (OSHA) hearing damage risk requirements in this Standard. Permissible A-weighted employee time-weighted average sound exposure limits have been promulgated by the U.S. Department of Labor pursuant to OSHA, and by state labor departments. Refer to the Federal Register for current employee occupational sound exposure limits, or to applicable state regulations.

Where the manufacturer provides all of the equipment in the gas turbine installation, a typical gas turbine near-field sound emissions specification may be written as follows:

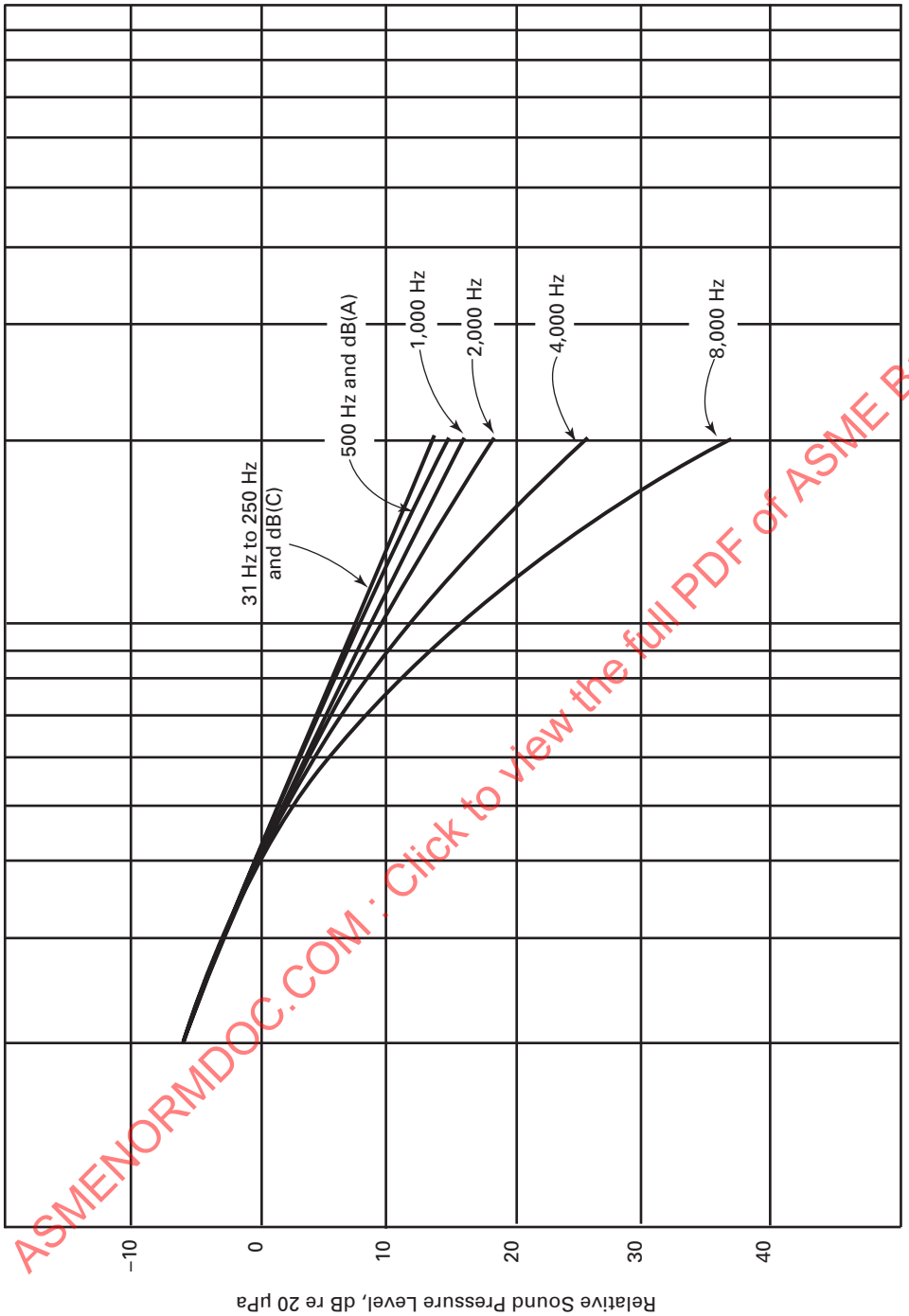
"Near-field sound levels from gas turbine auxiliary equipment and driven devices shall not exceed x dB[5] (A)[6] when measured 3 ft (1 m) in the horizontal plane and 5 ft (1.5 m) from the ground or personnel platform. This applies to any major surface of the gas turbine, its enclosure, auxiliary equipment, or driven equipment, with the equipment operating at the specified megawatt or horsepower load, in accordance with contract specifications and ASME B133.8 procedures."

If the gas turbine manufacturer does not provide all of the equipment, the specified sound emissions shall only apply to the equipment furnished by the gas turbine manufacturer.

[5] Where x is to be completed by the user based on estimated employee noise exposure.

[6] Typical average near-field A-weighted sound level values are 85 dB or 90 dB. It is important to note that specification of an 85-dB or 90-dB near-field A-weighted average sound level does not relate directly to the OSHA employee hearing damage risk criteria. The OSHA sound exposure criteria are distinct from any equipment near-field average A-weighted sound level. OSHA sound exposure criteria are only concerned with actual employee time-weighted daily noise dose associated with normal duty stations and rounds, and are thus independent of the specification addressed in this Standard.

Fig. 2-2-1 Estimated Sound Pressure Level at Far-Field Measurement Positions



GENERAL NOTES:

(a) Estimates are relative to the sound pressure level at 400 ft (120 m) from a point source, and 59°F at 50% relative humidity, for octave bands.

(b) This chart is an approximation only. The far-field positions of interest in this Standard are at a distance of 400 ft (120 m) from the sound source envelope. A more accurate approximation of the sound levels at various distances may be obtained via eq. (3-9.2-1), which takes into account the distance from the sound source envelope to the approximate acoustical center of the gas turbine installation, taken to be the center of the sound source envelope.

(c) More accurate values of atmospheric absorption at various temperatures and relative humidity are found in reference [1].

Form 2-2.1-1 Procedure A: Specified Sound Levels at 400 ft (120 m) for Total Gas Turbine Installation at Contract Conditions

Weighted Sound Level, dB re 20 μPa		
	Overall	
	dB(A)	dB(C)
Sound level at 400 ft (120 m)		
Specify average or maximum		

Form 2-2.2-1 Procedure B: Specified Octave Band Sound Pressure Levels at 400 ft (120 m) for Total Gas Turbine Installation at Contract Conditions

Octave Band Sound Pressure Levels, dB re 20 μPa									
	Octave Band Center Frequency, Hz								
	31.5	63	125	250	500	1,000	2,000	4,000	8,000
Sound pressure level at 400 ft (120 m)									
Specify average or maximum [Note (1)] and, if applicable, the specific location(s)									

NOTE:

(1) It is essential to specify that the given unweighted octave band sound pressure levels are either the average of the four or eight measured octave band levels, or the octave band levels corresponding to the position at which the measured A-weighted or C-weighted sound level is maximum. It is essential to specify the frequency weighting of the specified octave band sound pressure levels if other than unweighted. It is also essential to specify the exponential time weighting to be applied to the measured octave band sound pressure levels if other than slow.

Section 3
Field Sound Measurement Guidelines

3-1 INTRODUCTION

There are many detailed test procedures that have been codified by U.S. and worldwide standards bodies that may be used [3–6]. The purpose of these guidelines is to supplement such procedures with specific factors unique to gas turbine installations. These guidelines address ground level measurements at either near-field or far-field designated positions, whereas reference [4] includes methods for the measurement of exhaust stack exit sound levels as well as inlet filter face sound levels. Such exhaust stack exit or inlet filter face measurements are not expected to be a part of gas turbine procurement acoustical specifications under these guidelines.

Procedures are defined to adjust measured data to a standard distance of 400 ft (120 m) from the gas turbine installation. See para. 3-6(c) for allowable measurement distances.

3-2 QUALIFICATIONS

Gas turbine sound emissions are to be measured by an engineer, technician, or acoustical consultant qualified by experience or training.

3-3 GAS TURBINE OPERATION

The gas turbine plant will include all construction features described in the purchase agreement, regardless of whether they are essential for operation. All gas turbines will be running at specified rated load in megawatts or horsepower. All enclosure doors and access panels will be closed unless otherwise specified.

3-4 ACOUSTIC ENVIRONMENT

Many environmental factors affect the sound level measured at a specified orientation and distance relative to a gas turbine installation. These include weather, atmospheric temperature gradients, and the surrounding topography. Weather conditions are not controllable. The measurement time should be chosen to coincide with conditions typical of those in the installation area, if so specified. Refer to para. 3-4(a) for cautions regarding the adverse effects of atmospheric conditions on measurement accuracy. Terrain effects, including unlevel ground, wooded areas, and reflecting objects, are unique to each site, and they should be considered when selecting measurement position and interpreting sound level measurements. Such uncertainties are usually minor at distances up to 400 ft (120 m), but become of greater concern at greater distances.

(a) Atmospheric Conditions. Measurements should not be made when the average wind velocity exceeds 7 mph (3 m/s) measured 5 ft (1.5 m) above the ground at the level of the microphone. The wind velocity shall be averaged over the same time interval as the sound measurement. In general, relatively neutral atmospheric conditions are preferred, such as cloudy or overcast or nighttime conditions, when the atmosphere is stable, with no strong wind or temperature gradients. If the C-weighted sound level is to be measured, it is strongly recommended that wind velocity be minimal, below 7 mph (3 m/s), during the sound-level measurements. Measurements should be made at atmospheric conditions typical of the installation area and consistent with those in the requestor specifications. There may be instances where the regulatory authorities require compliance testing during specific conditions that might usually be regarded as unfavorable, but in such cases the specifics will be called out in the regulatory requirements.

(b) Terrain Effects. The normal terrain condition is relatively flat topography with a hard, acoustically reflective surface, and with a line of sight between the measurement position and the gas turbine. When the terrain is not flat, or is not a hard reflective surface between the gas turbine and any measuring point, it shall be noted and described in the test report. Also, any large reflecting surfaces with dimensions greater than 10 ft (3 m) and within 5λ of the source or 5λ of the microphone (λ is the wavelength at lowest frequency of interest) may be accounted for as described in para. 3-9.4 and noted in the report.

3-5 SOUND MEASUREMENT INSTRUMENTS

(a) Sound Level Meter (SLM). Sound level measurements shall be made with an SLM that meets the requirements of the latest edition of reference [2] or [7], Type 1 or 2. Type 1 is preferred. Integrating–averaging SLMs are preferred. The SLM shall have been laboratory calibrated, traceable to the National Institute of Standards and Technology (NIST), as specified by the manufacturer or within the previous 24 mo, whichever is shorter. The field calibrator shall have been calibrated, traceable to NIST, as specified by the manufacturer or within the

previous 12 mo, whichever is shorter. The SLM shall be checked for calibration in the field, using the field calibrator, before and after each measurement series, per para. 3-5(d).

(b) Octave Band Filter Set. Octave band filter set shall meet the requirements of the latest edition of reference [8].

(c) Recording Device. If a recording device is used for data storage, whether an AM or FM magnetic tape recorder or a digital format recorder of any type, it shall meet the provisions of the latest edition of reference [9]. If there is a disagreement between directly measured sound level meter data and recorded data, the direct data shall take precedence.

(d) Calibration. The SLM shall be acoustically calibrated using a sound level calibrator or pistonphone of known sound pressure level, both before and after each measurement series and after each battery change. A calibration level change exceeding ±1.0 dB may require the test series to be repeated.

(e) Microphone Windscreen. A microphone windscreen shall be used when making measurements. Its effect on the frequency response of the sound level meter shall not exceed ±0.5 dB at frequencies below 2,000 Hz, and ±1 dB at frequencies from 2,000 Hz to 10,000 Hz.

3-6 MICROPHONE LOCATIONS

(a) The microphone height shall be between 4 ft (1.2 m) and 5 ft (1.5 m) above the ground or personnel platforms.

(b) Near-field sound measurements using the A-weighted network shall be made at 3 ft (1 m) from major surfaces of the gas turbine, around the periphery of the turbine or its enclosure, auxiliary equipment and driven device at intervals not exceeding 15 ft (5 m), and at the point of maximum sound emissions (see Fig. 3-6-1).

(c) Environmental sound measurements shall be made at the eight positions, 45 deg apart, for single or multiple simple-cycle gas turbine installations, as shown in Fig. 3-6-2.

For simple-cycle modes of combined-cycle installations, see Fig. 3-6-3. Environmental sound measurements shall be made at as many as five candidate positions, modified as necessary to mutually agreeable positions in consideration of site-specific constraints. The position directly outboard of the air intake end of the gas turbine shall be designated as Position 1.

The standard distance from the microphone to the nearest point on the sound source envelope shall be 400 ft (120 m) as shown in dimension *d* in Figs. 3-6-2 and 3-6-3. The sound source envelope shall be defined as the smallest rectangle that just encloses the gas turbine manufacturer's scope of supply equipment. When the microphone cannot be located at this standard distance due to field constraints, an alternate measurement location shall be selected that shall not be less than 200 ft (60 m) nor more than 400 ft (120 m), or at a location specified in the purchase specifications or agreed to between the user and manufacturer. For gas turbine units in combined-cycle installations, the far-field sound level specification shall only apply for the case of simple-cycle operation of the gas turbine in bypass configuration. This Standard shall not apply to gas turbine operation in combined-cycle mode.

(d) Sound levels shall be reported at measurement locations specified in the purchase specifications. Measurements at distances other than that specified shall be adjusted as described in paras. 3-6(c) and 3-9.2 to the sound level expected at the specified distance.

3-7 SOUND MEASUREMENTS

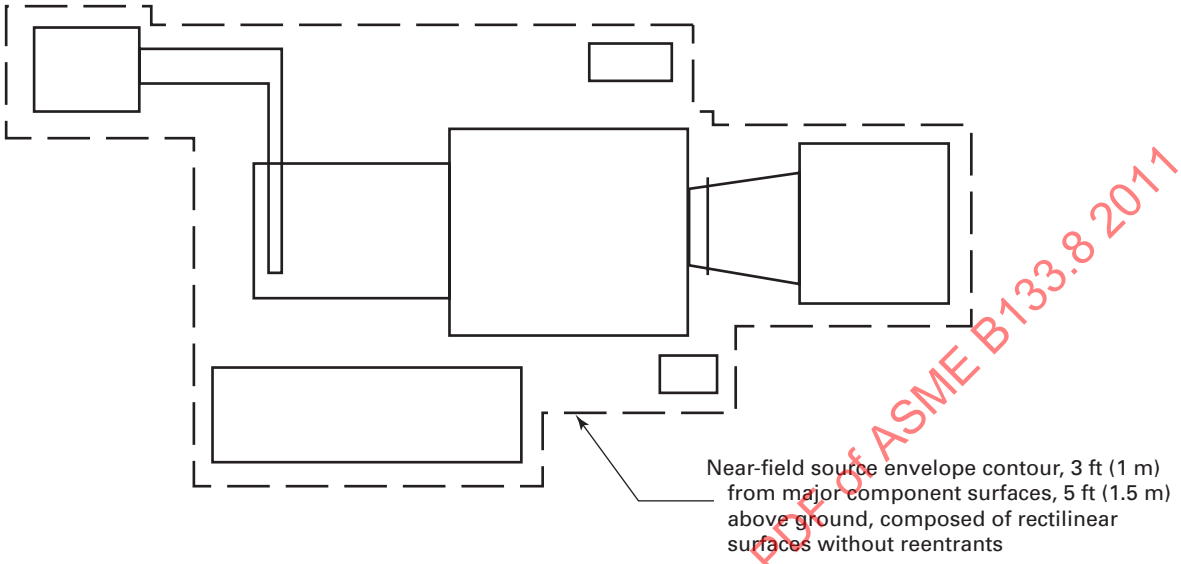
3-7.1 Equivalent Sound Levels

Multiple measurements of equivalent sound level, L_{eq}, shall be obtained with an integrating–averaging sound level meter over quiet intervals in the absence of sporadic interfering ambient sound. For instance, a minimum of three 20-sec intervals that demonstrate repeatability may be regarded as sufficient, if averaged, for far-field measurements. If "slow" and "fast" meter exponential time-weighting responses are available on the sound level meter being used, "slow" shall be selected. Ten-second intervals may be acceptable for near-field measurements, and a single such reading at each position of interest may be demonstrated to be sufficient. The measured sound level in each octave band with center frequencies from 31.5 Hz to 8,000 Hz, or the A-weighted and C-weighted sound levels shall be reported as specified by Procedure A or B (refer to paras. 2-2.1 or 2-2.2). The near-field sound emissions (refer to para. 2-4) shall be reported as A-weighted sound levels only.

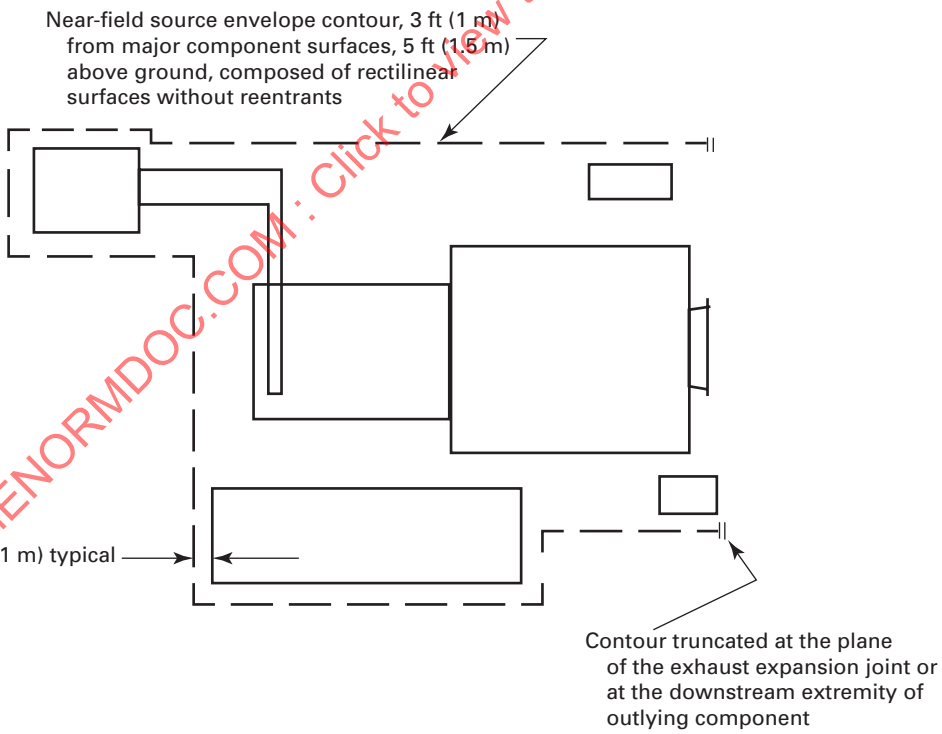
3-7.2 Ambient Sound Levels

Ambient or background sound may interfere with the sound emissions from the gas turbine installation and usually must be measured and evaluated. In many instances, the specified sound level limit may be at or below prevailing ambient sound levels. For simple-cycle installations with limits specified at 400 ft (120 m), the ambient sound level at each measurement position shall be measured using the A-weighted and C-weighted networks as applicable, or each octave band, before and/or after operational measurements are obtained. The ambient measurements shall be obtained using the same interval-measuring technique as for the operational measurements and shall involve, as nearly as practical, prevailing ambient sound level characteristics similar to those prevailing during the operational measurements. The ambient sound level during operation shall be

Fig. 3-6-1 Near-Field Contours

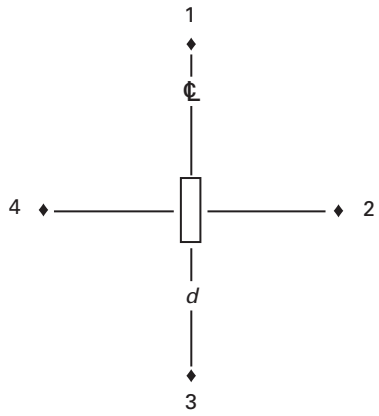


(a) Simple-Cycle Gas Turbine

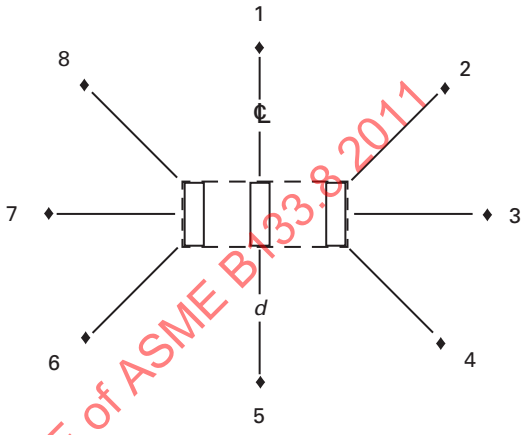


(b) Combined-Cycle Gas Turbine or Simple-Cycle Gas Turbine With Exhaust Stack by Other Than Gas Turbine Supplier

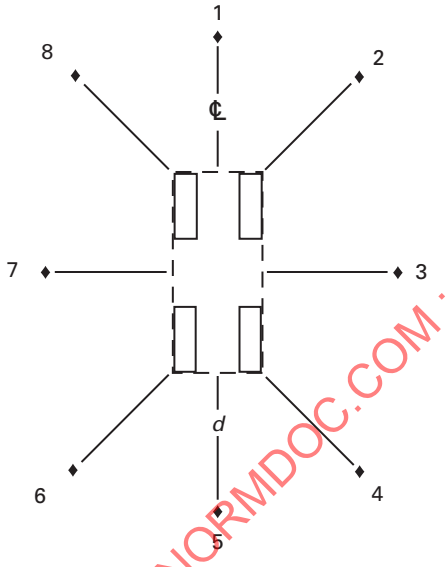
Fig. 3-6-2 Gas Turbine Sound Level Measurement Locations



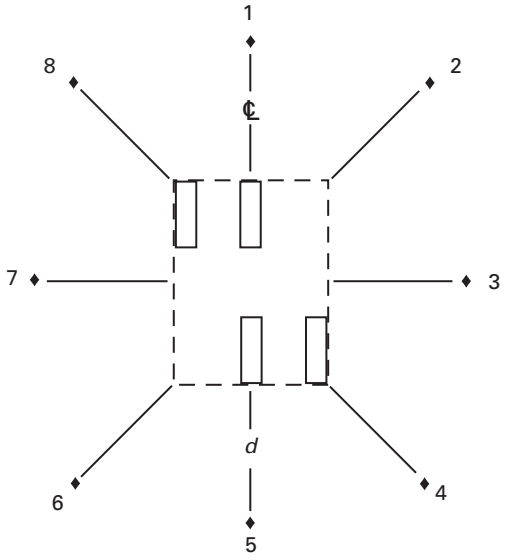
(a) Single Unit



(b) Multiple Unit — In Line



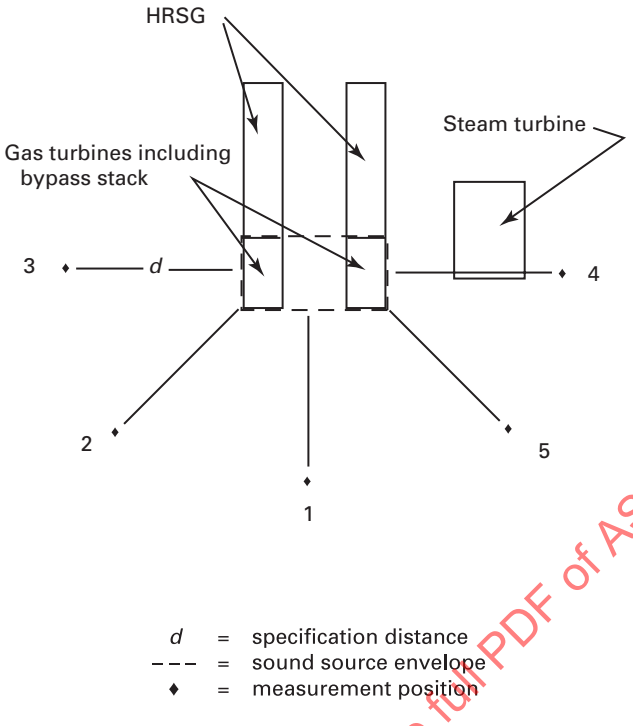
(c) Multiple Unit — Square



(d) Multiple Unit — Offset

d = specification distance
– – – = sound source envelope
♦ = measurement position
℄ = axial centerline of gas turbine

Fig. 3-6-3 Gas Turbines in a Combined-Cycle Installation Operating in Simple-Cycle Mode



regarded as the average of the measurements taken before and after, if available and if appropriate. Whenever the ambient sound level at a measurement position is at or near the operational sound level or is unsteady, various special techniques may be required to assess the ambient and operational sound levels properly. The interested parties shall agree upon the methodology beforehand in such instances.

3-8 DATA REPORTING

The following information shall be included in the test report:

(a) gas turbine plant
- *(1)* user
- *(2)* location
- *(3)* number of gas turbines and their model
- *(4)* load at time of sound measurements
- *(5)* date and time of measurements
- *(6)* description of gas turbine, driven equipment, auxiliary equipment, and sound control treatment

(b) acoustical environment
- *(1)* dimensioned sketch showing gas turbines, measurement points, buildings, or other sound-reflecting structures [see para. 3-4(b)]
- *(2)* physical and topographical description of the site
- *(3)* meteorological conditions at 5 ft (1.5 m) above ground, including temperature, relative humidity, wind speed, wind direction, and time of day

(c) instrumentation (refer to para. 3-5)
- *(1)* name
- *(2)* manufacturer
- *(3)* model number
- *(4)* serial number
- *(5)* ANSI type
- *(6)* dates of last calibration

(d) acoustical data (all sound level measurements shall be reported to the nearest one-tenth decibel or to the nearest whole decibel)

(e) auxiliary equipment in operation

(f) names of the personnel who performed and observed the measurements

3-9 AVERAGE AND MAXIMUM SOUND LEVEL CALCULATION

3-9.1 Data Correction

Measured sound levels at each location shall be corrected for the effect of measured ambient sound levels at each data location using Table 3 of the latest edition of reference [6]. If the sound level with the gas turbine operating does not exceed the ambient sound level by more than 3 dB, the gas turbine sound level shall be considered to be indeterminate. In this case, if it is necessary to establish the actual turbine emissions levels more clearly, the measurements may be repeated at a measurement position that is closer to the installation (see para. 3-6 for limitations), and/or at a time when the ambient sound levels can be expected to be lower, as

verified by measurements made during the previous 12-mo period.

3-9.2 Data Adjustment

Sound levels measured at a distance other than 400 ft (120 m) may be extrapolated to the standard distance after correction for ambient sound. Corrections for distance and air absorption are shown in Fig. 2-2-1, although such correction shall be merely an approximation. Alternatively, the improved accuracy for distance correction may be achieved through the use of the following equation:

$$L_{400} = L_{R1} + 20 \times \log_{10} [R_1/(400+R_2)] \qquad (3\text{-}9.2\text{-}1)$$

where

L_{400} = the estimated A-weighted sound level at 400 ft (120 m) from the sound source envelope

L_{R1} = the measured A-weighted sound level at the position from the sound source envelope other than 400 ft (120 m), subject to the limits of para. 3-6(c)

R_1 = the distance in feet from the acoustical center of the sound source envelope to the L_{R1} measurement position

R_2 = the distance in feet from the acoustical center of the sound source envelope to the edge of the sound source envelope along the azimuth toward the L_{R1} measurement position and the L_{400} position

3-9.3 Measurement Tolerance

There will always be measurement uncertainties due principally to meteorological conditions, but also to other influences. The use of the prescribed 400-ft (120-m) distance herein is given to minimize such uncertainties and to acquire repeatable data sets. The expected uncertainty of measurements at 400 ft (120 m) from the sound source envelope of gas turbine installations, using recognized standard international procedures, should be on the order of 3 dB(A) or 5 dB(C). Uncertainties would be higher at greater distances. For measurements at near-field positions using standard international procedures, the expected uncertainty should be less than 2 dB(A).

Whether to account for the tolerances, i.e., the instrumentation accuracy and measurement uncertainty, by adjusting the measured sound levels is a contractual matter to be agreed upon by the parties to the test prior to the test.

3-9.4 Reflective Surfaces

There may be unavoidable reflecting surfaces between the gas turbine installation and various measuring points, or in the vicinity of the associated azimuths, such that the measurement of operational sound will be affected. Corrections for these effects per Table 3-9.4-1 shall be presented in the test report. In the absence of mutually agreeable alternative analytical methods of determining the actual effects of reflections from nearby reflective surfaces, the adjustments of Table 3-9.4-1 may be applied.

Table 3-9.4-1 Corrections for Sound-Reflecting Surfaces

Overall Correction, dB re 20 μPa		Octave Band Corrections, dB re 20 μPa		
dB(A)	dB(C)	31.5 Hz Through 125 Hz	250 Hz	500 Hz Through 8 kHz
3	5	5	4	3

3-9.5 Ground Surfaces

The ground surface between the facility and the measurement positions may be acoustically hard or soft. For the prescribed 400-ft (120-m) distance, no correction shall be applied to the data for the actual absorption of the ground surface during the operational test.

3-9.6 Data Averaging

If the average of the sound measurements has been specified as the permissible limit, the corrected far-field sound levels at the four or eight locations shall be averaged[1] to yield the average sound level of the gas turbine installation at 400 ft (120 m).

3-10 COMPARISON OF MEASURED AND SPECIFIED SOUND LEVEL

The corrected sound emissions from the gas turbine installation, rounded to the nearest whole decibel, shall be considered acceptable if the following applicable condition(s) has been satisfied:

(a) the measured average or maximum sound level (whichever has been specified) corrected for ambient conditions is equal to or less than the specified A-weighted and C-weighted sound levels at the standard distance of 400 ft (120 m).

(b) the measured average or maximum sound level (whichever has been specified) in each of the nine octave bands is equal to or less than the specified octave band sound level at the standard distance of 400 ft (120 m).

[1] The average sound level, L_e, is defined as the average sound level (rms) measured at either the four or eight locations, computed by the following formula:

$$L_e = 10 \log \frac{1}{N} \sum_{n=1}^{N} 10^{L_n/10} \qquad (3\text{-}9.6\text{-}1)$$

where

L_n = weighted or octave band sound level at point n, dB

N = total number of measurements around the gas turbine installation (generally four or eight)

(c) the measured average or maximum, weighted or octave band sound levels (whichever have been specified) are equal to or less than the specified levels at locations agreed to by the user and manufacturer. This paragraph may apply to sites where governmental regulations or other specific limits have been contractually agreed to.

(d) the measured average or maximum, weighted or octave band sound levels (whichever have been specified) are equal to or less than the value specified except for the additive corrections given in Forms 2-2.1-1 and 2-2.2-1. [These corrections only apply when there are major buildings, fences, walls, or other large structures (see para. 3-4.2) within a distance of 5λ (λ is the wavelength of sound at the lowest frequency of interest) of the turbine installation or the microphone location. In this context an additive correction consists of subtracting the applicable values of Forms 2-2.1-1 and 2-2.2-1 from the appropriate measured value. If the specification is in the form of an A-weighted sound level, the lowest frequency of interest shall be 100 Hz (λ = 55 ft). If the C-weighted sound levels are specified, the lowest frequency of interest shall be 31.5 Hz (λ = 55/0.31 = 175 ft).]

Section 4
References

4-1 REFERENCES

[1] ISO 9613, Acoustics — Attenuation of sound during propagation outdoors — Part 1: Calculation of the absorption of sound by the atmosphere.

[2] ANSI S1.4, Specification for Sound Level Meters.

[3] ASME PTC 36-2004, Measurement of Industrial Sound.

[4] ISO 10494, Gas turbines and gas turbine sets — Measurement of emitted airborne noise — Engineering/survey method.

[5] DIN 45635, Part 47, Measurement of noise emitted by machines; airborne noise emissions; enveloping surface method.

[6] ANSI S12.18, Procedures for Outdoor Measurement of Sound Pressure Level.

[7] ANSI S1.43, Specifications for Integrating–Averaging Sound Level Meters.

[8] ANSI S1.11, Specification for Octave-Band and Fractional-Octave-Band Analog and Digital Filters.

[9] ANSI S6.1, Qualifying a Sound Data Acquisition System.

[10] ANSI S12.9, Quantities and Procedures for Description and Measurement of Environmental Sound — Part 4: Noise Assessment and Prediction of Long-term Community Response.

[11] "Community Noise," U.S. Environmental Protection Agency Report No. NTID 300.3, December 1971.

[12] "Information on Levels of Environmental Noise Requisite to Protect Health and Welfare with an Adequate Margin of Safety," U.S. Environmental Protection Agency, 550/9-74-004, March 1974.

[13] K. M. Eldred, "Assessment of Community Noise," Noise Control Engineering, Vol. 3, No. 2, September–October 1974.

[14] ANSI S1.13, Measurement of Sound Pressure Levels in Air.

[15] R. M. Hoover, "Beware Low-Frequency Gas-Turbine Noise," Power, May 1973.

[16] G. F. Hessler, "Proposed criteria in residential communities for low frequency noise emissions from industrial sources," Noise Control Engineering Journal, Vol. 52, No. 4, July–August 2004.

[17] N. Broner, "A simple criterion for low-frequency noise emission assessment," Journal of Low Frequency Noise, Vibration and Active Control, Vol. 129, No. I, Multi-Science Publishing, 2010.

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ISO 9613, Acoustics — Attenuation of sound during propagation outdoors — Part 2: General method of calculation.

R. B. Tatge, "Effect of community population on the applicability of noise rating procedures," Noise Control Engineering, Vol. 4, No. 1, January–February 1975.

L. L. Beranek, *Noise and Vibration Control*, McGraw-Hill, New York, 1971.

Noise Control Engineering, Vol. 4, No. 1, January–February 1975.

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NONMANDATORY APPENDIX A
GUIDE TO DETERMINING ACCEPTABLE A-WEIGHTED SOUND LEVEL

This Nonmandatory Appendix is not a part of ASME B133.8 but is included for information purposes only. Users interested in estimating acceptable sound emissions should also refer to reference [10]. Where local or state regulatory criteria exist they will supersede this Nonmandatory Appendix.

This Nonmandatory Appendix suggests a procedure that may be used to select acceptable A-weighted gas turbine sound emissions for an installation site where there is a nearby community. It may be used to develop procurement sound level specifications, or alternatively, if previously established sound level limits such as property line noise regulations are to be used as a design goal, to predict the expected community subjective response to the noise. Available information regarding community response to noise has been used (see references [11], [12] and [13]). However, community response criteria relates to average group response, and in some cases, individual judgments may vary, as shown by Fig. A-1. Therefore, some degree of uncertainty is inherent in this procedure.

Use of this Nonmandatory Appendix requires anticipation of the gas turbine installation operation cycle, and a familiarity with the proposed site and its surrounding neighborhood. Special consideration may be required for sites with unusual topographic or demographic features. The procedure described should be followed for each proposed gas turbine installation location. For those installations where noise may have an environmental impact or there are unusual topographic or demographic features, professional advice may be needed.

Two community sound emissions limits are calculated: one for turbines that do not emit prominent discrete tones,[1] and one for turbines that do emit prominent discrete tones. The user may want to reference both values in the bid specifications so that a prospective manufacturer can identify which specified noise level is appropriate to the offering. The manufacturer should state whether or not the sound emissions from his plant include a prominent discrete tone. Care should be taken to ensure proper definition of "prominent discrete tone" if the provision is included in the specification, since all such determinations are dependent on such variables as ambient background sound levels, measurement sampling durations, time of day, distance and direction from the gas turbine installation, and the influence of other plant sources.

Sound specifications apply to the sound emissions from an entire installation, and not to the individual turbines in a multiple array.

Form A-1 is a step-by-step worksheet for selecting an acceptable A-weighted community sound level for a complete gas turbine installation. The A-weighted sound level may be calculated by completing the following steps and entering the results in the appropriate boxes on Form A-l:

Step 1: An expected community subjective sound acceptance response category is selected on Fig. A-l (ordinate) and the corresponding normalized outdoor day/night sound level, L_{dn}, is determined. Table A-1, showing typical residential area A-weighted sound levels, may assist in this selection.

Step 2: Corrections are then obtained from Table A-2 for the season of operation and the ambient sound characteristics of the nearby neighborhood, and from Table A-3 and Fig. A-2 for the expected daily operational cycle of the gas turbine installation. The corrections are then summed.

Step 3: The sum of the corrections from Step 2 is then added to the normalized L_{dn} criteria to yield the gas turbine A-weighted sound level in decibels (dB) at the selected community location, usually the closest neighbor.

Step 4: By reference to Fig. A-3, determine the correction in decibels for the distance between the nearest residential area and the standard sound specification distance of 400 ft (120 m).

Step 5: Add the distance correction factor from Step 4 to the sound level in dB(A) of Step 3 to obtain the sound level in dB(A) at 400 ft (120 m).

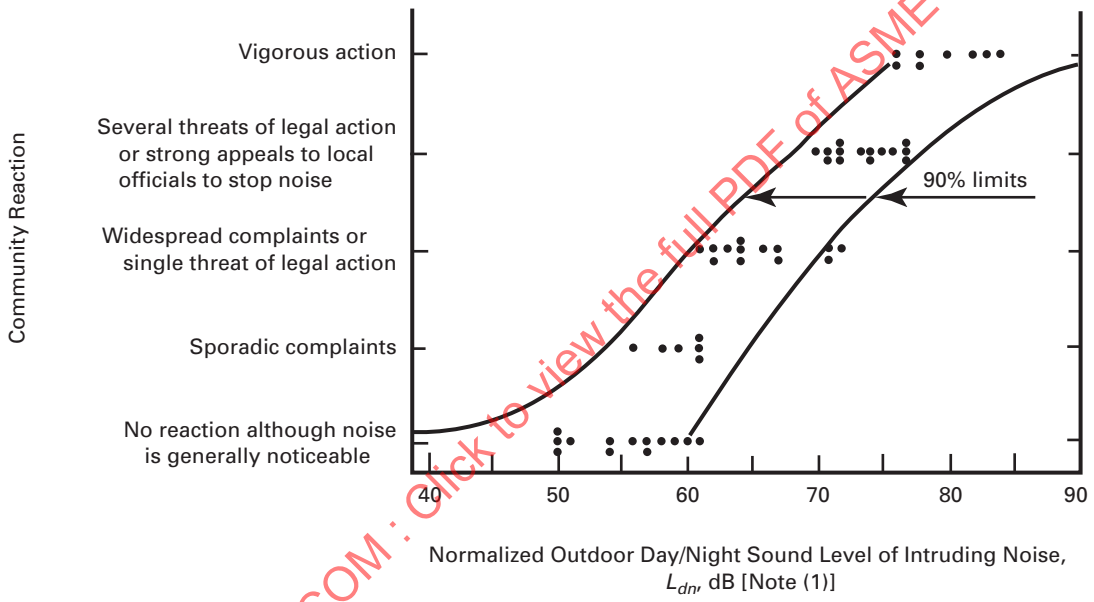
Step 6: Add a correction of –5 dB(A) to the level calculated at 400 ft (120 m) in Step 5 if the turbine sound emissions contain one or more prominent discrete tones.

[1] For this procedure, a prominent discrete tone is taken to be as defined in Annex A of reference [14], with the quantity X equal to 10 dB. Actually, X may range from 5 dB, for more-critical installations, to 15 dB, for less-critical installations.

(This procedure should be repeated for other noise-sensitive locations that surround the proposed site, and the most stringent noise emissions requirement would be used in Step 7.)

Step 7: Enter the calculated A-weighted sound level in dB(A) from Step 5 or 6 as the A-weighted specification sound level for Procedure A as shown in Form 2-2.1-1.

Fig. A-1 Community Reaction to Noises of Many Types as a Function of the Normalized Outdoor Day/Night Sound Level of the Intruding Noise



NOTE:

(1) L_{dn} designates the day/night sound level that is the equivalent A-weighted sound level during a 24-hr time period with a 10-dB weighting applied to the equivalent sound level during the hours of 10 p.m. to 7 a.m.

Form A-1 Suggested Procedure to Develop A-Weighted Sound Level Specification at Standard Distance of 400 ft (120 m)

	Steps	Value
1.	Choose appropriate value of normalized outdoor day/night sound level at nearest residence (see Fig. A-1 and Table A-1)	_____ dB
2.	Enter corrections	
	(a) seasonal (see Table A-3)	_____ dB
	(b) background sound (see Table A-2)	_____ dB
	(c) operational cycle (see Table A-3 and Fig. A-2) [Note (1)]	_____ dB
	Sum of corrections	_____ dB
3.	Line 1 value + sum of corrections in Line 2 = recommended sound level at nearest residence	_____ dB(A)
4.	Enter distance correction (see Fig. A-3 or para. 3-9.4)	_____ dB(A)
5.	Line 3 value + Line 4 value = specification level at 400 ft (120 m) for installations without prominent discrete tones	_____ dB(A)
6.	Line 5 value – 5 dB = specification level at 400 ft (120 m) for installations with prominent discrete tones	_____ dB(A)
7.	Specify the appropriate value from Line 5 or 6 for Procedure A as shown in Form 2-2.1-1	_____ dB(A)

NOTE:
(1) Sum = $D + N$.

Table A-1 Residential Area Sound Levels

Description	Daytime Sound Level Exceeded 90% of the Time, dB re 20 μPa [Note (1)]	
	Typical Range	Average
Very quiet rural area	31 to 35 inclusive	33
Quiet suburban residential	36 to 40 inclusive	38
Normal suburban residential	41 to 45 inclusive	43
Urban residential	46 to 50 inclusive	48
Noisy urban residential	51 to 55 inclusive	53
Very noisy urban residential	56 to 60 inclusive	58

GENERAL NOTE: See reference [11].

NOTE:

(1) Add 5 dB to estimate median sound level.

Table A-2 Corrections for Background Sound

Type of Correction	Description	Amount Correction, dB
Seasonal	Summer for year-round operation	0
	Winter only for windows always closed	+5
Background sound [Note (1)]	Quiet suburban or rural community (remote from large cities and from industrial activity and trucking)	−10
	Normal suburban community (not located near industrial activity)	−5
	Urban residential community (not immediately adjacent to heavily traveled roads and industrial areas)	0
	Noisy urban residential community (near relatively busy roads or industrial areas)	+5
	Very noisy urban residential community	+10

NOTE:

(1) These corrections are based on reported typical residual noise levels as shown in Table A-2. If measured data at the site under investigation differs significantly from the Table, different corrections may be warranted. The residual sound level is that sound level exceeded 90% of the time.