2014 Standard for
Reverberation Room Qualification and Testing Procedures for Determining Sound Power of HVAC Equipment

Approved by ANSI on November 6, 2015
IMPORTANT

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Note:

This standard supersedes ANSI/AHRI Standard 220-2012.

This standard describes the methodology for determination of Sound Power Levels of broad-band, and/or discrete-frequency noise, and narrow-band noise sources in reverberation rooms. It is based on ANSI S12.51/ISO 3741. The method described herein requires reverberation room pre-qualification through test and the use of the Comparison Method to determine Sound Power Levels. This standard specifies the physical environment, procedures and equipment to qualify the reverberation room by test. Pre-qualifying the room ensures adequate modal density with the use of one source location to obtain acceptable accuracy and repeatability of results. The Reference Sound Source (RSS) used for the Comparison Method relies on ANSI/AHRI Standard 250 to accurately calibrate the RSS at all frequencies of interest. The use of the Comparison Method reduces a number of potential sources of data collection and calculation errors. The standard contains information on instrumentation, installation and operation of the source, procedures for determining the number of microphone positions or length of traverse, and procedures for the calculation of Sound Power Levels.

This standard is more restrictive than ANSI Standard S12.51/ISO 3741, which allows the user to test using either the Direct Method or the Comparison Method and also allows the user to employ a space with general characteristics. The intent of ANSI S12.51/ISO 3741 is to have a room that shall provide a “good” environment for testing, with the understanding that if the end result has a variation that is too high the user can increase the number of measurement locations to improve the spatial averaging and thus lower the variation. This is not practical for sources that are difficult to move.
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REVERBERATION ROOM QUALIFICATION AND TESTING PROCEDURES FOR DETERMINING SOUND POWER OF HVAC EQUIPMENT

Section 1. Purpose

1.1 Purpose. The purpose of this standard is to provide the methodology for the determination of Sound Power Levels of noise sources that emit Broadband Sound and/or Discrete Frequency Sounds/Tones in reverberation rooms. The method described herein requires reverberation room pre-qualification through test and the use of the Comparison Method to determine Sound Power Levels. This standard specifies the physical environment, procedures, and equipment used to qualify the reverberation room by test. Pre-qualifying the room ensures adequate modal density with the use of one source locations to obtain acceptable accuracy and repeatability of results. The Reference Sound Source (RSS) used for the Comparison Method relies on ANSI/AHRI Standard 250 to accurately calibrate the RSS at all frequencies of interest. Sound rating values are often useful for applications and design, therefore it is important to acquire data and qualify measurement rooms in One-third Octave Bands. The use of the Comparison Method reduces a number of potential sources of error. The standard contains information on instrumentation, installation and operation of the source, procedures for determining the number of microphone positions or length of traverse, and procedures for the calculation of Sound Power Level. Measurements made in conformity with this standard will, with very few exceptions, result in standard deviations equal to or less than specified in Table 1.

The frequencies covered in this standard range from the 50 Hz to the 10,000 Hz One-third Octave Band (63 Hz to 8000 Hz Octave Bands). The 50 to 80 Hz one-third octave band sound for HVAC equipment affects product applications and often cannot be ignored. The product specific AHRI standard will specify the frequency range of interest for qualification, calculation, and reporting. This standard is based on ANSI S12.51/ISO 3741 but provides additional exceptions and extensions.

<table>
<thead>
<tr>
<th>Table 1. Maximum Standard Deviations of Sound Power Level Reproducibility Determined in Accordance with this Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>One-third Octave Band Center Frequency, Hz</td>
</tr>
<tr>
<td>-----------------------------------------------</td>
</tr>
<tr>
<td>50 - 80</td>
</tr>
<tr>
<td>100 - 160</td>
</tr>
<tr>
<td>200 - 315</td>
</tr>
<tr>
<td>400 - 5000</td>
</tr>
<tr>
<td>6000 - 10000</td>
</tr>
</tbody>
</table>

1.1.1 Intent. This standard is intended for the guidance of the industry, including manufacturers, engineers, installers, contractors and users.

1.1.2 Review and Amendment. This standard is subject to review and amendment as technology advances.

Section 2. Scope

2.1 Scope. This standard applies to HVAC products where sound power is determined by measurement using the Comparison Method in a reverberation room that meets the qualification requirements as defined in Section 4 of this standard.
Section 3. Definitions

All terms in this document will follow the standard industry definitions in the ASHRAE Terminology website (https://www.ashrae.org/resources-publications/free-resources/ashrae-terminology) unless otherwise defined in this section.

3.1 **Broadband Sound.** Sound that is random in nature with frequency components distributed over a broad frequency band. Typically pure tones or periodic disturbances will not be distinguishable in this type of sound spectrum.

3.2 **Comparison Method.** A method of determining Sound Power Level by comparing the average Sound Pressure Level produced in the room to a Reference Sound Source of known sound power level output. The difference in Sound Power Level is equal to the difference in Sound Pressure Level when conditions in the room are the same for both sets of measurements.

3.3 **Direct Method.** A method of determining sound power level from the measured sound pressure levels produced by the source under test in a reverberation room and from the reverberation time and volume of the reverberation room.

3.4 **Discrete Frequency Sounds/Tones.** These consist of one or more sound waves, each of which is essentially sinusoidal.

3.5 **Discrete Frequency Source.** A noise source that produces Discrete Frequency Sounds/Tones.

3.6 **Low Frequency Data.** Data in the 63 Hz Octave Band (50, 63, and 80 Hz One-third Octave Bands).

3.7 **Octave Band.** A band of sound covering a range of frequencies such that the highest is twice the lowest. The Octave Bands used in this standard are those defined in ANSI Standard S1.11.

3.8 **One-third Octave Band.** A band of sound covering a range of frequencies such that the highest frequency is the cube root of two times the lowest frequency. The One-third Octave Bands used in this standard are those defined in ANSI Standard S1.11.

3.9 **Reference Sound Source (RSS).** A portable, aerodynamic sound source that produces a known stable broadband sound power output.

3.10 "Shall" or "Should." "Shall" or "should" shall be interpreted as follows:

3.10.1 **Shall.** Where "shall" or "shall not" is used for a provision specified, that provision is mandatory if compliance with the standard is claimed.

3.10.2 **Should.** "Should" is used to indicate provisions which are not mandatory but which are desirable as good practice.

3.11 **Sound Power Level, \(L_{w}\).** Ten times the logarithm to the base ten of the ratio of the sound power radiated by the source to a reference sound power, expressed in decibels, dB. The reference sound power used in this standard is 1 picowatt, pW.

3.11.1 **A-weighted Sound Power Level \((L_{wA})\).** The logarithmic summation of A-weighted, one-third octave band Sound Power Levels.

3.12 **Sound Pressure Level, \(L_p\).** Twenty times the logarithm to the base ten of the ratio of a given sound pressure to a reference sound pressure of 20 µ Pa, expressed in decibels, dB.

3.13 **Unit Under Test (UUT).** HVAC equipment or duct termination for which the sound power is to be determined.
Section 4. Requirements for Qualification of Reverberation Rooms

4.1 Reverberation Room Requirements. The acoustic and physical environment of the reverberation room shall be qualified by test to meet the requirements of ANSI Standard S12.51/ISO 3741 Sections 5.1, 5.5, Annex A, Annex E, and Annex D except as noted in Sections 4.3 and 4.4 and the room volume requirements below. The minimum room volume for qualification of frequencies below the 100 Hz One-third Octave Band shall be 280 m$^3$. If only One-third Octave Bands equal to and above 100 Hz are required, the minimum room volume shall be 200 m$^3$.

4.2 Instrumentation Requirements. Instrumentation shall meet or exceed the requirements of Class 1 as specified in ANSI Standard S1.4, over the frequency range of interest. The microphone(s) used for all measurements shall be of the diffuse field/random incident type.

4.3 Standard Deviation Requirements for Broadband Room Qualification. The requirements of this standard for broadband room qualification are defined in Table 2.

<table>
<thead>
<tr>
<th>Octave Band Center Frequency, Hz</th>
<th>One-third Octave Band Center Frequency, Hz</th>
<th>Standard Deviation $S_0$, dB</th>
</tr>
</thead>
<tbody>
<tr>
<td>63</td>
<td>50, 63, 80</td>
<td>2.0</td>
</tr>
<tr>
<td>125</td>
<td>100, 125, 160</td>
<td>1.5</td>
</tr>
<tr>
<td>250</td>
<td>200, 250, 315</td>
<td>1.0</td>
</tr>
<tr>
<td>500</td>
<td>400, 500, 630</td>
<td>1.0</td>
</tr>
<tr>
<td>1000</td>
<td>800, 1000, 1250</td>
<td>0.5</td>
</tr>
<tr>
<td>2000</td>
<td>1600, 2000, 2500</td>
<td>0.5</td>
</tr>
<tr>
<td>4000</td>
<td>3150, 4000, 5000</td>
<td>1.0</td>
</tr>
<tr>
<td>8000</td>
<td>6300, 8000, 10000</td>
<td>1.0</td>
</tr>
</tbody>
</table>

4.3.1 Broadband Source. For the purposes of this standard, the RSS used to qualify the reverberation room for broadband measurements shall meet the requirements of ANSI/AHRI Standard 250.

4.4 Standard Deviation Requirements for Discrete Frequency Room Qualification. The requirements of this standard for discrete-frequency room qualification are defined in Table 3.

<table>
<thead>
<tr>
<th>Octave Band Center Frequency, Hz</th>
<th>One-third Octave Band Center Frequency, Hz</th>
<th>Standard Deviation $S_0$, dB</th>
</tr>
</thead>
<tbody>
<tr>
<td>63</td>
<td>50, 63, 80</td>
<td>4.0</td>
</tr>
<tr>
<td>125</td>
<td>100, 125, 160</td>
<td>3.0</td>
</tr>
<tr>
<td>250</td>
<td>200, 250, 315</td>
<td>2.0</td>
</tr>
<tr>
<td>500</td>
<td>400, 500, 630</td>
<td>1.5</td>
</tr>
<tr>
<td>1000</td>
<td>800, 1000, 1250</td>
<td>1.0</td>
</tr>
<tr>
<td>2000</td>
<td>1600, 2000, 2500</td>
<td>1.0</td>
</tr>
</tbody>
</table>
4.4.1 Discrete Frequency Source. For the purposes of this standard, the Discrete Frequency Source used to qualify the reverberation room shall meet the requirements of Section 5.2.2.

4.5 Microphone Locations. No microphone position or point on a traverse shall be less than 1.5 m from any of the reverberation room’s surfaces. At no point shall the microphone be any closer than 0.5 m to any surface on a rotating diffuser. The minimum distance between the microphone and each measurement location shall be determined using Equation 1.

\[ d_{\text{min}} = D_2 \cdot 10^{(L_{\text{wr}} - L_{\text{pr}})/20} \]  

Where:

- \( d_{\text{min}} \) = Minimum distance between the microphone and source, m
- \( D_2 \) = 0.4 for One-third Octave Bands from 50 to 80 Hz and from 6300 Hz to 10,000 Hz
- \( D_2 \) = 0.8 for One-third Octave Bands from 100 to 5000 Hz
- \( L_{\text{pr}} \) = The Sound Pressure Level of the RSS in any One-third Octave Band measured in the reverberation room
- \( L_{\text{wr}} \) = The calibrated Sound Power Level of the RSS in any One-third Octave Band

The \( d_{\text{min}} \) shall be computed for each One-third Octave Band and each potential source location for which the room is to be qualified. The maximum calculated \( d_{\text{min}} \) value shall be the minimum distance between the microphone and the source for room qualification and for unit testing.

4.6 Microphone Traverse. If a traversing microphone is used, the space averaging of the sound data shall be measured using a microphone traversing at a constant speed over a path length greater than or equal to \( 3\lambda \) for One-third Octave Bands of 100 Hz and above and \( 3\lambda/2 \) for the 50 Hz through 80 Hz One-third Octave Bands. The same microphone traverse shall be used for both room qualification and sound power determination.

\[ \lambda = \frac{c}{f} \]  
\[ c = 20.05 \cdot \sqrt{(273 + \theta)} \]

Where:

- \( c \) = The speed of sound of the air, m/s
- \( f \) = The center frequency of the lowest band of interest, Hz
- \( \theta \) = The temperature of the air in the reverberation test room at the time of test, °C

4.6.1 Path of Microphone Travel. The path may be a line, semicircle, circle, or other geometric shape.

4.6.2 Microphone Traverse Speed. The speed of the traversing microphone shall be constant and shall not exceed 1 meter per second. There shall be a whole number of microphone traverses completed during the analyzer’s measurement time interval, no partial traverses are allowed.

4.6.3 Microphone Traverse Location. The microphone traverse shall be within the reverberant field.

Note: It is good practice for the microphone traverse to not lie in a plane parallel to any room surface, including walls, the floor or the ceiling.

4.7 Fixed Microphones. If an array of microphones is used, it shall consist of at least six fixed microphones (or microphone positions) spaced at least \( \lambda/2 \) from each other. The entire array of microphone positions shall not share a common plane. Either the outputs of the microphones shall be scanned automatically and averaged by the indicating device, or the space average shall be computed from the sound pressure levels at each individual microphone position. The array shall be located within the reverberant field. The same six or more microphone locations used for the array shall be used for both room qualification and sound power determination.
Section 5. Reverberation Room Qualification Procedures

A reverberation room to be used per this standard shall first be broadband qualified per Section 5.1 and then for discrete frequencies per Section 5.2. This is required because it is not possible to determine before testing if discrete frequency contributions to the source spectrum are small enough to only negligibly affect the variation in the resulting sound power calculation.

5.1 Broadband Room Qualification. The procedures described in this section shall be used to determine whether the reverberation room meets one-third octave band broadband requirements for measurement uncertainties as specified in Section 4.3.

5.1.1 Broadband Qualification Test Procedure. The Sound Pressure Levels due to operation of a Reference Sound Source, calibrated per ANSI/AHRI Standard 250, shall be measured at eight or more RSS measurement locations (placed so that the microphone is located in the room’s reverberant field during the RSS operation). The RSS shall be located on a reflecting plane. The resulting Sound Pressure Levels shall be used to determine the sample standard deviation.

5.1.2 RSS Considerations. For the purposes of this standard, the RSS shall have the characteristics required by ANSI/AHRI Standard 250 and be calibrated in accordance with ANSI/AHRI Standard 250. Each measurement location selected for the Reference Sound Source shall be such that the distance between any two locations is between \( \frac{1}{4} \) and \( \frac{1}{2} \) wavelength of the center frequency of the lowest One-third Octave Band for which the room or portion thereof is to be qualified. The selected locations shall be no closer than 1.5 m to any wall and no closer to the microphone than \( d_{\text{min}} \) as described in Section 4.5. Additionally the selected locations shall not be within 0.25 m of the room centerlines. The locations selected shall be as close as possible to the intended test locations for test units and cover a region surrounding the test unit or to either side of a test duct. The RSS shall be operated at no more than plus or minus 2 rpm from its calibrated rpm. To prevent the need for background correction and the corresponding added uncertainty, it is recommended that the RSS Sound Pressure Levels be 15 dB above background levels over the frequency range of interest.

5.1.3 Data to Be Taken. Data shall be taken at each of the RSS measurement locations in One-third Octave Bands over the frequency range as defined in Section 5.1.5. Sound Pressure Levels shall be measured to the nearest 0.1 dB at each one of the source locations.

5.1.3.1 Analyzer Measurement Time Interval. The sound analyzer measurement time interval shall be equal to or greater than 30 seconds.

5.1.3.2 Microphone Traverses. The microphone shall make at least two complete traverses during the measurement time interval. The microphone traverse shall be per Section 4.6.

5.1.3.3 Fixed Microphones. Fixed microphones shall be per Section 4.7.

5.1.4 Computational Procedures. For each one-third octave frequency band, the sample standard deviation \( (S_s) \) shall be computed using Equation 44.

\[
S_s = \sqrt{\frac{\sum_{i=1}^{N_s} (L_{pi} - L_{pm})^2}{(N_s - 1)}}
\]

Where:

- \( L_{pi} \) = Measured one-third octave band Sound Pressure Level in a given band and for the \( i \)th RSS location averaged across all microphone positions or for a microphone traverse
- \( L_{pm} \) = Arithmetic mean for all measurement locations for a given One-third Octave Band
- \( N_s \) = Number of RSS measurement locations, minimum of 8 locations
- \( S_s \) = Standard deviation in a given One-third Octave Band
5.1.5  **Broad Band Qualification.** The portion of the reverberation room encompassed by the RSS locations shall be deemed qualified if computed standard deviations do not exceed the values listed in Section 4.3 for the full range of required One-third Octave Bands. The reverberation room shall be qualified over the full range of one-third octave band frequencies as specified by the referencing standard, and the qualified frequency range shall be stated in documentation. Note: The common ranges of qualification for reverberation rooms are either from 50 Hz to 10,000 Hz or from 100 Hz to 10,000 Hz. The range to be qualified shall be specified in the product specific AHRI standard.

5.1.6  **Additional.** Once the region of the reverberation room is qualified; the microphone traverse or fixed microphone positions, sound diffuser (if used) instrumentation, and analyzer measurement time interval shall be identical to those used when performing unit testing in order to claim compliance with this standard. Sound diffuser design is recommended per ANSI S12.51/ISO 3741 Annex B.

5.2  **Discrete Frequency Room Qualification.** Procedures described in this section shall be used to determine whether the portion of the reverberation room to be used in subsequent tests meets the one-third octave band discrete frequency requirements for measurement uncertainties as specified is Section 4.4. The broadband room qualification procedure shall be completed first so that the location for the test is shown to be one-third octave band broadband qualified prior to doing the discrete frequency room qualification. For the purposes of Section 5.2, the Discrete Frequency Source is a speaker.

5.2.1  **Discrete Frequency Test Procedure.** One (or more) measurement location(s) as specified in Section 5.2.4 shall be used to determine the sample standard deviation of the measured Sound Pressure Levels as calculated per Section 5.2.8. Multiple locations shall be qualified if the test source is large. The area between qualified sources defines the qualified region. The device under test shall be placed within the qualified region. Each location shall be qualified individually. The microphone traverse or fixed microphones, sound diffuser (if used) instrumentation, and analyzer measurement time interval shall be that used in the broadband room qualification procedure of Section 5.1. The one-third octave band upper frequency limit for discrete frequency testing shall be determined from Section 5.2.7.

5.2.2  **Discrete Frequency Source and Operational Equipment.** The Discrete Frequency Source and its operational equipment shall meet the requirements of ANSI S12.51/ISO 3741 Annex A.3. The exception is that when qualifying the 50, 63, and 80 Hz One-third Octave Bands, use of a speaker with a diameter greater than 200 mm may be required, but the diameter shall be no greater than 400 mm.

5.2.3  **Speaker Qualification and Normalization.** This procedure describes how to qualify the speaker and normalize the system. Annex A.4 of ANSI S12.51/ISO 3741 is to be used for this procedure except the microphone and associated equipment (excluding traverse) used in Section 5.1 shall be used and the Sound Pressure Levels are to be measured to the nearest 0.1 dB. These Sound Pressure Levels shall be designated $L_{\text{A}sc}$. The difference between levels of adjacent tones within a given One-third Octave Band is recommended to be less than or equal to 1 dB for frequencies in the 100 Hz One-third Octave Band and above and 2 dB for frequencies below the 100 Hz One-third Octave Band. If the reverberation room’s microphone(s) requires that a microphone windscreen be used, then that windscreen shall be installed on the microphone when doing the speaker qualification and normalization. Additionally, the windscreen shall meet the requirements specified in Section 5.10 of ANSI/AHRI Standard 250.

Note: If fixed microphones are to be used, it is recommended that the sound level be measured for each microphone and associated cable and/or windscreen.

5.2.4  **Discrete Frequency Source Speaker Location(s).** The speaker(s) shall be located at the broadband qualified location(s) and within the boundary created by the broadband qualified locations. The cone of the speaker(s) shall be oriented so that it points away from the nearest reflecting plane.

5.2.5  **Discrete Test Frequencies.** The discrete test frequencies that are used for a reverberation room’s discrete frequency room qualification are listed in Table 4.
Table 4. Test Frequencies for Discrete Frequency Qualification

<table>
<thead>
<tr>
<th>Octave Band</th>
<th>Center Frequency (Hz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>63</td>
</tr>
<tr>
<td>60</td>
<td>63</td>
</tr>
<tr>
<td>70</td>
<td>63</td>
</tr>
<tr>
<td>80</td>
<td>63</td>
</tr>
<tr>
<td>90</td>
<td>63</td>
</tr>
<tr>
<td>100</td>
<td>63</td>
</tr>
<tr>
<td>125</td>
<td>63</td>
</tr>
<tr>
<td>160</td>
<td>63</td>
</tr>
<tr>
<td>200</td>
<td>63</td>
</tr>
<tr>
<td>250</td>
<td>63</td>
</tr>
<tr>
<td>315</td>
<td>63</td>
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<tr>
<td>350</td>
<td>63</td>
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<tr>
<td>400</td>
<td>63</td>
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<tr>
<td>500</td>
<td>63</td>
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<td>600</td>
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<td>800</td>
<td>63</td>
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<tr>
<td>1000</td>
<td>63</td>
</tr>
<tr>
<td>1250</td>
<td>63</td>
</tr>
<tr>
<td>1600</td>
<td>63</td>
</tr>
<tr>
<td>2000</td>
<td>63</td>
</tr>
<tr>
<td>2500</td>
<td>63</td>
</tr>
</tbody>
</table>

5.2.6 Discrete Frequency Testing. At each required discrete test frequency, the speaker shall be operated at the same voltage that was used in Section 5.2.3. With the instrumentation as stated in Section 5.2.1 operating normally, one-third octave band Sound Pressure Levels shall be measured in the reverberation room at each one of the required test frequencies. The voltage measured at the speaker shall not vary by more than plus or minus 0.1% and the frequency shall not vary by more than plus or minus 0.1Hz during sound pressure level measurements at each one of the test frequencies. For each of the required One-third Octave Bands, the full set of test frequencies identified in Table 4 shall be measured. These Sound Pressure Levels shall be designated, $L_{eq}$.

5.2.7 Determining Upper Frequency Qualification Limit. The upper frequency limit of required testing shall be determined as specified below and shall not be greater than the maximum frequency listed for the 2500 Hz One-third Octave Band in Table 4. Calculate the frequency limit using the equations below. If a traversing microphone is used, calculate the frequency limit as the larger of both Equations 5 and 6. If fixed microphones are used, calculate the frequency limit using Equation 6 only. Using the calculated frequency limit value, determine the one-third octave band for which that value falls between the lower band limit and upper band limit as listed in Table 5. The qualification shall cover the bands up through the entire band containing the frequency limit.

- Frequency Limit = 6000 / $L$
- Frequency Limit = 5000 / $V^{1/3}$

Where:
- $L$ = Length of one complete microphone traverse, m
- $V$ = Volume of the reverberation room, m$^3$
Table 5. One-third Octave Band Frequency Range

<table>
<thead>
<tr>
<th>Center Frequency, Hz</th>
<th>50</th>
<th>63</th>
<th>80</th>
<th>100</th>
<th>125</th>
<th>160</th>
<th>200</th>
<th>250</th>
<th>315</th>
<th>400</th>
<th>500</th>
<th>630</th>
<th>800</th>
<th>1000</th>
<th>1250</th>
<th>1600</th>
<th>2000</th>
<th>2500</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lower Band Limit, Hz</td>
<td>44.7</td>
<td>56.2</td>
<td>70.8</td>
<td>89.1</td>
<td>112</td>
<td>141</td>
<td>178</td>
<td>224</td>
<td>282</td>
<td>354</td>
<td>447</td>
<td>562</td>
<td>707</td>
<td>891</td>
<td>1122</td>
<td>1414</td>
<td>1778</td>
<td>2239</td>
</tr>
<tr>
<td>Upper Band Limit, Hz</td>
<td>56.2</td>
<td>70.8</td>
<td>89.1</td>
<td>112</td>
<td>141</td>
<td>178</td>
<td>224</td>
<td>282</td>
<td>354</td>
<td>447</td>
<td>562</td>
<td>707</td>
<td>891</td>
<td>1122</td>
<td>1414</td>
<td>1778</td>
<td>2239</td>
<td>2828</td>
</tr>
</tbody>
</table>

Source of Table 5: ANSI Standard S1.6

5.2.8 Computational Procedures. For each One-third Octave Band, the measured Sound Pressure Level for each tone shall be corrected for room response using Equation 7:

\[ L_{ptq} = L_{pia} - L_{pir} \]

Where:
- \( L_{pia} \) = Sound Pressure Level measured near the speaker from Section 5.2.3
- \( L_{ptq} \) = Measured one-third octave band Sound Pressure Level in a given band and for a given speaker location that has been corrected for speaker response
- \( L_{pir} \) = Sound Pressure Level measured in the reverberation room from Section 5.2.6

The sample standard deviation \( (S_f) \), dB, shall be computed using Equation 8:

\[ S_f = \sqrt{\frac{\sum_{f=1}^{N_f}(L_{ptq} - L_{pmq})^2}{N_f - 1}} \]

Where:
- \( L_{pmq} \) = Arithmetic mean of the corrected Sound Pressure Level for all test frequencies for a given One-third Octave Band
- \( N_f \) = Number of measurement frequencies in a given One-third Octave Band
- \( S_f \) = Standard deviation in a given One-third Octave Band

5.2.9 Discrete Frequency Qualification. The reverberation room shall be deemed qualified if the computed standard deviations do not exceed the values listed in Section 4.4 for the full range of One-third Octave Bands. The reverberation room shall be qualified over the full range of one-third octave band frequencies as specified by the referencing AHRI standard, and the qualified frequency range must be stated in documentation.

5.2.10 Additional. Once the reverberation room is qualified; the microphone traverse or positions, sound diffuser (if used), windscreen, instrumentation and analyzer observation times shall be identical when doing unit testing in order to claim compliance with this standard. Sound diffuser design is recommended to be per ANSI S12.51/ISO 3741 Annex B.

Section 6. Sound Power Testing Requirements and Calculations

Sound Pressure Levels of the RSS, background sound, and the UUT shall be measured using the same microphone traverse or positions, sound diffuser (if used), windscreen, instrumentation, and analyzer observation times as were used for broadband and discrete frequency qualifications.

6.1 Volume of Unit Under Test (UUT). The volume of the UUT shall be no more than 5% of the room volume.

6.2 Location of Unit Under Test (UUT). Measurements shall be carried out with the UUT at a location within the area qualified per Sections 4 and 5.

6.3 Reference Sound Source Considerations. For the purposes of this standard, the RSS shall have the characteristics required by ANSI/AHRI Standard 250 and be calibrated in accordance with ANSI/AHRI Standard 250. The RSS shall be placed at a broadband qualified location 1.5 meters from the UUT. The RSS shall be operated at no more than ±2 rpm from its
calibrated rpm. To prevent the need for background correction and the corresponding added uncertainty, it is recommended that the RSS Sound Pressure Levels be 15 dB above background levels over the frequency range of interest. However, the RSS shall be at least 6 dB above background for One-third Octave Bands from 50 to 315 Hz and from 6,300 to 10,000 Hz and at least 10 dB for One-third Octave Bands with frequencies between 400 and 5,000 Hz.

6.4  **Measurements.** Measurements of the UUT, RSS, and background Sound Pressure Levels shall be made in terms of One-third Octave Bands to the nearest 0.1 dB.

6.5  **One-third Octave Band Sound Power Level Calculations.** The one-third octave band Sound Pressure Level, as measured in the room for the UUT, and the one-third octave band Sound Pressure Level, as measured in the room for the RSS, shall be corrected for background following Equations 9 and 10. The background limits and corrections are as indicated in Table 6. If the difference between the background and measured level is less than the limits shown in Table 6, the values may be reported but shall be identified as being influenced by the background and potentially having a higher uncertainty than described in Section 1.1. Note that when the differences between the background and UUT Sound Pressure Levels are less than those shown in Table 6, the resulting Sound Power Level will be conservative and the designation in any published results shall make it clear that it is an upper limit. One-third octave band Sound Power Levels shall be calculated per Equation 11 and rounded to the nearest 0.1 dB. Appendix C shows a sample calculation. When determining octave band levels (unless directed otherwise in the product specific standard), the octave band level shall be identified as being influenced by background sound if any of the background limited One-third Octave Band(s) contribute 0.5 dB or more to the octave band level.

\[
L''_p = L_p - K_i
\]

\[
L''_{pr} = L_{pr} - K_{ir}
\]

\[
L_w = L_{wr} + (L''_p - L''_{pr})
\]

Where:

\[K_i = \text{UUT background correction level, (dB re 20 } \mu \text{Pa), per Equation 14}\]

\[K_{ir} = \text{RSS background correction level, (dB re 20 } \mu \text{Pa), per Equation 15}\]

\[L_p = \text{Sound pressure level at a given microphone position}\]

\[L_{wr} = \text{One-third octave band Sound Power Level of the RSS, (dB re 1 pW)}\]

\[L''_p = \text{Background corrected one-third octave band time-averaged Sound Pressure Level with the UUT in operation, (dB re 20 } \mu \text{Pa)}\]

\[L''_{pr} = \text{Background corrected one-third octave band time-averaged Sound Pressure Level with the RSS in operation, (dB re 20 } \mu \text{Pa)}\]

6.5.1  **Corrections for Background Noise.** The background noise correction, \(K_i\) or \(K_{ir}\), averaged over all microphone positions or for the microphone traverse in each One-third Octave Band shall be calculated using the following equations:

\[
K_i = -10 \cdot \log \left(1 - 10^{-0.1 \Delta L_i}\right)
\]

\[
K_{ir} = -10 \cdot \log \left(1 - 10^{-0.1 \Delta L_{ir}}\right)
\]

Where:
\[ \Delta L = \bar{L}_{p(ST)}' - \bar{L}_{p(B)} \]
\[ \Delta L_r = \bar{L}_{pr(ST)}' - \bar{L}_{p(B)} \]

- \( K_f \) = UUT background correction level, (dB re 20 \( \mu Pa \))
- \( K_{fr} \) = RSS background correction level, (dB re 20 \( \mu Pa \))

\( \bar{L}_{p(ST)}' \) = Measured (uncorrected) one-third octave band time-averaged Sound Pressure Level averaged across all microphone positions or for the microphone traverse, with the UUT in operation, (dB re 20 \( \mu Pa \))

\( \bar{L}_{pr(ST)}' \) = Measured (uncorrected) one-third octave band time-averaged Sound Pressure Level averaged across all microphone positions or for the microphone traverse, with the RSS in operation, (dB re 20 \( \mu Pa \))

\( \bar{L}_{p(B)} \) = One-third octave band time-averaged Sound Pressure Level of the background noise averaged across all microphone positions or for the microphone traverse, (dB re 20 \( \mu Pa \))

If \( \Delta L \geq 15 \) dB, \( K_f \) is assumed equal to zero and if \( \Delta L \geq 15 \) dB, \( K_{fr} \) is assumed equal to zero, and no correction for background noise shall be applied.

If 6 dB \( \leq \Delta L \) or \( \Delta L < 15 \) dB, for One-Third Octave Bands of center frequency 315 Hz and below, and 6,300 Hz and above, \( K_f \) and \( K_{fr} \) shall be calculated according to Equations 14 and/or 15. If \( \Delta L < 6 \) dB then \( K_f \) shall be set at 1.26 dB and it shall be clearly stated in the text of the report as well as in graphs and tables of results that the data in such bands represent upper bounds to the Sound Power Level of the UUT. Table 6 lists the maximum background correction by One-Third Octave Band.

If 10 dB \( \leq \Delta L \) or \( \Delta L < 15 \) dB, for One-Third Octave Bands of center frequency 400 Hz to 5,000 Hz, \( K_f \) and \( K_{fr} \) shall be calculated according to Equations 14 and/or 15. If \( \Delta L < 10 \) dB then \( K_f \) shall be set at 0.46 dB and it shall be clearly stated in the text of the report as well as in graphs and tables of results that the data in such bands represent upper bounds to the Sound Power Level of the UUT. Table 6 lists the maximum background correction by One-Third Octave Band.

<table>
<thead>
<tr>
<th>Range of One-third Octave Band Center Frequencies, Hz</th>
<th>Difference Between Background and UUT or RSS Sound Pressure Levels, dB</th>
<th>Maximum Value of ( K_f ) or ( K_{fr} ), dB</th>
</tr>
</thead>
<tbody>
<tr>
<td>50 – 315</td>
<td>6</td>
<td>1.26</td>
</tr>
<tr>
<td>400 – 5,000</td>
<td>10</td>
<td>0.46</td>
</tr>
<tr>
<td>6,300 – 10,000</td>
<td>6</td>
<td>1.26</td>
</tr>
</tbody>
</table>

### 6.6 Octave Band Sound Power Level Calculations

Unless directed otherwise in the product specific AHRI standards, octave band sound power level calculations shall be made per Equation 16.

\[ L_{wl} = 10 \cdot \log \sum_{j=3i-2}^{3i} 10^{0.1(L_{wl})} \]

Where:

- \( j \) = An integer number lying within the range \( (3i – 2) \) and \( 3i \), and which identifies the three One-third Octave Bands (see Table 7) which make up the \( i^{th} \) Octave Band.
- \( L_{wl} \) = Sound Power Level in the \( i^{th} \) Octave Band
- \( L_{wj} \) = Sound Power Level in the \( j^{th} \) One-third Octave Band

### 6.6.1 Rounding

Data rounding shall be per directions in individual AHRI standards.
6.7  *A-weighted Sound Power Level.* Unless directed otherwise in the product specific AHRI standards, the A-weighted Sound Power Level shall be calculated per Equation 17.

\[ L_{WA} = 10 \cdot \log \sum_{j=j_{\text{min}}}^{j_{\text{max}}} 10^{0.1(L_{wj}+C_j)} \]

Where:

\[ C_j \text{ and } j = \text{Values given in Table 7} \]

\[ j_{\text{min}} \text{ and } j_{\text{max}} = \text{Values given in Table 7 of j corresponding, respectively, to the lowest } (j_{\text{min}}) \text{ and highest } (j_{\text{max}}) \text{ One-third Octave Bands of measurement} \]

\[ L_{WA} = \text{A-weighted Sound Power Level} \]

\[ L_{wj} = \text{Sound Power Level in the j}\text{th One-third Octave Band} \]

<table>
<thead>
<tr>
<th>Band Number, j</th>
<th>One-third Octave Band Center Frequency, Hz</th>
<th>A-Weighting factor, Cj</th>
<th>Band Number, j</th>
<th>One-third Octave Band Center Frequency, Hz</th>
<th>A-Weighting factor, Cj</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>50</td>
<td>-30.2</td>
<td>13</td>
<td>800</td>
<td>-0.8</td>
</tr>
<tr>
<td>2</td>
<td>63</td>
<td>-26.2</td>
<td>14</td>
<td>1000</td>
<td>0.0</td>
</tr>
<tr>
<td>3</td>
<td>80</td>
<td>-22.5</td>
<td>15</td>
<td>1250</td>
<td>0.6</td>
</tr>
<tr>
<td>4</td>
<td>100</td>
<td>-19.1</td>
<td>16</td>
<td>1600</td>
<td>1.0</td>
</tr>
<tr>
<td>5</td>
<td>125</td>
<td>-16.1</td>
<td>17</td>
<td>2000</td>
<td>1.2</td>
</tr>
<tr>
<td>6</td>
<td>160</td>
<td>-13.4</td>
<td>18</td>
<td>2500</td>
<td>1.3</td>
</tr>
<tr>
<td>7</td>
<td>200</td>
<td>-10.9</td>
<td>19</td>
<td>3150</td>
<td>1.2</td>
</tr>
<tr>
<td>8</td>
<td>250</td>
<td>-8.6</td>
<td>20</td>
<td>4000</td>
<td>1.0</td>
</tr>
<tr>
<td>9</td>
<td>315</td>
<td>-6.6</td>
<td>21</td>
<td>5000</td>
<td>0.5</td>
</tr>
<tr>
<td>10</td>
<td>400</td>
<td>-4.8</td>
<td>22</td>
<td>6300</td>
<td>-0.1</td>
</tr>
<tr>
<td>11</td>
<td>500</td>
<td>-3.2</td>
<td>23</td>
<td>8000</td>
<td>-1.1</td>
</tr>
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<td>12</td>
<td>630</td>
<td>-1.9</td>
<td>24</td>
<td>10000</td>
<td>-2.5</td>
</tr>
</tbody>
</table>

6.7.1  *Rounding.* Data rounding shall be per directions in individual AHRI standards.

6.8  *Linear Sound Power Level.* Unless directed otherwise in the product specific AHRI standards, the linear Sound Power Level shall be calculated per Equation 18.

\[ L_{WL} = 10 \cdot \log \sum_{j=j_{\text{min}}}^{j_{\text{max}}} 10^{0.1(L_{wj})} \]

Where:

\[ j = \text{Given in Table 7} \]

\[ j_{\text{min}} \text{ and } j_{\text{max}} = \text{Values given in Table 7 of j corresponding, respectively, to the lowest } (j_{\text{min}}) \text{ and highest } (j_{\text{max}}) \text{ One-third Octave Bands of measurement} \]

\[ L_{wj} = \text{Sound Power Level in the j}\text{th One-third Octave Band} \]

\[ L_{WL} = \text{Linear Sound Power Level} \]
6.8.1 *Rounding.* Data rounding shall be per directions in individual AHRI standards.

**Section 7. Information to Be Recorded**

7.1 *General.* The information listed in Sections 7.2 to 7.5, when applicable, shall be compiled and recorded for all measurements made in accordance with this International Standard.

Record the product specific standard (if any) applied to the test source.

7.2 *Noise Source Under Test.* Unless superseded by the product specific standard, the following information shall be recorded:

7.2.1 A description of the noise source under test (including the manufacturer, type, technical data, dimensions, serial number and year of manufacture)

7.2.2 The mode(s) of operation used for the test(s)

7.2.3 The relevant measurement time interval(s)

7.2.4 The installation and mounting conditions

7.2.5 The location(s) of noise source in the test room

7.2.6 The location(s) of the Reference Sound Source in the test room

7.3 *Test Environment.* The following information shall be recorded:

7.3.1 A description of the test room including:

7.3.1.1 Room dimensions, m

7.3.1.2 Surface treatment of the walls, ceiling, and floor

7.3.1.3 Sketch showing the location of the UUT

7.3.1.4 Room contents

7.3.2 The air temperature in degrees Celsius, °C, the relative humidity, %, and the static pressure, kPA, in the room at the time of test

7.4 *Instrumentation.* The following information shall be recorded:

7.4.1 The equipment used for the measurements, including the name, type, serial number, and manufacturer

7.4.2 The date and place of calibration; the methods used to calibrate the sound calibrator, and calibration verification of the instrumentation system (to calibrate the RSS).

7.5 *Acoustical Data.* The following information shall be recorded:

7.5.1 The microphone positions or traverse used for the measurements (with a sketch if necessary) and a description of how the microphone is traversed for each mode of operation under which the noise source was tested.

7.5.2 All sound pressure levels measured in the reverberation test room from the noise source under test; and for the background sound pressure levels, the corrected sound pressure levels

7.5.3 The sound power levels, dB, in one-third-octave bands
7.5.4 The date and time when the measurements were performed

Section 8. Test Report

8.1 Test Report. Unless otherwise specified by an AHRI product rating standard, the test report shall contain a statement that the results were obtained in accordance with ANSI/AHRI Standard 220-2014, the date and time of the test, the name and model number of the UUT, operating conditions during the test, and the Sound Power Levels.

Section 9. Conformance Conditions

9.1 Conformance. While conformance with this standard is voluntary, conformance shall not be claimed or implied for products or equipment within the standard’s Purpose (Section 1) and Scope (Section 2) unless such product claims meet all of the requirements of the standard and all of the testing and rating requirements are measured and reported in complete compliance with the standard. Any product that has not met all the requirements of the standard cannot reference, state, or acknowledge the standard in any written, oral, or electronic communication.
APPENDIX A. REFERENCES – NORMATIVE

A1  Listed here are all the standards, handbooks, and other publications essential to the formation and implementation of the standard. All references in this appendix are considered part of this standard.


A1.3  ANSI Standard S1.11-2004 (R2009), Specification for Octave-Band and Fractional Octave-Band Analog and Digital Filters, American National Standards Institute, 25 West 43rd Street, 4th Fl., New York, NY 10036, U.S.A.


APPENDIX B. REFERENCES – INFORMATIVE

B1  Listed here are standards, handbooks, and other publications which may provide useful information and background but are not considered essential. References in this appendix are not considered part of the standard.

None.
### APPENDIX C. SAMPLE CALCULATION RESULTS—INFORMATIVE

#### Table C1. One-third Octaves

<table>
<thead>
<tr>
<th>Center Frequency, Hz</th>
<th>Calibrated RSS, $L_{wT}$, dB</th>
<th>Test RSS $L_{pr}$, dB</th>
<th>Test Background $L_{p(B)}$, dB</th>
<th>Test UUT $L_p$, dB</th>
<th>UUT Background Correction $K_1$, dB</th>
<th>UUT Corrected $L''_p$, dB</th>
<th>UUT $L_w$, dB</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>73.6</td>
<td>59.5</td>
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<td>47.14</td>
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<td>45.74</td>
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<td>-1.26</td>
<td>13.74</td>
<td>38.6</td>
</tr>
</tbody>
</table>

Note: 1. To be rounded as directed in the product specific standard.

#### Table C2. UUT $L_w$

<table>
<thead>
<tr>
<th>Octave Band Center Frequency, Hz</th>
<th>UUT $L_w$, dB</th>
</tr>
</thead>
<tbody>
<tr>
<td>63</td>
<td>77.0</td>
</tr>
<tr>
<td>125</td>
<td>70.0</td>
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<tr>
<td>250</td>
<td>64.0</td>
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</tr>
<tr>
<td>4000</td>
<td>54.0</td>
</tr>
<tr>
<td>8000</td>
<td>46.0</td>
</tr>
</tbody>
</table>

A-weighted Sound Power ($L_{wA}$) 63.0

Linear Sound Power ($L_{wL}$) 78.0

Note: 1. To be rounded as directed in the product specific standard.