ANSI/AHRI Standard 220

2014 Standard for

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

Approved American National Standard
ANSI

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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 1. Maximum Standard Deviations of Sound Power Level Reproducibility Determined in Accordance with this Standard

One-third Octave Band Center Frequency, Hz	One-third Octave Band Maximum Standard Deviation of Reproducibility, σ_{R0}, dB
50 - 80	4.0
100 - 160	3.0
200 - 315	2.0
400 - 5000	1.5
6000 - 10000	3.0

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 2. Broadband Standard Deviation Limits

Octave Band Center Frequency, Hz	One-third Octave Band Center Frequency, Hz	Standard Deviation S_s, dB
63	50, 63, 80	2.0
125	100, 125, 160	1.5
250	200, 250, 315	1.0
500	400, 500, 630	1.0
1000	800, 1000, 1250	0.5
2000	1600, 2000, 2500	0.5
4000	3150, 4000, 5000	1.0
8000	6300, 8000, 10000	1.0

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 3. Discrete Frequency Standard Deviation Limits

Octave Band Center Frequency, Hz	One-third Octave Band Center Frequency, Hz	Standard Deviation S_s, dB
63	50, 63, 80	4.0
125	100, 125, 160	3.0
250	200, 250, 315	2.0
500	400, 500, 630	1.5
1000	800, 1000, 1250	1.0
2000	1600, 2000, 2500	1.0

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.

$$d_{min} = D_2 \cdot 10^{\left({}^{(L_{wr}-L_{pr})}/_{20}\right)} \quad (1)$$

Where:

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

The d_{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_{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 3λ for One-third Octave Bands of 100 Hz and above and 3λ/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.

$$\lambda = c/f \quad (2)$$

$$c = 20.05 \cdot \sqrt{(273 + \theta)} \quad (3)$$

Where:

c = The speed of sound of the air, m/s

f = The center frequency of the lowest band of interest, Hz

θ = The temperature of the air in the reverberation test room at the time of test, ºC

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 λ/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 ¼ and ½ 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_{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.

$$S_s = \sqrt{\sum_{i=1}^{N_s} (L_{pi} - L_{pm})^2 / (N_s - 1)} \qquad 4$$

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_{pia}. 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

One-Third Octave Band Center Frequencies																	
50	**63**	**80**	**100**	**125**	**160**	**200**	**250**	**315**	**400**	**500**	**630**	**800**	**1000**	**1250**	**1600**	**2000**	**2500**
-----	-----	-----	-----	-----	147	-----	-----	-----	361	-----	-----	-----	-----	-----	1470	-----	-----
-----	-----	-----	-----	113	148	-----	226	-----	364	-----	-----	-----	-----	1130	1480	-----	2260
-----	56.4	71.2	-----	114	149	-----	228	-----	367	-----	564	712	-----	1140	1490	-----	2280
45.0	57.0	72.0	90	115	150	180	230	285	370	450	570	720	900	1150	1500	1800	2300
45.5	57.6	72.8	91	116	151	182	232	288	373	455	576	728	910	1160	1510	1820	2320
46.0	58.2	73.6	92	117	152	184	234	291	376	460	582	736	920	1170	1520	1840	2340
46.5	58.8	74.4	93	118	153	186	236	294	379	465	588	744	930	1180	1530	1860	2360
47.0	59.4	75.2	94	119	154	188	238	297	382	470	594	752	940	1190	1540	1880	2380
47.5	60.0	76.0	95	120	155	190	240	300	385	475	600	760	950	1200	1550	1900	2400
48.0	60.6	76.8	96	121	156	192	242	303	388	480	606	768	960	1210	1560	1920	2420
48.5	61.2	77.6	97	122	157	194	244	306	391	485	612	776	970	1220	1570	1940	2440
49.0	61.8	78.4	98	123	158	196	246	309	394	490	618	784	980	1230	1580	1960	2460
49.5	62.4	79.2	99	124	159	198	248	312	397	495	624	792	990	1240	1590	1980	2480
50.0	**63.0**	**80.0**	**100**	**125**	**160**	**200**	**250**	**315**	**400**	**500**	**630**	**800**	**1000**	**1250**	**1600**	**2000**	**2500**
50.5	63.6	80.8	101	126	161	202	252	318	403	505	636	808	1010	1260	1610	2020	2520
51.0	64.2	81.6	102	127	162	204	254	321	406	510	642	816	1020	1270	1620	2040	2540
51.5	64.8	82.4	103	128	163	206	256	324	409	515	648	824	1030	1280	1630	2060	2560
52.0	65.4	83.2	104	129	164	208	258	327	412	520	654	832	1040	1290	1640	2080	2580
52.5	66.0	84.0	105	130	165	210	260	330	415	525	660	840	1050	1300	1650	2100	2600
53.0	66.6	84.8	106	131	166	212	262	333	418	530	666	848	1060	1310	1660	2120	2620
53.5	67.2	85.6	107	132	167	214	264	336	421	535	672	856	1070	1320	1670	2140	2640
54.0	67.8	86.4	108	133	168	216	266	339	424	540	678	864	1080	1330	1680	2160	2660
54.5	68.4	87.2	109	134	169	218	268	342	427	545	684	872	1090	1340	1690	2180	2680
55.0	69.0	88.0	110	135	170	220	270	345	430	550	690	880	1100	1350	1700	2200	2700
55.5	69.6	88.8	111	136	171	222	272	348	433	555	696	888	1110	1360	1710	2220	2720
56.0	70.2	-----	-----	137	172	-----	274	-----	436	560	702	-----	-----	1370	1720	-----	2740
-----	-----	-----	-----	138	173	-----	276	-----	439	-----	-----	-----	-----	1380	1730	-----	2760

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, $L_{pir.}$

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.

$$\text{Frequency Limit} = 6000 / L \quad (5)$$

$$\text{Frequency Limit} = 5000 / V^{1/3} \quad (6)$$

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

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:

$$L_{piq} = L_{pia} - L_{pir} \quad (7)$$

Where:

L_{pia} = Sound Pressure Level measured near the speaker from Section 5.2.3
L_{piq} = 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:

$$S_f = \sqrt{\sum_{f=1}^{N_f} \left(L_{piq} - L_{pmq}\right)^2 / \left(N_f - 1\right)} \quad (8)$$

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.

$$L''_p = L_p - K_1 \quad (9)$$

$$L''_{pr} = L_{pr} - K_{1r} \quad (10)$$

$$L_w = L_{wr} + (L''_p - L''_{pr}) \quad (11)$$

Where:

K_1 = UUT background correction level, (dB re 20 μPa), per Equation 14

K_{1r} = RSS background correction level, (dB re 20 μPa), per Equation 15

L_p = Sound pressure level at a given microphone position

L_w = Sound Power Level, dB

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

L''_p = Background corrected one-third octave band time-averaged Sound Pressure Level with the UUT in operation, (dB re 20 μPa)

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

6.5.1 *Corrections for Background Noise.* The background noise correction, K_1 or K_{1r}, averaged over all microphone positions or for the microphone traverse in each One-third Octave Band shall be calculated using the following equations:

$$K_1 = -10 \cdot \log\left(1 - 10^{-0.1 \cdot \Delta L}\right) \quad (12)$$

$$K_{1r} = -10 \cdot \log\left(1 - 10^{-0.1 \Delta L_f}\right) \quad (13)$$

Where:

$$\Delta L = \overline{L'_{p(ST)}} - \overline{L_{p(B)}}$$

$$\Delta L_r = \overline{L'_{pr(ST)}} - \overline{L_{p(B)}}$$

K_1 = UUT background correction level, (dB re 20 μPa)

K_{1r} = RSS background correction level, (dB re 20 μPa)

$\overline{L'_{p(ST)}}$ = 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 μPa)

$\overline{L'_{pr(ST)}}$ = 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 μPa)

$\overline{L_{p(B)}}$ = 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 μPa)

If $\Delta L \geq 15$ dB, K_1 is assumed equal to zero and if $\Delta L_r \geq 15$ dB, K_{1r} is assumed equal to zero, and no correction for background noise shall be applied.

If 6 dB $\leq \Delta L$ or $\Delta L_r < 15$ dB, for One-Third Octave Bands of center frequency 315 Hz and below, and 6,300 Hz and above, K_1 and K_{1r} shall be calculated according to Equations 14 and/or 15. If ΔL is <6 dB then K_1 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 $\Delta L_r < 15$ dB, for One-Third Octave Bands of center frequency 400 Hz to 5,000 Hz, K_1 and K_{1r} shall be calculated according to Equations 14 and/or 15. If ΔL is <10 dB then K_1 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 6. Background Correction Limits by One-third Octave Band

Range of One-third Octave Band Center Frequencies, Hz	Difference Between Background and UUT or RSS Sound Pressure Levels, dB	Maximum Value of K_1 or K_{1r}, dB
50 – 315	6	1.26
400 – 5,000	10	0.46
6,300 – 10,000	6	1.26

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.

$$L_{wi} = 10 \cdot \log \sum_{j=3i-2}^{3i} 10^{0.1(L_{wj})} \qquad 414$$

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_{wi} = 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.

$$L_{wA} = 10 \cdot \log \sum_{j=j_{min}}^{j_{max}} 10^{0.1\left(L_{wj}+C_j\right)} \quad 515$$

Where:

C_j and j = Values given in Table 7

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

L_{wA} = A-weighted Sound Power Level

L_{wj} = Sound Power Level in the j^{th} One-third Octave Band

Table 7. One-third Octave Band Numbers and A-Weighting Factors

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

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.

$$L_{wL} = 10 \cdot \log \sum_{j=j_{min}}^{j_{max}} 10^{0.1(L_{wj})} \quad 616$$

Where:

j = Given in Table 7

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

L_{wj} = Sound Power Level in the j^{th} One-third Octave Band

L_{wL} = 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, ℃, 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.

A1.1 ANSI Standard S1.4-1983 (R2006) *American National Standard Specification for Sound Level Meters*. American National Standards Institute, 25 West 43rd Street, 4th Fl., New York, NY 10036, U.S.A.

A1.2 ANSI Standard S1.6-1984 (R2011) *American National Standard Preferred Frequencies, Frequency Levels, and Band Numbers for Acoustical Measurements*. American National Standards Institute, 25 West 43rd Street, 4th Fl., New York, NY 10036, U.S.A.

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.

A1.4 ANSI Standard S12.51-2002/ISO 3741:1999 (R2010), Acoustics — *Determination of sound power levels of noise sources using sound pressure — Precision method for reverberation rooms*, Nationally Adopted International Standard (NAIS Standard) American National Standards Institute, 25 West 43rd Street, 4th Fl., New York, NY 10036, U.S.A.

A1.5 ANSI/AHRI Standard 250 with Addendum 1-2013, *Performance and Calibration of Reference Sound Sources*, 2013, Air-Conditioning and Refrigeration Institute, 2111 Wilson Boulevard, Suite 500, Arlington, VA 22201, U.S.A.

A1.6 *ASHRAE Terminology*, https://www.ashrae.org/resources--publications/free-resources/ashrae-terminology, 2014, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., 1791 Tullie Circle, N.E., Atlanta, GA 30329, 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

Center Frequency, Hz	Calibrated RSS, L_{wr}, dB	Test RSS L_{pr}, dB	Test Background $L_{p(B)}$, dB	Test UUT Lp, dB	UUT Background Correction K_1, dB	UUT Corrected L"$_p$, dB	UUT L_w, dB[1]
50	73.6	59.5	43.4	48.4	-1.26	47.14	61.2
63	73.4	55.1	40.1	53.8	-0.19	53.61	71.9
80	73.5	53.9	38.0	55.5	-	55.50	75.1
100	72.9	55.9	38	52.0	-0.18	51.82	95.8
125	72.7	58.1	41.3	47.0	-1.26	45.74	60.3
160	72.7	57.0	35.6	47.4	-0.30	47.10	62.8
200	72.8	57.5	36.2	44.4	-0.71	43.69	59.0
250	73.1	58.2	33.9	46.0	-0.27	45.83	60.7
315	73.8	58.9	26.9	42.9	-	42.90	57.8
400	74.3	59.7	29.7	43.3	-0.19	43.11	57.7
500	74.4	60.4	29.3	39.6	-0.43	39.17	53.2
630	75.7	62.0	26.0	37.2	-0.34	36.86	50.6
800	77.0	63.5	23.9	35.7	-0.30	35.40	48.9
1000	77.6	64.3	20.5	35.1	-0.15	34.95	48.3
1250	76.5	63.5	17.8	35.1	-	35.10	48.1
1600	75.5	62.4	16.1	36.2	-	36.20	49.3
2000	74.2	60.9	16.0	36.2	-	36.20	49.5
2500	73.1	60.0	16.4	37.7	-	37.70	50.8
3150	72.6	59.4	16.1	38.2	-	38.20	51.4
4000	71.9	58.6	14.0	35.1	-	35.10	48.4
5000	72.0	57.3	14.7	31.6	-	31.60	46.3
6300	71.1	54.9	13.5	27.3	-0.18	27.12	43.3
8000	68.4	49.4	10.1	21.6	-0.32	21.28	40.3
10000	66.1	41.2	9.0	15.0	-1.26	13.74	38.6

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

Table C2. UUT L_w

Octave Band Center Frequency,Hz	UUT L_w, dB[1]
63	77.0
125	70.0
250	64.0
500	60.0
1000	53.0
2000	55.0
4000	54.0
8000	46.0
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.