ANSI/AHRI Standard 220-2022 (SI)

2022 Standard for

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

Approved by ANSI on 12 June 2023

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ICS Code: 17.140.01

Note:

This standard supersedes ANSI/AHRI Standard 220-2015.

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Foreword

This standard describes the methodology for determination of *sound power levels* of HVAC noise sources containing broad-band or discrete-frequency noise, or both, in reverberation rooms. It is based on ASA/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 verifies modal density with the use of one source location to obtain uncertainty of results as defined by this standard. The *reference sound source* (*RSS*) used for the *comparison method* relies on AHRI Standard 250 to accurately calibrate the *RSS* at all frequencies of interest. 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 ASA/ANSI S12.51/ISO 3741, that allows the user to test using either the *direct method* or the *comparison method* and allows the user to employ a space with characteristics described. The intent of ASA/ANSI S12.51/ISO 3741 is to have a room that provides a specific environment for testing, with the understanding that if the 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 should not be used for sources that are difficult to move.

Intent

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

Review and Amendment

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

2022 Edition

This edition of ANSI/AHRI Standard 220 *Reverberation Room Qualification and Testing Procedures for Determining Sound Power of HVAC Equipment* was prepared by the Testing and Analysis Standards Technical Committee. The standard was approved by the Sound and Vibration Standards Subcommittee on 8 September 2022. It was approved as an American National Standard (ANS) on 12 June 2023.

Origin and Development of AHRI Standard 220

The initial publication was ARI Standard 220-2007, *Reverberation Room Qualification and Testing Procedures for Determining Sound Power of HVAC Equipment*. Subsequent revisions were:

ANSI/ARI Standard 220-2012, *Reverberation Room Qualification and Testing Procedures for Determining Sound Power of HVAC Equipment*

ANSI/AHRI Standard 220-2015, *Reverberation Room Qualification and Testing Procedures for Determining Sound Power of HVAC Equipment*

Summary of Changes

ANSI/AHRI Standard 220-2022 (SI) contains the following update(s) to the previous edition:

- Harmonized equations and Section 6.5.1 of AHRI Standard 220 with Section 9.1.2 of ASA/ANSI S12.51-2012 / ISO 3741:2010 (R2020)
- Updated references to ASA/ANSI S12.51-2012 / ISO 3741:2010 (R2020)
- Clarify Section 5.2.2, Section 5.2.3, and Section 5.2.4
- Updated Section 5.1 for accuracy of the minimum requirements
- Updated Section 4.6 to allow for arbitrarily traversing microphones

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Testing and Analysis Standards Technical Committee Scope:

The Testing and Analysis STC is responsible for development and maintenance of standards and guidelines related to procedures for testing, analysis, calibration of instrumentation, and qualification of test facilities for sound and vibration.

This STC will also be responsible for topics not in scope of the other Sound & Vibration STCs.

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Sound and Vibration Standards Subcommittee Scope:

The scope of the Sound & Vibration Standards Subcommittee is standards and guidelines related to sound and vibration for any AHRI product sector. (The definition of and list of products associated with each sector are found on the AHRI website.)

These lists represent the membership at the time the Standards Technical Committee and Standards Subcommittee were balloted on the final text of this edition. Since that time, changes in the membership may have occurred. Membership on these committees shall not in and of itself constitute an endorsement by the committee members or their employers of any document developed by the committee on which the member serves.

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REVERBERATION ROOM QUALIFICATION AND TESTING PROCEDURES FOR DETERMINING SOUND POWER OF HVAC EQUIPMENT

Section 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* or *discrete frequency sounds/tones*, or both 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. The *reference sound source (RSS)* used for the *comparison method* relies on 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. Measurements made in conformity with this standard will 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 ASA/ANSI S12.51/ISO 3741 but provides additional guidance and requirements to accommodate larger sources, typical of HVAC equipment.

Table 1 Maximum Standard Deviations of Sound Power Level Reproducibility

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 - 10 000	3.0

Section 2. 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 unless otherwise defined in this section.

3.1 Expressions of Provision

Terms that provide clear distinctions between requirements, recommendations, permissions, options, and capabilities.

3.1.1 "Can" or "cannot"

Express an option or capability.

3.1.2 "May"

Signifies a permission expressed by the document.

3.1.3 "Must"

Indication of unavoidable situations and does not mean that an external constraint referred to is a requirement of the document.

3.1.4 "Shall" or "shall not"

Indication of mandatory requirements to strictly conform to the standard and where deviation is not permitted.

3.1.5 "Should" or "should not"

Indication of recommendations rather than requirements. In the negative form, a recommendation is the expression of potential choices or courses of action that is not preferred but not prohibited.

3.2 Standard Specific Definitions

3.2.1 Broadband Sound

Sound that is random in nature with frequency components distributed over a broad frequency band. Pure tones or transient events will not be distinguishable in this type of sound spectrum.

3.2.2 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.

3.2.3 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.

3.2.4 Discrete Frequency Sounds/Tones

Consist of one or more sound waves that are a sinusoidal function of time.

3.2.5 Discrete Frequency Source

A noise source that produces *discrete frequency sounds/tones*.

3.2.6 Low Frequency

Data in the 63 Hz *octave band* (50, 63, and 80 Hz *one-third octave bands*).

3.2.7 Octave Band

A band of sound covering a range of frequencies such that the highest is twice the lowest, as defined in ASA S1.11.

3.2.8 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, as defined in ASA S1.11.

3.2.9 Reference Sound Source (RSS)

A portable, aerodynamic sound source that produces a known stable *broadband sound* power output.

3.2.10 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.

3.2.10.1 A-weighted Sound Power Level (L_{wA})

The logarithmic summation of A-weighted, *one-third octave band sound power levels*.

3.2.11 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 µPa, expressed in decibels, dB.

3.2.12 Unit Under Test (UUT)

HVAC equipment or duct termination whose *sound power level* is 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 for broadband room qualification and discrete frequency qualification, as described in Section 4.3 and Section 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. Room volumes of at least 500 cubic meters have been found to be necessary to meet the qualification criteria in this standard over the full frequency range without addition of diffusing and sound absorbing elements to the room and conducting multiple qualification trials. Additional guidance on room design that meets these requirements can be found in ASA/ANSI S12.51/ISO 3741.

4.2 Instrumentation Requirements

Instrumentation shall meet or exceed the requirements of Class 1 as specified in ASA 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, 10 000	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 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

The microphone position or point on a traverse shall not be less than 1.5 m from any of the reverberation room's surfaces. The microphone shall not be less than 0.5 m to any surface on a sound diffuser. The minimum distance between the microphone and each measurement location shall be determined using Equation 1.

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

Where:

d_{min} = Minimum distance between the microphone and source, m

D_2 = 0.4 for *one-third octave bands* from 50 Hz to 80 Hz and from 6300 Hz to 10 000 Hz

= 0.8 for *one-third octave bands* from 100 Hz to 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 the room that shall 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* where λ is the center frequency wavelength defined by Equation 2 and Equation 3. The same microphone traverse shall be used for both room qualification and sound power determination.

$$\lambda = c/\mathrm{f} \quad \textbf{2}$$

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

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, °C

4.6.1 Path of Microphone Travel

The path can be a line, semicircle, circle, or other geometric shape.

4.6.2 Microphone Traverse Speed

The speed of the traversing microphone shall be constant, with exception to path direction changes in the case of a line or semicircle path shapes and shall not exceed one meter per second. There shall be a whole number of microphone traverses completed during the analyzer's measurement time interval, partial traverses are not allowed.

4.6.3 Microphone Traverse Location

The microphone traverse shall be within the reverberant field.

Note: The microphone traverse should 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, where λ is defined by Equation 2 and Equation 3. 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.

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 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 Requirements

For the purposes of this standard, the *RSS* shall have the characteristics required by AHRI Standard 250 and be calibrated in accordance with AHRI Standard 250. A minimum of eight sound reference locations shall be used. 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 the room or portion thereof shall be qualified. The selected locations shall not be less than 1.5 m to any wall nor less than d_{min} to the microphone 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 include the region within and surrounding the footprint of the *unit under test*. The *RSS* shall be operated per the requirements of AHRI standard 250.

Note: To prevent the need for background correction and the corresponding added uncertainty, the *RSS sound pressure levels* should 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 thirty 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 4.

$$S_s = \sqrt{\sum_{i=1}^{N_s} \frac{\left(L_{pi} - L_{pm}\right)^2}{(N_s - 1)}} \quad \textbf{4}$$

Where:

L_{pi} = Measured *one-third octave band sound pressure level* in a given band and for the ith *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 eight 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 are 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), windscreen, instrumentation, and analyzer measurement time interval shall be identical to those used when performing unit testing in order to claim compliance with this standard.

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 the operational equipment shall meet the requirements of ANSI S12.51/ISO 3741 Annex D.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 can be required, but the diameter shall not be greater than 400 mm.

5.2.3 Speaker Qualification and Normalization

This procedure describes how to qualify the speaker and normalize the system. Locate the loudspeaker on a hard, reflecting floor of a hemi-anechoic facility, or on a reflecting surface located in a quiet and open outdoor space with the speaker cone facing away from the floor. Place a microphone, with the diaphragm oriented horizontally, 10 mm to 20 mm above the rim of the loudspeaker cone. *Sound pressure levels* shall be recorded at the test frequencies in Table 4. The same microphone and associated equipment (excluding traverse) used in Section 5.1 shall be used to qualify the speaker. *Sound pressure levels* are to be measured to the nearest 0.1 dB. These *sound pressure levels* shall be designated L_{pia}. The loudspeaker is allowable if the difference between levels of adjacent tones within a given *one-third octave band* is 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.

Note**:** In order for *sound pressure level* measurements to be valid, air velocity at the microphone(s) cannot exceed 400 ft/min (2.0 m/s) at any point during the test duration. A wind screen or nose cone approved by the microphone manufacturer shall be used for all measurements subject to airflow.

Note: If fixed microphones are to be used, the sound level should be measured for each microphone and associated cable or windscreen, or both.

5.2.4 Discrete Frequency Source Speaker Location(s)

The speaker(s) shall be located at the broadband qualified location(s) in Section 5.1 and within the boundary created by these 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, *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 0.1 Hz 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 Equation 5 and Equation 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* 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.

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

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

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

The values in Table 5 are calculated in accordance with ASA 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.

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

Where:

L_{pia} = *Sound pressure level* measured at 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.

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

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 shall be stated in documentation.

5.2.10 Additional

Once the reverberation room is qualified; the microphone traverse or fixed microphone positions, sound diffuser (if used), windscreen, instrumentation, and analyzer measurement time interval shall be identical to those used when performing unit testing in order to claim compliance with this standard.

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 Section 4 and Section 5.

6.3 Reference Sound Source Requirements

For the purposes of this standard, the *RSS* shall have the characteristics required by AHRI Standard 250 and be calibrated in accordance with AHRI Standard 250. The *RSS* shall be placed within the broadband-qualified region and 1.5 meters from the *UUT*. The *RSS* shall not be operated at more than ± 2 rpm from the calibrated rpm. The *RSS* shall be at least 6 dB above background for *one-third octave bands* from 50 to 315 Hz and from 6300 to 10 000 Hz and at least 10 dB for *one-third octave bands* with frequencies between 400 and 5000 Hz.

Note: To prevent the need for background correction and the corresponding added uncertainty, the *RSS sound pressure levels* should be 15 dB above background levels over the frequency range of interest.

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 Equation 9 and Equation 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 can be reported but shall be identified as being influenced by the background and potentially having a higher uncertainty than described in Section 1. Sample calculations can be found in Table 8 and Table 9 in Appendix C. 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.

$$L''_p = L_p - K_1 \quad \textbf{9}$$

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

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

Where:

K_1 = *UUT* background correction level, (dB re 20 μPa), per Equation 12

K_{1r} = *RSS* background correction level, (dB re 20 μPa), per Equation 13

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 Equation 12 and Equation 13.

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

$$K_{lr} = -10 \cdot \log(1 - 10^{-0.1 \cdot \Delta L_r}) \quad \textbf{13}$$

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 correction for background noise shall not be applied.

If 6 dB ≤ ΔL or ΔL_r < 15 dB, for *one-third octave bands* of center frequency 315 Hz and below, and 6300 Hz and above, K_1 and K_{1r} shall be calculated according to Equation 14 or Equation 15, or both. If ΔL is <6 dB, then K_1 shall be set at 1.26 dB and 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 ≤ ΔL or ΔL_r < 15 dB, for *one-third octave bands* of center frequency 400 Hz to 5000 Hz, K_1 and K_{1r} shall be calculated according to Equation 14 or Equation 15, or both. If ΔL is <10 dB then K_1 shall be set at 0.46 dB and 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 Background *Correction Limits by* One-third Octave Band 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 – 5000	10	0.46
6300 – 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 14.

$$L_{wi} = 10 \cdot \log \sum_{j=3i-2}^{3i} 10^{0.1(L_{wj})} \quad \textbf{14}$$

Where:

j = An integer number lying within the range (3i – 2) and 3i, identifying the three *one-third octave bands* (see Table 7) that 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 15.

$$L_{wA} = 10 \cdot \log \sum_{j=j_{min}}^{j_{max}} 10^{0.1\left(L_{wj}+C_j\right)} \quad \textbf{15}$$

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	10 000	-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 16.

$$L_{wL} = 10 \cdot \log \sum_{j=j_{min}}^{j_{max}} 10^{0.1(L_{wj})} \qquad \textbf{16}$$

Where:

J = Given in Table 7 One-third Octave Band Numbers and A-Weighting Factors

j_{min} and j_{max} = Values given in Table 7 One-third Octave Band Numbers and A-Weighting Factors 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 Section 7.2, Section 7.3, Section 7.4, and Section 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:

- A description of the noise source under test (including the manufacturer, type, technical data, dimensions,
- serial number and year of manufacture)
- The mode(s) of operation used for the test(s)
- The relevant measurement time interval(s)
- The installation and mounting conditions
- The location(s) of noise source in the test room
- 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 Test Room Description

A description of the test room including:

- Room dimensions, m
- Surface treatment of the walls, ceiling, and floor
- Sketch showing the location of the *UUT*
- Room contents

7.3.2 Room Conditions

The following room conditions at the time of test:

- Air temperature in degrees Celsius, °C
- Relative humidity, %
- Static pressure, kPA

7.4 Instrumentation

The following information shall be recorded:

- Equipment used for the measurements, including the name, type, serial number, and manufacturer
- 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:

- 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 during test.
- All *sound pressure levels* measured in the reverberation test room from the noise source under test
- Corrected *sound pressure levels* for the background *sound pressure levels*
- *Sound power levels*, dB, in one-third-octave bands
- Date and time when the measurements were performed

Section 8. 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 AHRI Standard 220-2022, 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

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

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.

A.1. AHRI Standard 250-2022 (SI), *Performance and Calibration of Reference Sound Sources*, 2022, Air-Conditioning and Refrigeration Institute, 2311 Wilson Boulevard, Suite 400, Arlington, VA 22201, USA.

A.2. ASA/ANSI S1.4-2014/Part 1 / IEC 61672-1:2013 (R2019), *AMERICAN NATIONAL STANDARD Electroacoustics – Sound Level Meters – Part 1: Specifications (a nationally adopted international standard)*, 2014 (Reaffirmed 2019), Acoustical Society of America, 1305 Walt Whitman Road, Suite 300, New York, NY 11747, USA.

A.3. ASA/ANSI S1.6-2016 (R2020), *AMERICAN NATIONAL STANDARD Preferred Frequencies and Filter Band Center Frequencies for Acousitcal Measurements*, 2016 (Reaffirmed 2020), Acoustical Society of America, 1305 Walt Whitman Road, Suite 300, New York, NY 11747, USA.

A.4. ASA/ANSI S1.11-2014/Part 1 / IEC 61260-1:2014 (R2019), *AMERICAN NATIONAL STANDARD Electroacoustics – Octave-band and Fractional-octave-band Filters – Part 1: Specifications (a nationally adopted international standard)*, 2014 (Reaffirmed 2019), Acoustical Society of America, 1305 Walt Whitman Road, Suite 300, New York, NY 11747, USA.

A.5. ASA/ANSI S12.51-2012 / ISO 3741:2010 (R2020), *AMERICAN NATIONAL STANDARD Acoustics - Determination of sound power levels and sound energy levels of noise sources using sound pressure – Precision methods for reverberation test rooms (a nationally adopted international standard)*, 2012 (Reaffirmed 2020), Acoustical Society of America, 35 Pinelawn Road, Suite 114 E, Melville, NY 11747-3177, USA.

A.6. ASHRAE Terminology. ASHRAE. Accessed January 6, 2022. https://www.ashrae.org/technical-resources/free-resources/ashrae-terminology.

APPENDIX B. REFERENCES – INFORMATIVE

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 8 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	55.5	-	55.5	75.1
100	72.9	55.9	38	52	-0.18	51.82	95.8
125	72.7	58.1	41.3	47	-1.26	45.74	60.3
160	72.7	57	35.6	47.4	-0.3	47.1	62.8
200	72.8	57.5	36.2	44.4	-0.71	43.69	59
250	73.1	58.2	33.9	46	-0.27	45.83	60.7
315	73.8	58.9	26.9	42.9	-	42.9	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	26	37.2	-0.34	36.86	50.6
800	77	63.5	23.9	35.7	-0.3	35.4	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	-	35.1	48.1
1600	75.5	62.4	16.1	36.2	-	36.2	49.3
2000	74.2	60.9	16	36.2	-	36.2	49.5
2500	73.1	60	16.4	37.7	-	37.7	50.8
3150	72.6	59.4	16.1	38.2	-	38.2	51.4
4000	71.9	58.6	14	35.1	-	35.1	48.4
5000	72	57.3	14.7	31.6	-	31.6	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
10 000	66.1	41.2	9	15	-1.26	13.74	38.6
Note: 1. To be rounded as directed in the product specific standard							

Table 9 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.	