AHRI Standard 230-2022 (SI)

2022 Standard for

Sound Intensity Testing Procedures for Determining Sound Power of HVAC Equipment

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ICS Code: 17.140.01

Note:

This standard supersedes AHRI Standard 230-2013 (SI).

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Forward:

This standard describes the methodology for determination of Sound Power Levels of broad-band, and/or discrete-frequency noise sources using the intensity method. It is based on sound tests utilizing the sound intensity method as described in ISO Standard 9614-1 (measurement at discrete points, grade 2) or ISO Standard 9614-2 (measurement by scanning, grade 2).

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 AHRI Standard 230, *Sound Intensity Testing Procedures for Determining Sound Power of HVAC Equipment*, was prepared by the Testing and Analysis Standards Technical Committee. The standard was published by the Sound and Vibration Standards Subcommittee in October 2022.

Origin and Development of AHRI Standard 230

The initial publication was AHRI Standard 220-2013, *Sound Intensity Testing Procedures for Determining Sound Power of HVAC Equipment*.

Summary of Changes

AHRI Standard 230-2022 (SI) contains the following update(s) to the previous edition:

- Updated definitions in Section 3
- Updated the high frequency correction determination method and frequency range in Section 6.4
- Clarified field indicator requirements and use in Appendix C

Committee Personnel

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Patrick Chinoda Revcor Inc.	Product Manufacturer	Primary	IL, USA
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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.

Sound and Vibration Standards Subcommittee

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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.)

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SOUND INTENSITY 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 determining the Sound Power Levels of noise sources using the sound intensity method. The standard contains information on instrumentation, installation and operation of the source, and procedures for the calculation of Sound Power Levels.

This standard covers the frequency range from the 50 Hz to the 10,000 Hz One-third Octave Band (63 Hz to 8000 Hz Octave Bands). Each product specific AHRI sound performance rating standard will specify its particular frequency range of interest for qualification, calculation, and reporting. This standard is based on ISO 9614-1 (grade 2) or ISO 9614-2 (grade 2) with certain exceptions and extensions. Section 7.2 refers to measurement at discrete points and Section 7.3 refers to measurement by scanning.

1.2 *Measurement Uncertainty.* Sound Power Levels obtained from intensity measurements made in conformance with this standard shall result in measurement standard deviations which are equal to or less than those in Table 1. The uncertainties in this table include uncertainty in the sound intensity measurement method due to the test environment, background noise levels and selection of measurement points as defined in ISO 9614-1 (grade 2) or measurement surfaces in ISO 9614-2 (grade 2). The standard deviations in Table 1 do not account for variations of sound power caused by changes in operating conditions.

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, dB
50 - 80	4.0
100 - 160	3.0
200 - 315	2.0
400 - 5000	1.5
6300 - 10000	3.0

Section 2. Scope

2.1 *Scope.* This standard applies to HVAC products whose sound power is determined by measurement using the sound intensity method. This standard provides a standalone method of test that is referenced by other AHRI sound performance rating standards and provides an alternative to the reverberation room method of test outlined in AHRI 220.

Section 3. Definitions

All terms in this document follow the standard industry definitions in the *ASHRAE Terminology* website (unless otherwise defined in this section. For acoustic related terms refer to *ASA Standard Term Database* website.

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

3.2 *Discrete Frequency Sounds/Tones*. These consist of one or more sounds, each of whose wave shape is essentially sinusoidal.

3.3 *Octave Band*. A contiguous range of frequencies such that the highest is twice the lowest. The Octave Bands used in this standard are those defined in ASA S1.6.

3.4 *One-third Octave Band, n*. A contiguous 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 ASA S1.6.

3.5 *Pressure-Residual Intensity Index (PRI).* The difference between the indicated Sound Pressure Level, L_p, and the indicated Sound Intensity Level, L_i, when the intensity probe is placed in a sound field such that L_i is zero for each frequency band. Details of determining the PRI are provided in Clause 6.1 of ISO 9614-1 and ISO 9614-2.

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

3.7 *Reproducibility*. Deviations in test results obtained with the same method on identical test items in different laboratories with different operators using different test instrumentation.

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

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

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

3.9 *Unit Under Test (UUT).* HVAC equipment or duct termination for which the sound power is to be determined.

Section 4. General Requirements

4.1 *Size of Noise Source.* The size and shape of the noise source is unrestricted and serves to define the measurement surface. The measurement surface shall consist of multiple sub-surfaces, that totally enclose the noise source under test. The basic concept is measurement of the sound intensity distribution around the equipment in all directions.

4.2 *Character of Noise Radiated by the Source.* The signal shall be stationary in time, as defined in Clause 3.13 of ISO 9614-1 (grade 2) and Clause 3.13 of ISO 9614-2 (grade 2). Care should be taken to avoid measurement during times of operation of non-stationary extraneous noise sources of which the occurrences are predictable. Measurements per this standard are appropriate for sources that produce tones, broadband sound or both.

4.3 *Time Averaging.* To minimize the random error in the measurement, the averaging time shall be long enough to give repeatable results. The minimum averaging time shall be thirty seconds per the smaller of each sub-surface or each square meter of measurement surface.

Section 5. Acoustic Environment

5.1 *Criteria for Adequacy of the Test Environment.* The temperature, humidity and barometric pressure of the test environment shall be within the instrument manufacturer's stated limits. In addition, the test environment shall satisfy the requirements stated in clauses 5.2 to 5.4 of ISO 9614-1 (grade 2) and 5.2 to 5.4 of ISO 9614-2 (grade 2) covering extraneous intensity, vibration, temperature, configuration of the surroundings and atmospheric conditions. Even though sound intensity measurements are relatively insensitive to background sound compared to other methods, an excessive amount of background sound will increase the uncertainty of the measurements.

Care shall be taken to ensure that flow–induced noise over the intensity probe does not influence the measurements. Measurements shall be performed with a windscreen at all times. Refer to IEC 1043 referenced in 9614-1 Sect 5.3. Intensity measurements in airflow shall meet the requirements in Section 6.3.

For some measurements consisting of discrete points according to ISO 9614-1 or scanned sub-surfaces according to ISO 9614-2, it may not be possible to eliminate flow-induced noise over the intensity probe. Provided all measurements that are invalid due to flow-induced noise do not exceed 10% of the total measurement surface area, such discrete points or scanned sub-surfaces may be excluded when determining the sound power of the noise source.

Section 6. Instrumentation

6.1 *General.* The sound intensity instruments and probes used for measurement shall meet the class 1 requirements of IEC 61043. Measurements and analysis shall be conducted in One-third Octave Bands using equipment in compliance with ASA S1.11. Synthesized One-third Octave Band levels from narrow band analysis are not allowed.

For the calibration and field check of the instruments, the requirements of Clause 6.2 of ISO 9614-1 (grade 2) and ISO 9614-2 (grade 2) shall be met. The two values of the normal sound intensity, $I_{(n)}$, at each One-third Octave Band for the field check should have opposite signs and the allowable difference in Sound Intensity Levels, L_i, shall be less than 1.5 dB in all bands.

6.2 *Instrumentation.* The sound intensity instrumentation shall be capable of measurements from the 50 Hz to the 10,000 Hz One-third Octave Band. A common sound intensity probe consists of two 12 mm diameter pressure microphones in a face-to-face configuration with a solid spacer between the microphone grids. The use of two different intensity microphone spacers may be required to cover the entire frequency range in conformance with Table 1. A 50 mm microphone spacer is typically used for the one-third octave band frequency range from 50 Hz to 315 Hz; a 12 mm microphone spacer is typically used for the one-third octave band frequency range from 400 Hz to 10,000 Hz. The use of a single microphone spacer for the entire range of frequency bands is, however, permitted if the requirements of Section 6.3 and Section 6.4 are met.

The Pressure-Residual Intensity Index (PRI) of the measurement instrumentation (microphone pair, spacer, and analyzer) shall be recorded according to the procedure in Clause 6.1 of ISO 9614-1 and ISO 9614-2 for each frequency band. This procedure is referred to as phase calibration. The procedure in Section 6.3 of this standard is then used to check the quality of each sound intensity measurement.

6.3 *Qualification of Sound Intensity Measurements.* To conform with this standard, the quality of each measurement shall meet the requirements defined by Equation 1 for each One-third Octave Band:

$$PI < L_d \qquad \textbf{1}$$

Where:
L_d = Dynamic capability index for each One-third Octave Band, see Equation 2
PI = Pressure-intensity index (time-averaged sound pressure level minus the time-averaged sound intensity level) of the measurement for each One-third Octave Band, dB

$$L_d = PRI - 10 \qquad \textbf{2}$$

Where:
PRI = Pressure-Residual Intensity Index, determined by the phase calibration of the particular microphone pair, spacer and analyzer used for the measurement for each One-third Octave Band, dB

Measurements in each frequency band that do not meet this requirement are invalid. Measurements in each frequency band where the time-averaged sound pressure level is less than the time-averaged sound intensity level (PI index is negative) are also invalid. This condition often occurs when the measurement is influenced by flow-induced noise over the probe.

6.4 *High Frequency Correction*. The useable frequency range is physically limited by the microphone spacer. This range can be expanded by applying a high frequency correction or using multiple spacers. One of the following methods shall be used:

6.4.1 *Built in High Frequency Correction.* Intensity analyzers can have a built-in high frequency correction for a specific spacer. If the analyzer used has a built-in correction, measurements shall only be made across the instrumentation manufacturer's recommended frequency range using the specified spacer.

6.4.2 *High Frequency Correction Using Section 6.5.* If the analyzer does not provide a high frequency correction, but a single 10 to 15 mm spacer is used, the results in Section 6.5 shall be used to determine the high frequency correction for each individual sound intensity probe and analyzer combination. The high frequency correction, $L_{wc(n)}$, is the difference between the calibrated one-third octave band sound power level and the measured one-third octave band sound power level in decibels, determined by the intensity measurements. The high-frequency probe correction shall only be applied to the 2500 Hz through 10,000 Hz One-third Octave Bands.

6.4.3 *Multiple Microphone Spacers.* The use of two or more different intensity microphone spacers shall be used to cover the entire frequency range in conformance with Table 1. Useable spacer range shall be defined by instrumentation manufacturer.

NOTE: High frequency corrections can be applied to any intensity microphone spacer, but only to One-third Octave Bands where the wavelength is between twelve times and three times the spacer length. Example: A 12 mm spacer can have the correction applied between 2382 Hz (144 mm) and 9528 Hz (36 mm) or 2500 Hz to 10,000 Hz One-third Octave Bands.

6.5 *Performance Verification by Comparison with a Reference Sound Source.* In order to ensure consistent and accurate sound intensity results, it is required to periodically verify the performance of the instrumentation system and the skill of the test operator. The performance of the sound intensity instrumentation system shall be verified at an interval no longer than 90 days by determining the sound power of a Reference Sound Source (RSS) according to ASA S12.12, Section 5.8. The performance of the test operator shall be verified every thirty days by: 1) determining the sound power of a Reference Sound Source (RSS) according to ASA S12.12, Section 5.8, or 2) by having demonstrated the successful execution of additional sound intensity tests. The Reference Sound Source used for this verification shall have the characteristics required in AHRI 250 and be calibrated in accordance with AHRI 250 for the frequency range of 50 Hz to 10 kHz. The measurement surface, as defined in Section 7.1, shall be as shown in Figure 1. The same sound intensity probe, windscreen and analyzer combination shall be used during the performance verification and all subsequent intensity measurements. The sound power level value in each one-third octave band, as determined by intensity measurements with the high frequency correction as determined in Section 6.4, shall differ from the RSS value as determined by AHRI 250 by no more than the levels shown in Table 2.

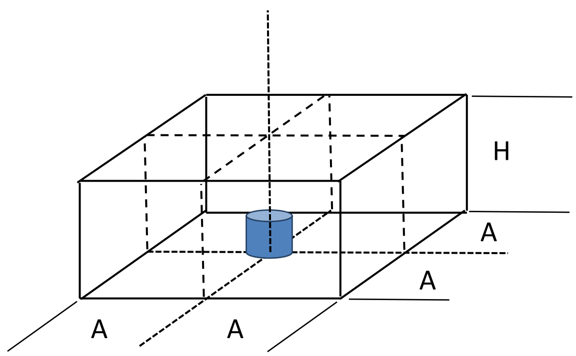

Figure 1. Performance Verification Measurement Surface

The RSS shall be mounted on the floor with the vertical axis at the center of the measurement grid passing through the center of the RSS fan wheel. Dimensions "A" and “H” shall be no less than one meter.

Table 2. Performance Verification Limits

One-third Octave Band, Hz	Tolerance, dB
50 to 80	3.0
100 to 160	2.0
200 to 5000	1.5
6300 to 10000	2.5

Section 7. Measurement of Component Sound Intensity Levels

7.1 *Measurement Surface*. The measurement surface shall enclose the source or sources of interest and to exclude other noise sources or absorptive materials that are not an integral part of the source under test. The measurement surface shall be divided into sub-surfaces with known areas, preferably equal in size. A suggested size of each sub-surface is 1 m^2. If the sub-surface has a size greater than 1 m^2, the convergence index shall be determined according to Appendix C. Subsequent measurements of the same UUT with the same configuration set-up can be assumed to have the same convergence properties.

Note 1: The measurement surface should be planar to minimize error by maintaining a repeatable and consistent surface area.

Note 2: The sound emitted by HVAC equipment can be minimally directive. When this is the case a one square meter grid size with a thirty second average should be used. For highly directive sources, the convergence index as described in Appendix C should be used to verify that the sub-surface size is adequate. The negative partial power and partial-power repeatability checks in Appendix C provide guidance on whether the source is omni-directional and the user can uniformly scan the sub-surface. If the source directivity is unknown Appendix C should be used.

7.2 *Measurements Employing Discrete Points – ISO Standard 9614-1 (grade 2).*

7.2.1 *Initial Test.* Measure the sound intensity on an initial measurement surface. If this initial surface proves to be unusable, modify it according to Annex B of ISO 9614-1 (grade 2). The initial measurement surface shall be defined around the source under test.

Note: This surface should take one of the geometrically simple and quantifiable forms indicated in Figure 1 of ISO 9614-1 (grade 2). Follow the procedures outlined in Clause 8 of ISO 9614-1 (grade 2) for conducting the initial tests and any additional tests that can be required.

7.2.2 *Calculation of Sound Power Level.*

7.2.2.1 *Calculation of Partial Sound Power for Each Sub-surface of the Measurement Surface(s).* Calculate a partial sound power in each frequency band for each sub-surface of the measurement surface from Equation 3.

$$P_{(n)k} = I_{(n)k} \cdot S_k \qquad \textbf{3}$$

Where:
$I_{(n)k}$ = Signed magnitude of the normal sound intensity component measured at position *k* on the measurement surface for the n^{th} One-third Octave Band, W/ m^2
$P_{(n)k}$ = Partial sound power for sub-surface *k* for the n^{th} One-third Octave Band, W
S_k = Area of sub-surface *k*, m^2

Where the normal sound intensity level, $L_{i(n)k}$, for sub-surface *k* and the n^{th} One-third Octave Band is expressed in decibels, the value of $I_{(n)k}$ shall be calculated from Equation 4.

$$I_{(n)k} = I_0 \cdot 10^{L_{i(n)k}/10} \qquad \textbf{4}$$

Where:
$I_0 = 10^{-12}$ W/m^2

Where the normal Sound Intensity Level $L_{i(n)k}$ for sub-surface *k* and the n^{th} One-third Octave Band is a negative vector indicating that it points towards the source, the value of $I_{(n)k}$ shall be calculated from Equation 5.

$$I_{(n)k} = -I_0 \cdot 10^{L_{i(n)k}/10} \quad (5)$$

7.2.2.2 *Calculation of the Sound Power Level of the Noise Source.* Calculate the Sound Power Level of the noise source in each frequency band from Equation 6.

$$L_{w(n)} = 10 \log \sum_{k=1}^{N} \left(\frac{P_{n(k)}}{P_0}\right) + L_{wc(n)} \quad (6)$$

Where:

$L_{wc(n)}$ = High frequency correction determined in Section 6.4 for the nth One-third Octave Band, dB

$L_{w(n)}$ = Test unit component Sound Power Level for the nth One-third Octave Band, dB

N = Total number of measurement positions and sub-surfaces

$P_{n(k)}$ = Partial sound power for sub-surface *k*, calculated from Equation 3 for the nth One-third Octave Band, W

P_0 = Reference sound power = 10^{-12} W

7.3 *Measurements Employing Scanning – ISO Standard 9614-2 (grade 2).* The scanning procedure and the definition of the initial measurement surface shall be as described in Clause 8.l and Clause 8.2 of ISO 9614-2.

7.3.1 Within human ability, the intensity probe shall move at a constant speed during each surface scan. This can be achieved by timing each pass of the intensity probe throughout the entire surface scan.

7.3.2 When scanning, the sub-surfaces shall be small enough to facilitate the reach of the operator and to maintain even coverage with time.

7.3.3 Each surface shall be scanned two times with the second scan orthogonal (90-degrees) to the first. The difference in sound power levels between the two scans shall not exceed the tolerance limits in Table 2.

7.3.4 *Calculation of Partial Sound Power.* Calculate a partial sound power in each frequency band for each sub-surface of the measurement surface from Equation 7.

$$P_{(n)k} = I_{(n)k} \cdot S_k \quad (7)$$

Where:

$I_{(n)k}$ = Signed magnitude of the sub-surface average normal sound intensity measured on partial surface *k* on the measurement surface for the nth One-third Octave Band, W/m^2

$P_{(n)k}$ = Partial sound power determined by scanning for sub-surface *k* for the nth One-third Octave Band, W

S_k = Area of sub-surface *k*, m^2

7.3.5 *Calculation of Sound Power Level.* Calculate the sound power, P, of the source under test in each frequency band of interest using Equation 8.

$$P_{(n)} = \sum_{k=1}^{N} P_{(n)k} \quad (8)$$

Where:

N = Number of sub-surfaces of the measurement surface

$P_{(n)}$ = Sound power for each 1/3rd octave band, n

Calculate the Sound Power Level, L_w, of the source under test in each frequency band of interest using Equation 9.

$$L_{w(n)} = 10 \cdot \log\left(\frac{P_{(n)}}{P_0}\right) + L_{wc(n)} \quad (9)$$

Where:
$L_{w(n)}$ = Test unit component Sound Power Level for the n^{th} One-third Octave Band, dB
$L_{wc(n)}$ = High frequency correction determined in Section 6.4 for the n^{th} One-third Octave Band, dB
$P_{(n)}$ = Source sound power for the n^{th} One-third Octave Band, W
P_0 = Reference sound power = 10^{-12} W

Note: When the intensity vector is negative, P is negative. In this case, the Sound Power Level, L_{wc}, is expressed as a negative value.

7.4 *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 10.

$$L_{wm} = 10 \cdot \log \sum_{n=3m-2}^{3m} 10^{0.1(L_{wn})} \qquad \textbf{10}$$

Where:
n = An integer number lying within the range (3m – 2) and 3m, and which identifies the three One-third Octave Bands which make up the m^{th} Octave Band.
L_{wm} = Sound Power Level in the m^{th} Octave Band
L_{wn} = Sound Power Level in the n^{th} One-third Octave Band

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

7.5 *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 11.

$$L_{wA} = 10 \cdot \log \sum_{n=n_{min}}^{n_{max}} 10^{0.1(L_{wn}+ C_n)} \qquad \textbf{11}$$

Where:
C_n and n = A-weighting factor and band index as given in Table 3
n_{min} and n_{max} = Values given in Table 3 of n corresponding, respectively, to the lowest (n_{min}) and highest (n_{max}) One-third Octave Bands of measurement
L_{wA} = A-weighted Sound Power Level
L_{wn} = Sound Power Level in the n^{th} One-third Octave Band

Table 3. One-third Octave Band Numbers and A-weighting Factors					
Band index, n	One-third Octave Band Frequency, Hz	A-weighting factor, C_n	Band index, n	One-third Octave Band Frequency, Hz	A-weighting factor, C_n
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

7.5.1 *Rounding*. Data rounding shall be per directions in individual AHRI product rating standards.

7.6 *Linear Sound Power Level.* Unless directed otherwise in the product specific AHRI standards, the linear Sound Power Level shall be calculated per Equation 12.

$$L_{wL} = 10 \cdot \log \sum_{n=n_{min}}^{n_{max}} 10^{0.1(L_{wn})} \qquad \textbf{12}$$

Where:

n = Band index from Table 3
n_{min} and n_{max} = Values given in Table 3 of band indexes corresponding, respectively, to the lowest (n_{min}) and highest (n_{max}) One-third Octave Bands of measurement
L_{wn} = Sound Power Level in the n^th One-third Octave Band
L_{wL} = Linear Sound Power Level

Section 8. Information to be Recorded

8.1 *General*. The information listed in Section 7, when applicable, shall be compiled and recorded for all measurements made in accordance with this standard. In addition to the information required in Section 7.2 through 7.6, the information to be reported shall be in accordance with Clause 10 of ISO 9614-1 (grade 2) and 9614-2 (grade 2) as applicable.

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

8.2 *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, model number serial number and year of manufacture)
- The mode(s) of operation and the operating conditions used for the test(s)
- The relevant measurement time interval(s)
- The installation and mounting conditions

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

- The air temperature in degrees Celsius, ℃, the relative humidity, %, and the barometric pressure, kPA, if outdoors wind speed m/s and direction in the test area immediately before and after making the measurements at the location of the measurement.
- Description of the test environment including the geometry and nature of the enclosure surfaces and a physical description or a photo of the test environment.
- Measurement surfaces that were excluded due to flow induced noise.

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

- The equipment used for the measurements, including the name, type, model number, serial number, and manufacturer; and
- The date and place of calibration; the methods used to calibrate the sound calibrator, and calibration verification of the instrumentation system.

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

- The sound power levels, dB, in One-third Octave Bands; and
- The date and time when the measurements were performed

Section 9. Test Report

9.1 *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 AHRI Standard 230-2022, 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 10. Conformance Conditions

10.1 *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/ASA Standard S1.6-2016 (R2020) *Preferred Frequencies and Filter Band Center Frequencies for Acoustical Measurements*, 2016 (Reaffirmed 2020), Acoustical Society of America, 1305 Walt Whitman Road, Suite 300, Melville, NY 11747, USA.

A1.2 ANSI/ASA S1.11-2014 (R2019) /Part 1 / IEC 61260-1:2014, *Electroacoustics - Octave-Band and Fractional-Octave-Band Filters - Part 1: Specifications (A Nationally Adopted International Standard*, 2019 (Reaffirmed 2019), Acoustical Society of America, 1305 Walt Whitman Road, Suite 300, Melville, NY 11747, USA.

A1.3 ANSI/ASA Standard S12.12-1992 (R2020), *Engineering Method for the Determination of Sound Power Levels of Noise Sources Using Sound Intensity*, 1992 (Reaffirmed 2020), Acoustical Society of America, 1305 Walt Whitman Road, Suite 300, Melville, NY 11747, USA.

A1.4 ANSI/AHRI Standard 220-2022, *Reverberation Room Qualification and Testing Procedures for Determining Sound Power of HVAC Equipment*, 2012, Air-Conditioning, Heating and Refrigeration Institute, 2311 Wilson Boulevard, Suite 400, Arlington, VA 22201, USA.

A1.5 ANSI/AHRI Standard 250-2022, *Performance and Calibration of Reference Sound Sources*, 2013, Air-Conditioning, Heating and Refrigeration Institute, 2311 Wilson Boulevard, Suite 400, Arlington, VA 22201, USA.

A1.6 ASHRAE Terminology. ASHRAE. Accessed July 23, 2021. https://www.ashrae.org/technical-resources/free-resources/ashrae-terminology.

A1.7 IEC 61043:1993, Electroacoustics - *Instruments for the measurement of sound intensity - Measurements with pairs of pressure sensing microphones*, 1993, International Electrotechnical Commission, 3, rue de Varembe, P.O. Box 131, 1211 Geneva 20, Switzerland.

A1.8 ISO Standard 9614-1:1993, Acoustics – *Determination of sound power levels of noise sources using sound intensity - Part 1: Measurement at discrete points*, 1993, International Organization for Standardization, Chemin de Blandonnet 8, CP 401, 1214 Vernier, Geneva, Switzerland.

A1.9 ISO Standard 9614-2:1996, Acoustics -- *Determination of sound power levels of noise sources using sound intensity - Part 2: Measurement by scanning*, 1996, International Organization for Standardization, Chemin de Blandonnet 8, CP 401, 1214 Vernier, Geneva, Switzerland.

A1.10 ASA Standard Term Database (http://asastandards.org/asa-standard-term-database/.)

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 this standard.

None.

APPENDIX C. FIELD INDICATORS – NORMATIVE

C1. *Convergence Index.* An adequate convergence index confirms that the sub-surface size and scan density are sufficient. This is especially important for tonal noise sources or highly directive sources. The convergence index is used to verify that the number of intensity measurements N is sufficient, and hence that the determined sound power is equal to the true sound power within the uncertainty of the standard. The convergence index is defined as the difference between two estimates of the surface-average sound intensity level, from N and N/2 intensity measurements.

After a set of measurements is made, the surface-average sound intensity level of the original set of measurement points or sub-surfaces shall be compared to the surface-average sound intensity level from a set with half the number of measurements to ensure the adequacy of the number of measurement points or sub-surfaces. The choice of measurement points or sub-surfaces shall result in a convergence index less than or equal to the values provided in Table C1.

Table C1. Convergence Index

One-third Octave Band, Hz	Tolerance, dB
50 to 160	0.75
200 to 5000	0.4
6300 to 10000	0.65

The convergence index shall be the difference between values of the surface Sound Intensity Level using N and N/2 sub-surface evenly distributed areas using Equation 13.

$$\delta_{(n)} = L_{Ia(n)} - L_{Ib(n)} \qquad \textbf{13}$$

Where:

$\delta_{(n)}$ = Convergence index for the nth One-third Octave Band
$L_{Ia(n)}$ = Intensity level determined from N sub-surface areas for the nth One-third Octave Band
$L_{Ib(n)}$ = Intensity level determined from N/2 sub-surface areas for the nth One-third Octave Band
N = Total number of measurement positions and sub-surfaces

C1.2. *Alternate Procedure for large surfaces.* The most accurate method of determining the convergence index is to perform the measurement with a set of large sub-surfaces, for example 1 m by 1 m, and then measure the sound using smaller sub-surfaces such as 1 m by 0.5 m. This can be tedious for large surfaces. An optional method to determine the adequacy of these large surfaces follows.

Test-to-test variability of this alternative procedure may be substantially greater than that of the standard procedure, but the absolute accuracy can be expected to be similar to that of the standard procedure.

C1.2.1 *Measurement surface*. Except for specified reflecting plane(s), all room surfaces should be at least twice the distance between the measurement and equipment surfaces, or 2 m whichever is larger, from the measurement surface.

C1.2.1 *Number of Measurements*. The minimum number of measurements shall depend on the surface area of the measurement surface as set forth in Table C2. For fan measurements the tolerance for the convergence index shall be as given in Table C3.

C1.3 *Results*
All reports shall be marked to indicate that this alternative procedure, and not the standard procedure, was followed.

Table C2. Minimum Number of Measurements (Alternate Procedure)	
Surface Area of Measurement Surface, m^2	Number of Measurements
Less than 80	8
Between 80 and 500	1 per 10 m^2
More than 500	50

Table C3. Tolerance for Convergence Index (Alternative Procedure)	
Octave Band, Hz	Tolerance, dB
63 to 125	±1.5
250 to 500	±1.0
1000 to 4000	±0.8
8000	±1.3

C2. *Negative Partial Power.* The partial sound power from Section 7.2.1, $P_{(n)k}$, and Section 7.3.1, $\overline{P_{(n)k}}$, is the time-averaged energy flow through a single point or segment of the measurement surface.

The negative partial power indicator is the difference between the magnitude of the total power through the entire measurement surface and the signed total power through the entire measurement surface. The indicator shall be calculated according to Equation 14.

$$F_{+/-} = 10 \cdot \log\left(\frac{\sum_{k=1}^{N}\left|P_{(n)k}\right|}{\sum_{k=1}^{N} P_{(n)k}}\right) \qquad \mathbf{14}$$

Where:
$F_{+/-}$ = Negative partial power indicator
N = Number of sub-surfaces of the measurement surface

The test environment is adequate when the negative partial power indicator, $F_{+/-}$, is less than or equal to 3 dB. If this is not the case, then care should be taken to shield the test surface from background noise or strong reflective surfaces. Alternatively, reduce the distance of the measurement surface from the source.

C3. *Partial-power Repeatability.* Most HVAC applications are considered stable and steady state. A field check can be used to determine repeatability. When using the scanning method in Section 7.3, measure the partial power as defined in Section 7.3.1 twice, scanning once in each direction. The difference between each partial power in each octave band for these two measurements shall be less than the values found in Table 2, if not take the following actions and repeat:

C3.1 Identify any temporal variation. This could indicate a non-stable operating condition.
C3.2 Increase the number of intensity probe passes for this segment
C3.3 Increase the distances of the measurement surface from the source