ANSI/AHRI Standard 1280

2014 Standard for

Sound Power Rating of Water-cooled Chillers

Approved by ANSI on June 3, 2015

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IMPORTANT

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AHRI uses its best efforts to develop standards/guidelines employing state-of-the-art and accepted industry practices. AHRI does not certify or guarantee that any tests conducted under its standards/guidelines will be non-hazardous or free from risk.

Note:

This is a new standard.

At each of the four Integrated Part Load Value (IPLV) load points, the following ratings are required:

- Un-weighted octave band Sound Power Levels, dB (63 Hz to 8,000 Hz)
- Overall A-weighted Sound Power Level, dB (A-weighted 50 Hz to 10,000 Hz)

Optional Information:

- Un-weighted one-third octave band Sound Power Levels, dB (50 Hz to 10,000 Hz)

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SOUND POWER RATING OF WATER-COOLED CHILLERS

Section 1. Purpose

1.1 *Purpose.* The purpose of this standard is to establish methods for determining the sound power ratings of commercial and industrial Water-cooled Chillers. It establishes definitions; test requirements; rating requirements; minimum data requirements for Published Ratings; marking and nameplate data; and conformance conditions.

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 commercial and industrial Water-cooled Chillers used for refrigerating or air-conditioning of spaces, as defined in Section 3 of this standard and covered by ANSI/AHRI Standards 550/590 (I-P) and 551/591 (SI), *Performance Rating of Water Chilling Packages Using the Vapor Compression Cycle.*

2.2 *Exclusions.* This standard does not apply to air-cooled equipment, which falls within the scope of ANSI/AHRI Standard 270, *Sound Rating of Outdoor Unitary Equipment* and AHRI Standard 370, *Sound Performance Rating of Large Outdoor Refrigerating and Air-conditioning Equipment.*

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 *Comparison Method.* A method of determining Sound Power Level of the equipment under test in a reverberation room by comparing the average Sound Pressure Level of that equipment to the average Sound Pressure Level of 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 *Hertz (Hz).* A unit of frequency equal to one cycle per second.

3.3 *Integrated Part-Load Value (IPLV).* A single number part-load efficiency figure of merit calculated per the method described in ANSI/AHRI Standards 550/590 (I-P) and 551/591 (SI) at Standard Rating Conditions.

3.4 *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.

3.5 *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. The One-third Octave Bands used in this standard are those defined in ANSI Standard S1.11.

3.6 *Published Rating.* A statement of the assigned values of those performance characteristics, under stated IPLV rating conditions, by which a unit may be chosen to fit its application. These values apply to all units of like

nominal size and type (identification) produced by the same manufacturer. As used herein, the term Published Rating includes the rating of all performance characteristics shown on the unit or published in specifications, advertising or other literature controlled by the manufacturer, at stated IPLV rating conditions.

3.6.1 *Application Rating*. A rating based on tests performed at Application Rating Conditions (other than Standard Rating Conditions).

3.6.2 *Standard Rating*. A rating based on tests performed at Standard IPLV Rating Conditions.

3.7 *Rating Conditions*. Any set of operating conditions under which a single level of performance results, and which cause only that level of performance to occur.

3.7.1 *Standard IPLV Rating Conditions*. Rating Conditions used as the basis of comparison for performance characteristics.

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

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

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

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

3.10 *Sound Intensity*. The average sound power transmitted through a unit area.

3.11 *Sound Intensity Level, L_i*. This is ten times the logarithm to the base ten of the ratio of the Sound Intensity component radiated by the source to a reference Sound Intensity, expressed in decibels (dB). The reference Sound Intensity used in this standard is 1 picowatt per square meter, pW/m^2 (internationally recognized units). The sound intensity component is the value of the intensity vector, normal to a measurement surface, directed out of a volume enclosing the sound source.

3.12 *Sound Power Level, L_w.* This is 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).

3.12.1 *A-weighted Sound Power Level, L_{WA}*. The logarithmic summation of A-weighted, One-third Octave Band levels.

3.13 *Sound Pressure Level, L_p.* This is 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.

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

3.515 *Water-cooled Chiller.* A factory-made and prefabricated assembly (not necessarily shipped as one package) of one or more compressors, condensers and evaporators, with interconnections and accessories, designed for the purpose of cooling water. It is a machine specifically designed to make use of a vapor compression refrigeration cycle to remove heat from water and reject the heat to a cooling medium, usually water. The refrigerant condenser may or may not be an integral part of the package.

Section 4. Test Requirements

4.1 *Test Requirements.* All standard Sound Power Level ratings shall be determined by tests conducted in a qualified reverberation room, hemi-anechoic room, or an indoor or outdoor space that is an essentially free field over a reflecting plane or by tests using Sound Intensity.

4.1.1 Sound tests in a reverberation room shall be conducted in a reverberation room meeting the requirements of and qualified per ANSI/AHRI Standard 220, as adapted for Water-cooled Chillers in Appendix E of this standard. Sound tests shall be conducted in accordance with ANSI/AHRI Standard 220 using a RSS that meets the performance requirements of and is calibrated per ANSI/AHRI Standard 250.

4.1.2 Sound tests in a hemi-anechoic room which affords a free field condition above the measurement space or above a reflecting plane shall be conducted in accordance with ISO 3745, as adapted for Water-cooled Chillers in Appendix F of this standard.

4.1.3 Sound tests in indoor or outdoor spaces that qualify as an essentially free field over a reflecting plane shall be conducted in accordance with ISO 3744, as adapted for Water-cooled Chillers in Appendix F of this standard.

4.1.4 Sound tests using Sound Intensity shall be conducted in accordance with AHRI Standard 230, as adapted for Water-cooled Chillers. For Water-cooled Chillers, the sound component of interest as discussed in Section 7 of ANSI/AHRI Standard 230 is the entire chiller. The measurement grid shall enclose the entire chiller.

4.2 *Test Conditions.* Standard sound ratings shall be based on sound tests conducted with the unit operating at the Rating Conditions specified in ANSI/AHRI Standard 550/590 (I-P) and ANSI/AHRI Standard 551/591 (SI). Sound tests shall be conducted as prescribed below:

4.2.1 *Standard Sound Ratings*. Standard sound ratings shall be based on sound tests conducted with the unit operating at voltage, V, phase and frequency, Hz, for each of the four load conditions required for IPLV determination.

4.2.2 *Application Sound Rating.* Application Sound Ratings are for conditions other than the AHRI standard rating conditions.

4.2.3 *Test Condition Tolerances*. During sound rating tests, the equipment operating conditions shall not deviate from the specified operating conditions by more than the tolerances specified in ANSI/AHRI Standard 550/590 (I-P) and ANSI/AHRI Standard 551/591 (SI).

4.3 *Data to be Taken.* Sound Pressure Level or Sound Intensity Level data taken shall be in One-third Octave Bands (50 Hz to 10,000 Hz are required) in accordance with the procedure specified for the type of test being conducted.

4.4 *Unit Installation*. The unit under test shall be located within the reverberation room as specified in ANSI/AHRI Standard 220 or per Appendix F when testing per Sections 4.1.2 or 4.1.3 of this standard or per Appendix H when testing per Section 4.1.4.

Section 5. Rating Requirements

5.1 *Product Ratings.* The Sound Power Rating shall be for the complete unit operating at AHRI Standard IPLV Rating Conditions.

5.1.1 At each of the four IPLV load points, the following ratings are required:

5.1.1.1 Un-weighted octave band Sound Power Levels, dB (63 Hz to 8,000 Hz)

5.1.1.2 Overall A-weighted Sound Power Level, dB (A-weighted 50 Hz to 10,000 Hz)

5.1.2 The following information is optional:

5.1.1.2 Un-weighted one-third octave band Sound Power Levels, dB (50 Hz to 10,000 Hz).

5.2 *Application Ratings.* If these are to be published, application ratings shall include the following information:

5.2.1 Un-weighted octave band Sound Power Levels, dB (63 Hz to 8,000 Hz)

5.2.2 Overall A-weighted Sound Power Level, dB (A-weighted 50 Hz to 10,000 Hz)

5.2.3 The following information is optional:

5.2.3.1 Un-weighted one-third octave band Sound Power Levels, dB (50 Hz to 10,000 Hz)

5.3 *Determination of One-third Octave Band Sound Power Levels.* The unit's one-third octave band Sound Power Levels shall be determined per ANSI/AHRI Standard 220.

5.3.1 *Octave Band Sound Power Level Calculations.* Octave band sound power level calculations shall be made per ANSI/AHRI Standard 220. Each octave band Sound Power Level shall be rounded to the nearest decibel. An example of the calculation procedure is provided in Appendix C.

5.3.2 *A-weighted Sound Power Level.* The A-weighted Sound Power Level shall be calculated per ANSI/AHRI Standard 220.

The A-weighted Sound Power Level shall be rounded to the nearest decibel. An example of the calculation procedure is provided in Appendix D.

5.4 *Application Sound Ratings.* Application sound ratings for conditions other than the AHRI standard rating condition shall be based on sound tests conducted with the equipment operating at those conditions.

Section 6. Minimum Data Requirements for Published Ratings

6.1 *Published Ratings*. Published sound power ratings shall be for the unit with all components running that are necessary to produce the AHRI standard rating. Additionally, sound power data may be published for the unit operating at application rating points.

6.1.1 *Required*.

6.1.1.1 The octave band un-weighted Sound Power Levels to the nearest decibel from 63 Hz to 8,000 Hz.

6.1.1.2 The overall A-weighted Sound Power Level to the nearest decibel covering the range of 50 Hz to 10,000 Hz.

6.1.1.3 Sound measurement type; reverberation room, hemi-anechoic room, free-field over a reflecting plane, or Sound Intensity

6.1.1.4 Rating Conditions and capacity (including entering condenser water and leaving chilled water temperatures)

6.1.2 *Optional*. The one-third octave band un-weighted Sound Power Levels.

Section 7. Conformance Conditions

7.1 *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 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 standards, handbooks, and other publications essential to the formation and implementation of the standard. All references in this appendix are considered as part of this standard.

A1.1 AHRI Standard 370-2015, *Sound Performance Rating of Large Air-Cooled Outdoor Refrigerating and Air-Conditioning Equipment*, 2015, Air-Conditioning, Heating, and Refrigeration Institute, 2011, 2111 Wilson Boulevard, Suite 500, Arlington, VA 22201, U.S.A.

A1.2 ANSI Standard S1.11-2009, *Specification for Octave-Band and Fractional Octave-Band Analog and Digital Filters*, 2009, American National Standards Institute, 25 West 43rd Street, 4th Fl., New York, NY 10036, U.S.A.

A1.3 ANSI/AHRI Standard 220-2014, *Reverberation Room Qualification and Testing Procedures for Determining Sound Power of HVAC Equipment*, 2014, Air-Conditioning, Heating, and Refrigeration Institute, 2111 Wilson Boulevard, Suite 500, Arlington, VA 22201, U.S.A.

A1.4 ANSI/AHRI Standard 230-2013, *Sound Intensity Testing Procedures for Determining Sound Power of HVAC Equipment*, 2013, Air-Conditioning, *Heating*, and Refrigeration Institute, 2111 Wilson Boulevard, Suite 500, Arlington, VA 22201, U.S.A.

A1.5 ANSI/AHRI Standard 250-2008, *Performance and Calibration of Reference Sound Sources*, 2008, Air-Conditioning, Heating, and Refrigeration Institute, 2111 Wilson Boulevard, Suite 500, Arlington, VA 22201, U.S.A.

A1.6 ANSI/AHRI Standard 270-2008, *Sound Rating of Outdoor Unitary Equipment*, Air-Conditioning, 2008, Heating, and Refrigeration Institute, 2111 Wilson Boulevard, Suite 500, Arlington, VA 22201, U.S.A.

A1.7 ANSI/AHRI Standard 550/590 (I-P)-2011 with Addendum 3, *Performance Rating of Water Chilling Packages Using the Vapor Compression Cycle*, 2011, Air-Conditioning, Heating, and Refrigeration Institute, 2111 Wilson Boulevard, Suite 500, Arlington, VA 22201, U.S.A.

A1.8 ANSI/AHRI Standard 551/591 (SI)-2011 with Addendum 3, *Performance Rating of Water Chilling Packages Using the Vapor Compression Cycle*, 2011, Air-Conditioning, Heating, and Refrigeration Institute, 2111 Wilson Boulevard, Suite 500, Arlington, VA 22201, U.S.A.

A1.9 *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.

A1.10 ISO 3744, Acoustics -- *Determination of Sound Power Levels of Noise Sources Using Sound Pressure -- Engineering Method in an Essentially Free Field Over a Reflecting Plane***,** 2010**,** International Organization for Standardization, Case Postale 56, CH-1211, Geneva 21, Switzerland.

A1.11 ISO 3745, Acoustics -- *Determination of Sound Power Levels of Noise Sources Using Sound Pressure – Precision Methods for Anechoic and Hemi-anechoic Rooms***,** 2012, International Organization for Standardization, Case Postale 56, CH-1211, Geneva 21, Switzerland.

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. EXAMPLE CALCULATION OF OCTAVE BAND SOUND POWER LEVELS – INFORMATIVE

Table C1. Example Calculation of Octave Band Sound Power Levels, L_{wi}

One-third Octave Band Center Frequencies, Hz	One-third Octave Band Sound Power Levels, L_{wj}	$10^{0.1(L_{wj})}$	Octave Band Center Frequencies, Hz	$\sum_{j=3i-2}^{3i} 10^{0.1(L_{wj})}$	Octave Band Sound Power Levels, L_{wi}
50	61.2	1,318,257			
63	71.9	15,488,166	63	49,165,789	77
80	75.1	32,359,366			
100	68.8	7,585,776			
125	60.3	1,071,519	125	10,562,756	70
160	62.8	1,905,461			
200	59.0	794,328			
250	60.7	1,174,898	250	2,571,785	64
315	57.8	602,560			
400	57.7	588,844			
500	53.2	208,930	500	912,589	60
630	50.6	114,815			
800	48.9	77,625			
1000	48.3	67,608	1,000	209,798	53
1250	48.1	64,565			
1600	49.3	85,114			
2000	49.5	89,125	2,000	294,465	55
2500	50.8	120,226			
3150	51.4	138,038			
4000	48.4	69,183	4,000	249,879	54
5000	46.3	42,658			
6300	43.3	21,380			
8000	40.3	10,715	8,000	39,339	46
10000	38.6	7,244			

APPENDIX D. EXAMPLE CALCULATION OF A-WEIGHTED SOUND POWER LEVELS – INFORMATIVE

Table D1. Example Calculation of A-weighted Sound Power Levels, L_{wA}

One-third Octave Band Center Frequencies, Hz	One-third Octave Band Sound Power Levels, L_{Wj}	A-weighting Adjustments	A-weighted One-third Octave Band Sound Power Levels, L_{wAj}	$10^{0.1(L_{wAj})}$
50	61.2	-30.2	31.0	1,259
63	71.9	-26.2	45.7	37,154
80	75.1	-22.5	52.6	181,970
100	68.8	-19.1	49.7	93,325
125	60.3	-16.1	44.2	26,303
160	62.8	-13.4	49.4	87,096
200	59.0	-10.9	48.1	64,565
250	60.7	-8.6	52.1	162,181
315	57.8	-6.6	51.2	131,826
400	57.7	-4.8	52.9	194,984
500	53.2	-3.2	50.0	100,000
630	50.6	-1.9	48.7	74,131
800	48.9	-0.8	48.1	64,565
1000	48.3	0.0	48.3	67,608
1250	48.1	0.6	48.7	74,131
1600	49.3	1.0	50.3	107,152
2000	49.5	1.2	50.7	117,490
2500	50.8	1.3	52.1	162,181
3150	51.4	1.2	52.6	181,970
4000	48.4	1.0	49.4	87,096
5000	46.3	0.5	46.8	47,863
6300	43.3	0.1	43.2	20,893
8000	40.3	-1.1	39.2	8,318
10000	38.6	-2.5	36.1	4,074
$\sum_{j=1}^{24} 10^{0.1(L_{wAj})}$ = 2,098,136				
$L_{wA} = 10 \cdot [\log_{10}(2{,}098{,}136)] = 63$ dBA				

APPENDIX E. DETERMINING SOUND POWER LEVELS USING SOUND PRESSURE MEASUREMENTS MADE IN A REVERBERATION ROOM-NORMATIVE

Section E1. Purpose

E 1.1 *Purpose.* The purpose of this appendix is to provide a procedure for determining the Sound Power Levels, L_W, by following a Comparison Method measurement in a broadband qualified reverberation room following ANSI/AHRI Standard 220.

All standard sound power level ratings shall be determined by tests conducted in a reverberation room meeting the requirements of ANSI/AHRI Standard 220. The room shall also be broadband qualified in accordance with ANSI/AHRI Standard 220. Only requiring broadband qualification is justified because the room volume is required to be large due to the size of the equipment to be measured. Because of the large room size and because most tones in this type of equipment will be at frequencies above the upper frequency qualification limit from ANSI/AHRI Standard 220 Section 5.2.7, discrete frequency qualification is allowed but not required.

Section E2. Sound Power Testing Requirements and Calculations

Sound Pressure Levels of the Reference Sound Source, background sound, and the Unit Under Test shall be measured using the same microphone traverse or positions, sound diffuser (if used), windscreen, instrumentation, and analyzer observation times as were used for the room qualification.

E2.1 *Volume of Unit Under Test, UUT*. The volume of the UUT shall be no more than 10% of the room volume.

E2.2 *Location of Unit Under Test*. Measurements shall be carried out with the UUT at a location within the area qualified per Section 4 of ANSI/AHRI Standard 220.

E2.3 *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 (in meters) between the microphone and each measurement location shall be determined from the Equation 1 in ANSI/AHRI Standard 220.

E2.4 *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 defined in Section 4.6 of ANSI/AHRI Standard 220.

E2.5 *Fixed Microphones.* If an array of microphones is used, it shall consist of at least six fixed microphones (or microphone positions) located per Section 4.7 in ANSI/AHRI Standard 220.

E2.6 *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. 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 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. 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.

E2.7 *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.

E2.8 *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 E1 and E2. The background limits and corrections are as indicated in Table E1. If the difference between the background and measured level is less than the limits shown in Table E1, 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 of ANSI/AHRI Standard 220. Note that when the differences between the background and UUT Sound Pressure Levels are less than those shown in Table E1, 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 E3 and rounded to the nearest 0.1 dB. When determining octave band levels per Section 6.6 in ANSI/AHRI Standard 220, 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.

$$L''_p = L_p - K_l \quad \text{E1}$$

$$L''_{pr} = L_{pr} - K_{lr} \quad \text{E2}$$

$$L_w = L_{wr} + (L''_p - L''_{pr}) \quad \text{E3}$$

Where:

K_1 = UUT background correction level, (dB re: 20 μPa), per Equation E5

K_{1r} = RSS background correction level, (dB re: 20 μPa), per Equation E6

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)

E2.8.1 *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 E4 through E7.

$$\Delta L = \overline{L'_{p(ST)}} - \overline{L_{p(B)}} \quad \text{E4}$$

$$\Delta L_r = \overline{L'_{pr(ST)}} - \overline{L_{p(B)}} \quad \text{E5}$$

$$K_1 = -10 \cdot \log\left(1 - 10^{-0.1 \cdot \Delta L}\right) \quad \text{E6}$$

$$K_{1r} = -10 \cdot \log\left(1 - 10^{-0.1 \Delta L_f}\right) \quad \text{E7}$$

Where:

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 E5 and/or E6. 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 E1 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 E5 and/or E6. 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 E1 lists the maximum background correction by One-third Octave Band.

Table E1. 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

The resulting values for Sound Power Level, $L_{W(n)}$ by One-third Octave Band shall be used to determine the equipment sound rating levels as described in Section 5 of this standard.

APPENDIX F. DETERMINING SOUND POWER LEVELS USING SOUND PRESSURE MEASUREMENTS MADE IN A FREE FIELD OVER A REFLECTING PLANE - NORMATIVE

Section F1. Purpose

F1.1 *Purpose.* The purpose of this appendix is to provide a procedure for determining the Sound Power Levels (L_W) by measuring sound pressure in an essentially free field over a reflecting plane, as adapted from ISO 3744 or in a free field condition above a reflecting plane in a hemi-anechoic room as adapted from ISO 3745.

Section F2. Test Method

F2.1 *Instrumentation.* The instrumentation and instrumentation systems employed shall meet the requirements of ANSI/AHRI Standard 220 except that the measurement microphone(s) shall be free field type.

F2.2 *Test Environment.* The test site shall be a flat, indoor or outdoor area free of reflecting objects other than the reflecting plane, such that the source radiates into a free field over a reflecting plane.

F2.2.1 The reflecting plane shall extend at least 3.5 m beyond the measurement surface. This distance is approximately equal to half a wavelength (λ/2) at 50 Hz (the lowest frequency of interest).

F2.2.2 The site shall meet the qualification requirements of ISO 3744 or ISO 3745 as applicable.

F2.2.3 The need for and the value of the environmental correction (K_2) to account for departures of the test environment from the ideal condition shall be determined using the procedure described in Appendix H. For the purposes of this document, the value of K_2 shall be limited to: -2.0 dB ≤ K_2 ≤ + 2.0 dB. The environmental correction (K_2) shall be determined by test only using a vertical shafted RSS that meets the requirements of and is calibrated per ANSI/AHRI Standard 250.

F2.3 *Microphone Measurement Points.* The points of sound pressure measurement shall be determined relative to a reference parallelepiped, the smallest imaginary rectangular parallelepiped, terminating on the reflecting plane, which will just enclose the machine. In determining the size of the reference parallelepiped, minor projections from the machine which are unlikely to be major radiators of sound energy may be disregarded.

F2.3.1 The measurement parallelepiped on which the microphones are positioned is a hypothetical surface of area enveloping the machine whose sides and top are parallel to the sides and top of the reference parallelepiped and are spaced at a distance of 1.0 m outward from the reference parallelepiped.

F2.3.2 The area of the measurement surface, *S*, is given by Equation F1 below:

$$S = \pi \cdot (L/2) \cdot ((W/2) + H) \qquad \text{F1}$$

Where:

H = Height of the measurement parallelepiped, m
L = Length of the measurement parallelepiped, m
S = Area of the measurement surface, m^2
W = Width of the measurement parallelepiped, m
Such that L ≥ W (Figures F1).

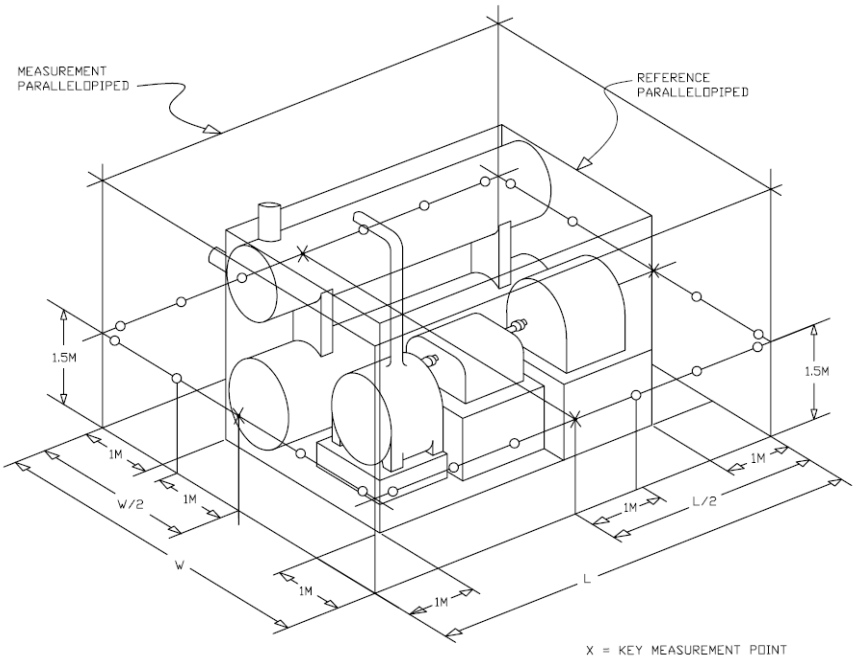

Figure F1. Three Dimensional View of Measurement Parallelepiped

Note: Equation F1 calculates an equivalent hemisphere area which is based on empirical data to give equivalency between the survey method and reverberation room method.

F2.3.3 The key measurement stations shall be located at the mid-point of each of the four sides of the measurement parallelepiped (Figure F1).

F2.3.3.1 Additional intermediate measurement stations shall be added extending outward at 1.0 m intervals from the key stations towards the corners of the measured parallelepiped. The distance between the last immediate and the corner stations may be less than, but shall be no greater than 1.0 m (Figure F1).

F2.3.3.2 Measurements shall be taken at two elevations at each station. The uppermost shall be in a horizontal plane 1.0 m above the top of the reference parallelepiped. The height (H) of the uppermost microphone shall not exceed 6.0 m. The second shall be at a level 1.5 m above the reflecting plane (Figure F1). If the height of the reference parallelepiped is 3.0 m or less, then measurements are only required at a height of 1.5 m.

F2.3.3.3 The surface Sound Pressure Level, L_{pf}, shall be adjusted by adding the value of the environmental correction, K_2 to account for departures of the test environment from the ideal condition.

F2.4 *Data to be Taken.* The Sound Pressure Level shall be measured and recorded in each of the One-third Octave Bands from 50 Hz to 10,000 Hz at each measurement position.

F2.4.1 A full set of measurements shall be taken with the equipment operating in each of the two modes specified in Section 4.2.1 of this standard.

F2.4.2 An additional measurement run shall be made to determine the background noise level at each measurement position.

Section F3. Calculation of Results

F3.1 *Correction for Background Noise.* Each of the measured Sound Pressure Levels, $L_{p(m)}$, shall be compared to the measured background noise, $L_{p(b)}$, at the same position and frequency and the correction for each microphone position and frequency shall be determined per ANSI/AHRI Standard 220.

F3.2 *Calculation of Surface Sound Pressure Level.* For each One-third Octave Band, once the measured value has been corrected for background noise, calculate the average Sound Pressure Level over the measurement surface, $\overline{L}_P$, adjusted for the environmental effects, $\overline{L}_{Pf}$, using Equations F2 and F3.

$$\overline{L}_P = 10 \cdot \log_{10}\left(\frac{1}{M}\sum_{m=1}^{M} 10^{0.10 \cdot L_{P(m)}}\right) \quad \text{F2}$$

Where:

$\overline{L}_P$ = Sound Pressure Level for each One-third Octave Band, averaged over the measurement surface, in dB, re: 20 μPa
$L_{P(m)}$ = Sound Pressure Level of the mth measurement, in dB, re: 20 μPa
M = The total number of measurement positions

$$\overline{L}_{Pf} = \overline{L}_P - K_2 \quad \text{F3}$$

Where:

$\overline{L}_{Pf}$ = Surface Sound Pressure Level in dB, re: 20 μPa
K_2 = Mean value of environmental correction over the measurement surface in decibels, as determined from Appendix H

F3.3 *Calculation of Sound Power Level.* The Sound Power Level, $L_{W(n)}$, characterizing the noise emitted by the source for each One-third Octave Band shall be calculated using Equation F4.

$$L_{W(n)} = \overline{L}_{Pf} + 10 \cdot \log\left(\frac{S}{S_0}\right) \quad \text{F4}$$

Where:

$L_{W(n)}$ = Sound Power Level in the nth One-third Octave Band, dB
S = Area of the measurement surface over which the measurements were averaged, m^2
S_0 = Reference surface area = 1.0 m^2

The resulting values for Sound Power Level, $L_{W(n)}$, by One-third Octave Band shall be used to determine the equipment sound rating levels as described in Section 5 of this standard.

APPENDIX G. POSSIBLE MAGNITUDE OF MEASUREMENT ERRORS – INFORMATIVE

Table G1. 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 - 5,000	1.5
6,300 - 10,000	3.0
Octave Band Center Frequency, Hz	Octave Band Maximum Standard Deviation of Reproducibility, σ_{R0}, dB
63	3.5
125	2.5
250	1.5
500 - 4,000	1.0
8,000	2.0
A-weighted 50-10,000 Hz	A-weighted Maximum Standard Deviation of Reproducibility, σ_{R0}, dB
A-weighted	0.5[1]

Note:
1. Applicable to a source which emits noise with a relatively "flat" spectrum in the frequency range 50 Hz to 10,000 Hz.

APPENDIX H. DETERMINATION OF K_2 – NORMATIVE

Section H1. Purpose

H1.1 *Purpose.* The purpose of this appendix is to provide a procedure for determining a correction factor, K_2, which quantifies the behavior of a Water-cooled Chiller test environment that deviates slightly from a free-field over a reflecting plane or a hemi-anechoic test room. This factor is used to mitigate the effects that the reverberant build-up of acoustic energy in the space will have on the calculation of sound power. The method detailed in this appendix compares a series of reference sound source sound pressure level measurements made in a known environment with a series of identical sound pressure level measurements made in the chiller test space to calculate the correction factor.

Section H2. Test Method

H2.1 *Instrumentation.* The instrumentation and instrumentation systems employed shall meet the requirements of ANSI/AHRI Standard 220 except that the measurement microphone(s) shall be a ½" diameter free field microphone with a windscreen. For all measurements, the microphone shall be oriented to point directly at the RSS.

H2.2 *Test Environments.* The test site for the control measurement shall be a flat, indoor or outdoor area free of reflecting objects other than the reflecting plane on which the test unit sits, such that the source radiates into a free field over a reflecting plane. The chiller test measurement site shall meet the requirements of Section F2.2.

Note: As examples, an outdoor space on a hard reflective surface with no walls (or obstructions) within 15 meters of the parallelepiped surface should qualify as a free field or a hemi-anechoic room qualified in accordance with ISO 3745 would meet the requirements for the test environment for the control series of measurements.

H2.3 *Microphone Measurement Points.* The points of sound pressure measurement shall be determined relative to a reference parallelepiped, the smallest imaginary rectangular parallelepiped, terminating on the reflecting plane, which will just enclose the machine to be tested. In determining the size of the reference parallelepiped, minor projections from the machine which are unlikely to be major radiators of sound energy may be disregarded.

H2.3.1 The measurement parallelepiped on which the microphones are positioned is a hypothetical surface enveloping the machine whose sides and top are parallel to the sides and top of the reference parallelepiped and are spaced at a distance of 1.0 m outward from the reference parallelepiped.

H2.3.2 The key measurement stations shall be located at the mid-point of each of the four sides of the measurement parallelepiped (Figure F1).

H2.3.3 Additional intermediate measurement stations shall be added extending outward at 1 m intervals, d, from the key stations towards the corners of the measured parallelepiped. The distance, f, between the last intermediate stations may be less than, but shall be no greater than 1m (Figure F1).

H2.3.4 The exact measurement parallelepiped shall be used for both the measurements conduct in the control space and in the chiller test area.

H2.4 *Reference Sound Source Positions.* The required number of reference sound source positions is a function of the length of the measurement parallelepiped and shall be determined using Figure H1 and Table H1:

Table H1. Required Number of RSS Positions Based on Parallelepiped Length

Measurement Parallelepiped Length, D(m)	Number of RSS positions
$D < 6$	1
$6 \leq D < 8$	2
$8 \leq D < 10$	3
$10 \leq D < 12$	4

H2.5 *Test Procedure – Qualified Room or Free-Field Area (Control).* In the qualified test area, the Sound Pressure Level shall be measured and recorded in each of the One-third Octave Bands from 50 Hz to 10,000 Hz at each measurement position using the following steps:

H2.5.1 Place the RSS at one of the source locations as indicated in Figure H1.

H2.5.2 Position a microphone that is fixed in a constant location and orientation within the parallelepiped at least 2 meters but not greater than 3 meters from the RSS. This measurement is used to monitor the stability of the RSS. Data at this fixed microphone shall be taken simultaneously with the measurements of the parallelepiped position data. The sound pressure level measured at this fixed location shall not vary by more than 0.5 dB over the duration of the test in any of the One-third Octave Bands from 50 Hz to 10,000 Hz in order for the measurement to be considered valid.

H2.5.3 Acquire one-third octave band sound pressure level data at each of the measurement positions on the parallelepiped with the RSS not in operation.

H2.5.4 Acquire one-third octave band sound pressure level data at each of the measurement positions on the parallelepiped with the RSS operating.

H2.5.4.1 If multiple RSS positions are required per Section H2.4, relocate the RSS to the additional position(s) and repeat the step in Section H2.5.3.

H2.6 *Test Procedure – Chiller Sound Test Area.* The Sound Pressure Level shall be measured and recorded in each of the One-third Octave Bands from 50 Hz to 10,000 Hz at each measurement position in the chiller test area using the method outlined in Sections H2.5.1 through H2.5.4.1.

Section H3. Calculation of Results

H3.1 *Correction for Background Noise.* Each of the measured Sound Pressure Levels, $L_{p(m)}$, shall be compared to the measured background noise ($L_{p(b)}$) at the same position and frequency and the correction for each microphone position and frequency shall be determined per ANSI/AHRI Standard 220 for both sets of data acquired in Sections H2.5 and H2.6.

H3.2 *Calculation of Surface Sound Pressure Level – Control Area.* For each One-third Octave Band, once the measured values from Section H2.5 have been corrected for background noise, calculate the average Sound Pressure Level over the control area measurement surface, $\overline{L}_{P_{CONTROL}}$, using Equation H1.

$$\overline{L}_{P_{CONTROL}} = 10 \cdot \log_{10}\left(\frac{1}{M} \sum_{m=1}^{M} 10^{0.10 \cdot L_{P(m)}} \right) \quad \text{H1}$$

Where:

$\overline{L}_{P\ CONTROL}$ = Sound Pressure Level for each One-third Octave Band, averaged over the control measurement surface, in dB, re: 20 μPa

$L_{P(m)}$ = Sound Pressure Level of the m^{th} measurement, in dB, re: 20 μPa

M = The total number of measurements made including all RSS locations

H3.3 *Calculation of Surface Sound Pressure Level – Test Area.* For each One-third Octave Band, once the measured values from Section H2.6 have been corrected for background noise, calculate the average Sound Pressure Level over the test area measurement surface, $\overline{L}_{P_{TEST}}$, using Equation H2.

$$\overline{L}_{P_{TEST}} = 10 \cdot \log_{10}\left(\frac{1}{M} \sum_{m=1}^{M} 10^{0.10 \cdot L_{P(m)}} \right) \quad \text{H2}$$

Where:

$\overline{L}_{P\ TEST}$	=	Sound Pressure Level for each One-third Octave Band, averaged over the test measurement surface, in dB, re: 20 μPa
$L_{P(m)}$	=	Sound Pressure Level of the m^{th} measurement, in dB, re: 20 μPa
M	=	The total number of measurements made including all RSS locations

H3.4 *Calculation of K_2.* For each One-third Octave Band, the environmental correction, K_2, can be calculated by subtracting the average sound pressure level for the control area from the test area using Equation H3.

$$K_2 = \overline{L}_{P_{TEST}} - \overline{L}_{P_{CONTROL}} \quad \text{H3}$$

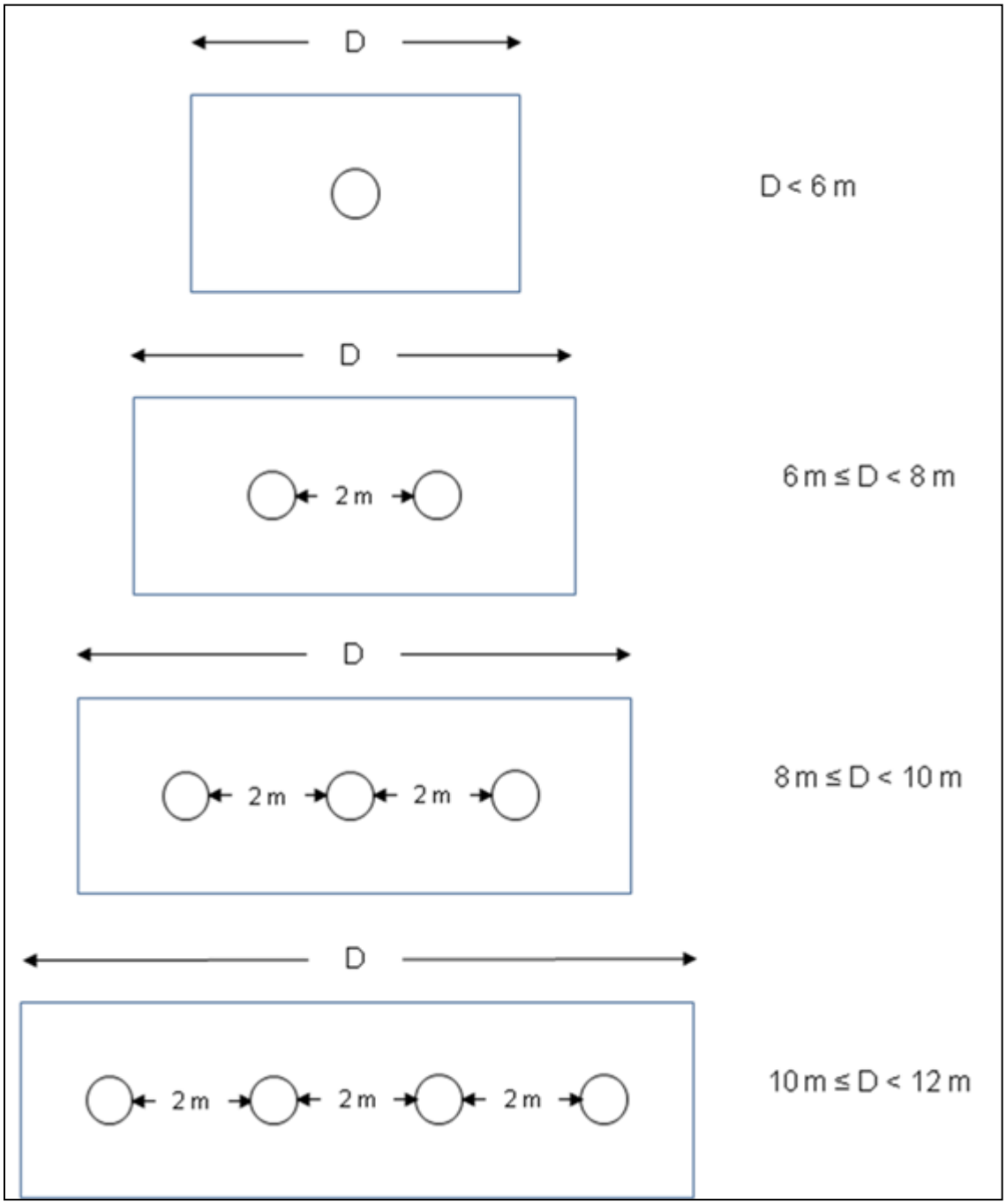

Figure H1. Schematic of RSS Locations Required for Determination of K_2