ANSI/AHRI Standard 261 (SI)

2012 Standard for

Sound Rating of Ducted Air Moving and Conditioning Equipment

Approved by ANSI on June 26, 2013

AHRI Air-Conditioning, Heating, and Refrigeration Institute

2111 Wilson Boulevard, Suite 500
Arlington, VA 22201, USA
www.ahrinet.org

PH 703.524.8800
FX 703.562.1942

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Note:

This standard supersedes AHRI Standard 260-2001 and differs in the following ways.

- Data in the 63 Hertz Octave Band is required;
- Sound power shall be determined following AHRI Standard 220 procedures if a reverberation room is used;
- Sound power shall be determined following ISO 9614 procedures if Sound Intensity is used;
- The Duct End Correction shall be determined following ASHRAE Technical Report 1314;
- Acoustic Test Elbow corrections shall follow the method described by Beranek (1960).

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SOUND RATING OF DUCTED AIR MOVING AND CONDITIONING EQUIPMENT

Section 1. Purpose

1.1 *Purpose*. The purpose of this standard is to establish a method of sound rating the indoor portions of ducted air moving and conditioning equipment. The standard provides definitions; requirements for acquiring mapped sound data; sound power level calculations and ratings; minimum data requirements for published sound ratings; 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.

1.2 *Rationale*. Ducted Equipment presents unique challenges when providing sound ratings since their ratings are used to both compare products and to provide the information necessary to predict application sound levels. For these reasons, the sound ratings shall define the sound coming from various portions of the equipment (Sound Components). The Sound Components are the Sound Sources that impact the application sound paths.

Ducted air-conditioning equipment can have ducted discharge, ducted inlet, and casing radiated Sound Components. Depending on its applied configuration, free discharge (or free inlet) combined with the casing radiated sound component may also be needed. All Sound Components are acoustically described/rated by utilizing a mapped sound rating approach that is typically referenced to the product's supply fan operating map. The supply fan is contained in the Base Unit of the product. In addition, this standard defines an approach to account for the acoustical effects of product Appurtenances (such as modulation devices or discharge/inlet plena) and other Sound Sources (such as the refrigeration circuit, return and exhaust fans, etc.) to the Base Unit Mapped Sound Rating. Thus, a Mapped Sound Rating can be developed for a given product configuration and each of its various Sound Components defining the sound for any product operating condition. Figure 1 presents an example of a typical product application showing the relationship between the product Sound Components and the various application sound paths. Figure 2 presents an example of a typical vertically ducted product depicting the contribution of the various product Sound Sources on the Sound Components.

All Sound Components are tested utilizing either a reverberation room (qualified by test) or using Sound Intensity. Reverberation room tests are conducted using the Comparison Method and a calibrated Reference Sound Source, while the Sound Intensity tests are conducted using measurements made at discrete points or by the scanning method. Sound ratings are in the form of Octave Band Sound Power Levels (dB) from 63 to 8000 Hz derived from One-third Octave Band measurements. In addition to the stated Octave Band ratings, this standard can be used to provide One-third Octave Band sound ratings from 50 to 10,000 Hz.

In the example presented in Figure 1, there are two Sound Components present, ducted discharge and free inlet combined with casing radiated. The ducted discharge sound component affects or defines the source strength for two application sound paths 1) the supply duct airborne sound and 2) the supply duct breakout sound. The free inlet combined with casing radiated sound component affects or defines the source strength for the 3) return airborne and 4) wall transmission application sound paths.

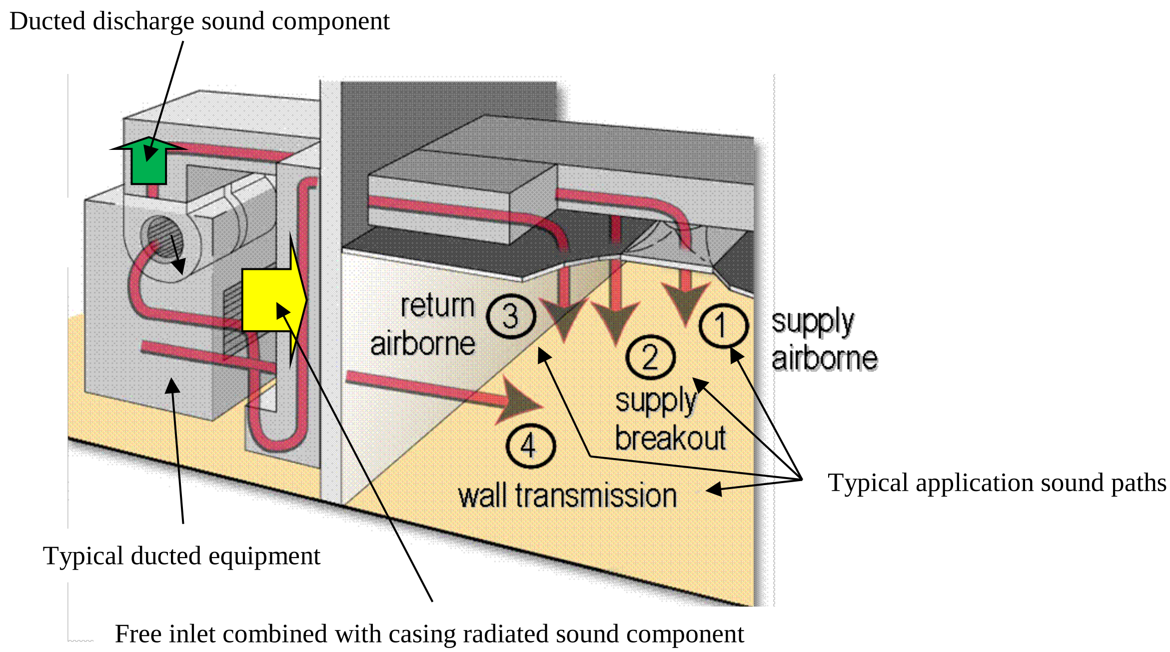

Figure 1 – Typical Ducted Product Application

In Figure 2, a typical vertical ducted unit is presented with its Sound Components and their contributing product Sound Sources. In this example, there are two Sound Components, the ducted discharge and the ducted inlet. The ducted discharge sound component is first defined by the supply fan discharge sound in the Base Unit coupled with the discharge plenum. The contribution of appurtenance sound from supply fan discharge airflow impinging the heat exchanger in the discharge plenum must also be added to the supply fan discharge sound. Finally, the effects of the other sources on the ducted discharge sound from the condenser fans and the refrigerant circuit must be considered. For the ducted inlet sound component, the sound from the return side of the return fan is first considered. In this case, the return side sound from the supply fan contributes as another sound source.

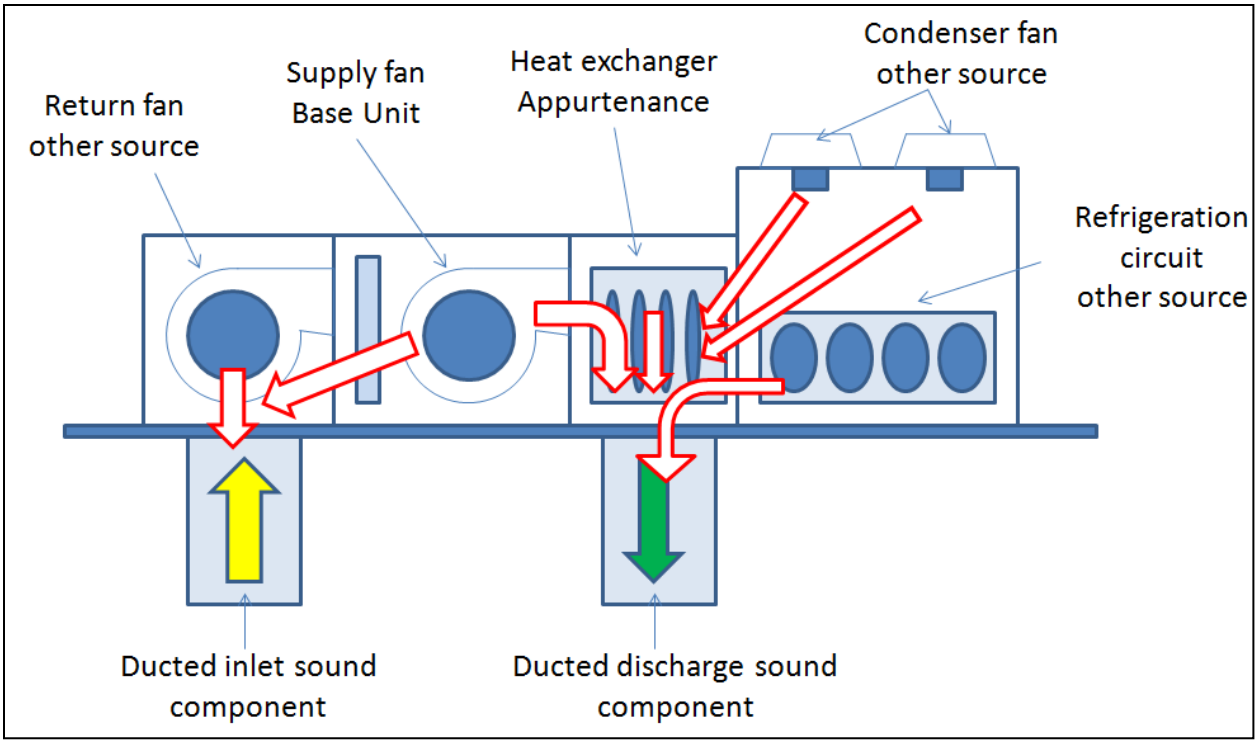

Figure 2 – Relationship Between Sound Components and Sound Sources

Section 2. Scope

2.1 *Scope.* This standard applies to Ducted Equipment and specifies the methods for the determination of the sound power rating of the indoor sections of factory-made residential, commercial and industrial air-conditioning and Heat Pump equipment, which are electrically driven, with mechanical compression and containing fans, using mapped sound data for rating the various product Sound Components. Sound power ratings reported are octave-band Sound Power Levels from 63 Hz to 8000 Hz. The terms Air-Conditioner and equipment are used to mean Air-Conditioners and Heat Pumps in this part of the standard. In addition to the stated Octave Band ratings, this standard can additionally be used to provide One-third Octave Band sound ratings from 50 to 10,000 Hz.

Section 3. Definitions

All terms in this document will follow the standard industry definitions in the *ASHRAE Wikipedia* website (http://wiki.ashrae.org/index.php/ASHRAEwiki) unless otherwise defined in this section.

3.1 *Acoustic Baffle*. A barrier that creates a well defined duct termination and test surface for a ducted sound intensity measurement. The barrier is rigid and non-absorbing.

3.2 *Acoustic Test Duct*. A duct used to convey the sound of the unit configuration under test to the reverberation room or intensity surface during a ducted discharge or ducted inlet sound component test. A Duct End Correction shall be added to the sound data measured in the reverberation room or from the intensity method to account for the presence of the duct termination.

3.3 *Acoustic Test Duct Elbow.* An elbow that may be added to the Acoustic Test Duct to facilitate testing. An Acoustic Test Duct Elbow Correction, shall be made (in addition to the Duct End Correction) to the sound data to account for the presence of the Acoustic Test Duct Elbow.

3.4 *Acoustic Test Duct Elbow Correction (E_2)***.** A correction in a frequency band to account for insertion loss effects of the elbow on the sound propagating through the Acoustic Test Duct. The table in Appendix C of this standard defines the Acoustic Test Duct Elbow Correction.

3.5 *Appurtenance***.** An addition to a Base Unit for purposes of air modulation, heat transfer, control, isolation, safety, static pressure regain, etc.

Examples of Appurtenances include:

1. Coil(s)
2. Electric heater(s)
3. Air filter(s)
4. Damper(s)
5. Moisture eliminator(s)
6. Fan-motor drive(s)
7. Gas heat exchanger(s)
8. Inlet or discharge plena
9. Modulating device(s) in the fan inlet/discharge
10. Application duct geometry(s) (such as duct elbow configurations)
11. Alternate unit casing construction(s) (such as double walled, lined, perforated face)

3.6 *Air-Conditioner***.** One or more factory-made assemblies which normally include an evaporator or cooling coil, a compressor and condenser combination, and may include a heating function; where such equipment is provided in more than one assembly, the separated assemblies shall be designed to be used together.

3.7 *Base Unit***.** A factory-made encased assembly consisting of one or more fans meant to be connected to a duct and other necessary equipment to perform one or more of the functions of circulating, cleaning, heating, cooling, humidifying, and mixing of air, but which may or may not include a source of heating or cooling.

3.8 *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.

3.9 *Ducted Equipment***.** Heating, ventilating and air conditioning equipment having one or more supply fans which employ ductwork to convey the conditioned air to and/or from the desired space. Ducted Equipment may have various combinations of discharges and inlets as follows:

3.9.1 Ducted discharge(s) and ducted inlet(s).
3.9.2 Ducted discharge(s) with free inlet(s).
3.9.3 Ducted inlet(s) with free discharge(s).

This equipment may be ducted in various configurations horizontally and vertically, and may incorporate multiple inlets and outlets.

3.10 *Duct End Correction (E_1)***.** A correction in a frequency band that accounts for the acoustic energy in an Acoustic Test Duct that is prevented from entering the test space by the impedance mismatch created by the termination of the Acoustic Test Duct. A method for computing the Duct End Correction is described in Section 5.2.1 of this standard.

3.11 *Effective Diameter*. The diameter of an Acoustic Test Duct which is equal to either the diameter of a circular duct or the Effective Diameter of a rectangular duct calculated according to Equation 1, m:

$$D_e = \left(\frac{4A}{\pi}\right)^{1/2} \qquad 1$$

Where:

A = Cross-sectional area of the duct, m^2
D_e = Effective Diameter, m

3.12 *Heat Pump***.** One or more factory-made assemblies which normally include an indoor conditioning coil, a compressor and outdoor heat exchanger (including means to provide a heating function), and may optionally include a cooling function. When such equipment is provided in more than one assembly, the separated assemblies shall be designed to be used together.

3.13 *Hertz (Hz).* Unit of frequency in cycles per second.

3.14 *Mapped Sound Rating.* Equipment sound ratings that are based upon a series of tests performed across the range of operating conditions determined typically from a flow pressure map for the product supply fan and as defined by the equipment manufacturer. Contributions due to Appurtenances and other sources such as return fans, exhaust fans, and the refrigeration circuit are superimposed on the supply fan sound rating map. One-third Octave Band Sound Power Levels are obtained for each test point of the series to provide Octave Band sound power ratings. The mapped rating process is defined in Section 6.2. A special case exists when a supply fan is used in conjunction with a return or exhaust fan in the Base Unit (See Appendix D).

3.15 *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.

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

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

3.18 *Reference Sound Source (RSS).* A portable, aerodynamic sound source that produces a known stable broad band sound power output as defined in AHRI Standard 250.

3.19 *Reproducibility*. The degree of agreement in test results obtained with the same method on identical test items in different laboratories with different operators using different equipment.

3.20 *Sound Components*. The product sound that can be independently defined to describe a product's contribution to the various sound paths in a typical application. The Sound Components that may need to be defined for a given product consist of one or more of the following:

3.20.1 Ducted discharge

3.20.2 Ducted inlet

3.20.3 Casing radiated

3.20.4 Free discharge (or free inlet) combined with casing radiated

3.20.5 Free discharge (or free inlet)

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

3.22 *Sound Intensity Level, L_i*. 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.

3.23 *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).

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

3.25 *Sound Sources*. Any phenomenon occurring within the unit that contributes to the product sound. For the purposes of this standard there are three types of Sound Sources. Their combined effects are added together to obtain the total sound for a given product sound component. The three types of Sound Sources are:

3.25.1 Base Unit: sound generated by the primary fan(s) in the Base Unit.

3.25.2 Appurtenance: *s*ound generated or attenuated due to the Appurtenance having airflow through or impacting it.

3.25.3 Other: *s*ound generated by an element that is not caused by primary fan airflow through or impacting the element in the product. The refrigerant circuit, airborne noise from a variable frequency drive (VFD) ventilation fan, motor noise, gas burner combustion noise, outdoor air condenser fans, and secondary fans, such as return fans and exhaust fans (See Appendix D).

Section 4. Requirements for Acquiring Sound Data

4.1 *General Test Considerations.* This standard incorporates a reverberation room Comparison Method and/or a Sound Intensity method to obtain the Sound Power Levels of the various Sound Components for ducted air-moving and air-conditioning equipment. These methods yield the Sound Power Levels for a complete ducted unit by adding the effects of Appurtenances and other Sound Sources to the sound of the Base Unit as required.

When using the reverberation room method, Sound Power Levels shall be determined using AHRI Standard 220. The reverberation room method of qualification, method of test, facilities, and requirements are per AHRI Standard 220 or as defined in the body of this standard in Sections 4.2 through 4.6.

When using the intensity method, Sound Power Level shall be determined in accordance with ISO 9614-1 (grade 2) and ISO 9614-2 (grade 2), using the method outlined in Appendix F and the requirements in Section 4.2 through 4.5 and 4.7.

4.2 *Equipment Configurations and Sound Components.*

Only those Sound Components that apply to how the product is installed and used shall be included in the product sound rating. The appropriate sound component(s) shall be selected based on the product application.

4.2.1 *Equipment with Ducted Discharge(s) and Ducted Inlet(s).* The following sound component Sound Power Levels can be determined for this configuration:

4.2.1.1 Ducted discharge
4.2.1.2 Ducted inlet
4.2.1.3 Casing radiated

4.2.2 *Equipment with Ducted Discharge(s) and Free Inlet(s).* The following sound component Sound Power Levels can be determined for this configuration:
4.2.2.1 Ducted discharge
4.2.2.2 Optional free inlet
4.2.2.3 Optional free inlet combined with casing radiated

The free inlet combined with casing radiated sound power component shall not be derived from separate free inlet and casing radiated sound tests.

4.2.3 *Equipment with Ducted Inlet(s) and Free Discharge(s).* The following sound component Sound Power Levels can be determined for this configuration:
4.2.3.1 Ducted inlet
4.2.3.2 Optional free discharge
4.2.3.3 Free discharge combined with casing radiated

The free discharge combined with casing radiated sound power component shall not be derived from separate free discharge and casing radiated sound tests.

4.3 *Method of Test.*

4.3.1 *General***.** All sound tests shall be conducted using either the AHRI Standard 220 reverberation room Comparison Method or the ISO 9614 Sound Intensity method. The specific test set-up will depend on the product Sound Components being tested. The tests can be divided into two basic types: ducted sound component tests and non-ducted sound component tests. For ducted sound component tests, the sound component of interest is ducted into the test space with an Acoustic Test Duct. For non-ducted sound component tests, the unit may either be located in the test space with the untested Sound Components being ducted out, or the unit is located adjacent to the test space without an Acoustic Test Duct.

4.3.2 *Ducted Sound Components* For ducted discharge and ducted inlet Sound Components tested in accordance with this standard, a Duct End Correction (E_1) (as computed in Section 5.2.1 of this standard) shall be added to each One-third Octave Band. The addition of the Duct End Correction (E_1) provides the user with the sound power that would be transmitted into an acoustically, non-reflective duct system.

Products having multiple ducted discharges or multiple ducted inlets on a common face that are meant by the manufacturer to join into a common duct shall be tested at the same time. A Duct End Correction (E_1) of only one of the ducts shall be made. However, if products have multiple ducted inlets or discharges on a common face or different faces, and are not joined into a common duct, each shall be tested separately. Duct End Corrections shall be made for each of the ducts.
An airflow control device, such as an orifice end plate, shall not be placed in the Acoustic Test Duct. However, airflow control devices can be part of other test ducts or plenum not related to the sound component under test.

Although a straight Acoustic Test Duct is preferred for ducted sound component tests, an Acoustic Test Duct Elbow may be used to accommodate test facility and unit set-up limitations. If an Acoustic Test Duct Elbow is employed, Acoustic Test Duct Elbow Corrections (E_2) shall be added to the sound data to account for attenuation of the Acoustic Test Duct Elbow using Appendix C.

4.3.3 *Test Unit Airflow Measurements.* All test airflow measurements shall be made in accordance with either ANSI/AMCA Standard 210/ASHRAE 51 or ASHRAE 37.

4.4 *Test Set-up Configurations.*

4.4.1 *Ducted Discharge Tests.* For this test the unit discharge is ducted into a test space using an Acoustic Test Duct. When using a reverberation room, sound measurements of the ducted discharge component shall be conducted using AHRI Standard 220. When using Sound Intensity, sound of the ducted discharge component shall be determined using Appendix F. Test configurations are conceptually shown (and not to scale) in Figure 3 or 4. For either reverberation room or Sound Intensity tests, a Duct End Correction (and Acoustic Test Duct Elbow Correction if needed) shall be added to the Sound Power Level to account for the acoustic energy that is prevented from entering the test space by the impedance mismatch created by the termination of the Acoustic Test Duct. For ducted discharge tests, it is recommended that the Acoustic Test Duct be three effective duct diameters in length, but shall not be less than 1m. However, duct lengths up to five effective duct diameters are permissible if needed for set-up or airflow performance measurement considerations.

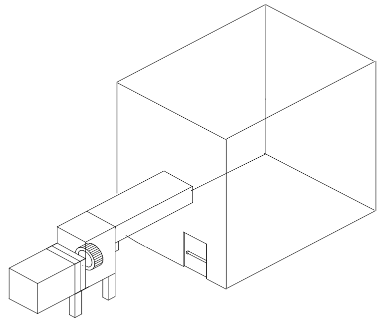

Figure 3 – Concept Reverberation Room Ducted Discharge Test Set-up

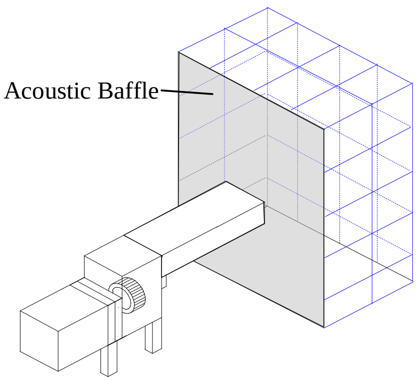

Figure 4 – Concept Sound Intensity Ducted Discharge Test Set-up

4.4.2 *Ducted Inlet Test.* For this test, the unit inlet is ducted into a test space using an Acoustic Test Duct. When using a reverberation room, sound measurements of the ducted inlet component shall be conducted using AHRI Standard 220. When using Sound Intensity, sound of the ducted inlet component shall be determined using Appendix F. Test configurations are conceptually shown (and not to scale) in Figure 5 or 6. For either reverberation room or Sound Intensity tests, a Duct End Correction (and Acoustic Test Duct Elbow Correction if needed) shall be added to the Sound Power Level to account for the acoustic energy that is prevented from entering the test space by the impedance mismatch created by the termination of the Acoustic Test Duct. For ducted inlet tests, it is recommended that the Acoustic Test Duct be one effective duct diameter in length, but shall not be less than 1m. However, duct lengths up to five effective duct diameters are permissible if needed for set-up or airflow performance measurements.

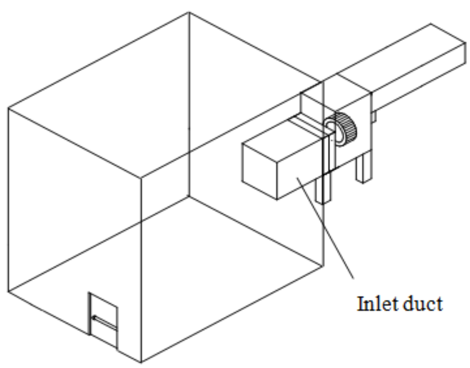

Figure 5 – Concept Reverberation Room Ducted Inlet Test Set-up

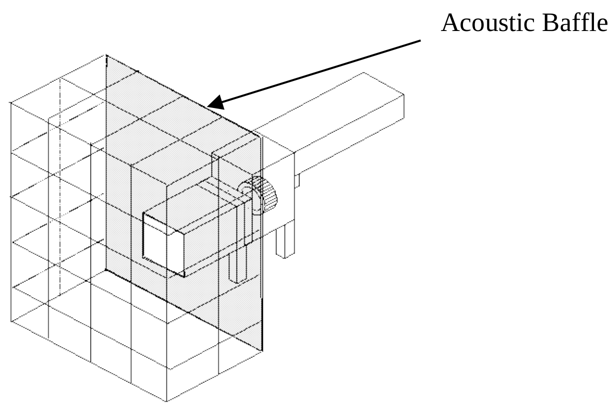

Figure 6 – Concept Sound Intensity Ducted Inlet Test Set-up

4.4.3 *Casing Radiated Test.* The casing of the unit shall be in the test space with both the inlet and the discharge ducted out of the test space. For reverberation room tests, the sound shall be measured using AHRI Standard 220. For Sound Intensity, the sound shall be determined in accordance with Appendix F. The test configurations are conceptually shown (and not to scale) in Figures 7 and 8. A duct with high transmission loss walls to minimize breakout into the test space per Section 4.6.1.3 shall be used.

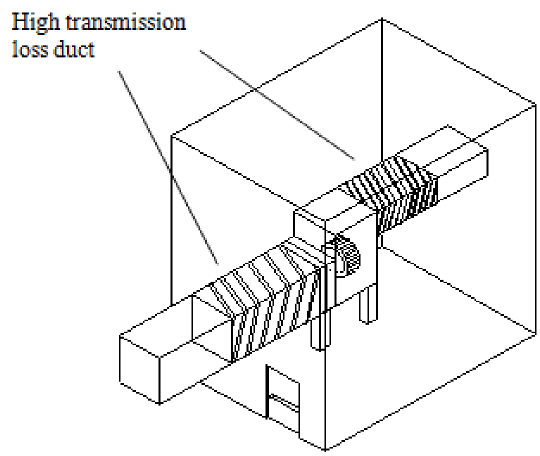

Figure 7 – Concept Reverberation Room Casing Radiated Test Set-up

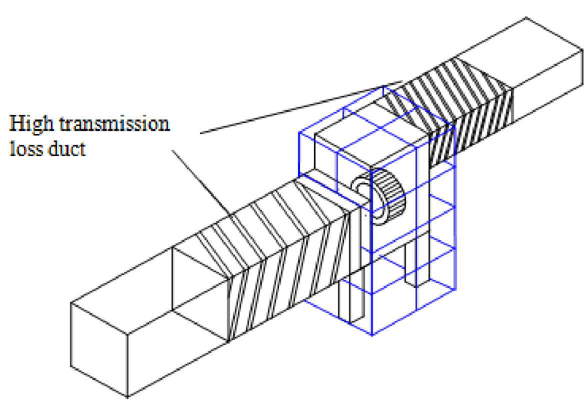

Figure 8 – Concept Sound Intensity Casing Radiated Test Set-up

4.4.4 *Free Discharge or (Free Inlet) Combined with Casing Radiated Test.* For this test, the unit discharge (or the inlet) is ducted out of the test space. The sound component of the free discharge (or inlet) combined with casing radiated sound shall be measured using AHRI Standard 220 when using a reverberation room and Appendix F when using Sound Intensity. The test configurations are conceptually shown (and not to scale) in Figures 9 and 10. A duct with high transmission loss walls to minimize breakout into the test space per Section 4.5.1.3 shall be used.

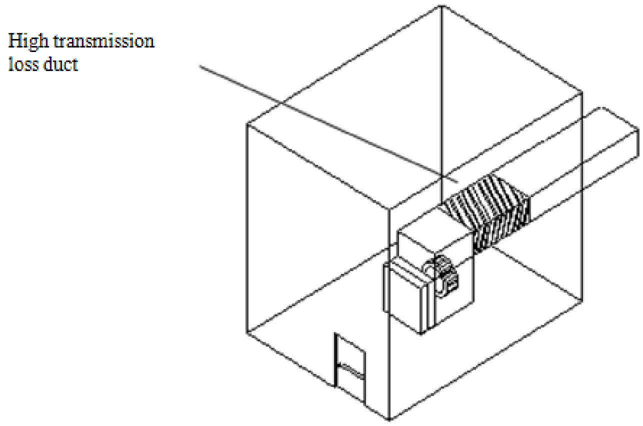

Figure 9 – Concept Reverberation Room Free Discharge (or Inlet) Combined with Casing Radiated Test Set-up

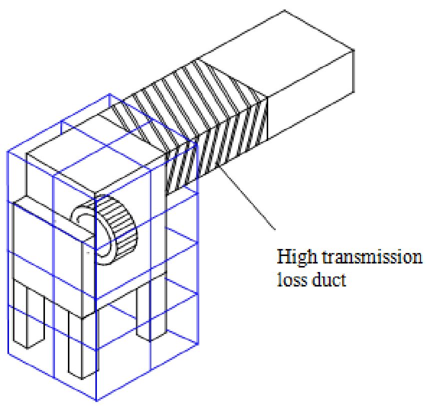

Figure 10 – Concept Sound Intensity Free Discharge (or Inlet) Combined with Casing Radiated Test Set-up

4.4.5 *Free Discharge or Free Inlet Test.* For this test, the free discharge or free inlet of the unit shall be directly connected to the test space with the minimum amount of duct. The sound component of the free discharge (or inlet) shall be measured using AHRI Standard 220 when using a reverberation room and Appendix F when using Sound Intensity. The test configurations are conceptually shown (and not to scale) in Figures 11 and 12. In Figure 12, the diagram on the left is typical for low air velocity and figure on right typical for high air velocity.

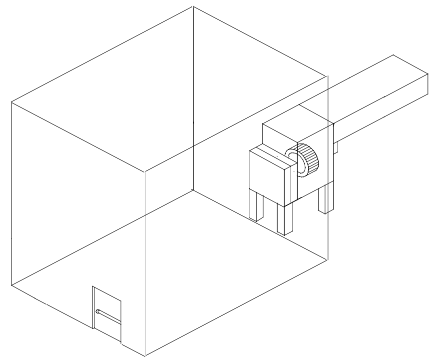

Figure 11. Concept Reverberation Room Free Discharge (or Inlet) Test Set-up

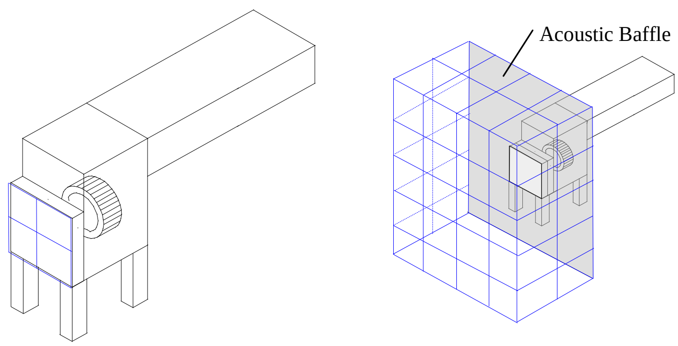

Figure 12 – Concept Sound Intensity Free Discharge (or Inlet) Test Set-up

4.5 *General Test Set-up (Reverberation Room and Sound Intensity).* Equipment configurations described in Sections 4.5.1 through 4.5.4 are applicable for both reverberation room testing per AHRI Standard 220 and for testing employing the Sound Intensity method as outlined in Appendix F of this standard.

4.5.1 *Ductwork Required for Testing*. Ductwork attached to the unit under test may influence the sound measured, thus care shall be taken in the attachment and treatment of all ductwork.

4.5.1.1 *Ductwork Size.* Ductwork shall be sized to match the manufacturer's recommended supply or return opening and shall maintain constant duct dimensions. If the manufacturer does not define the supply or return opening, it is recommended that the Acoustic Test Duct be sized for a maximum velocity of 10 m/s. The ratio of the longer to the shorter sides of the rectangular duct cross-section shall not exceed four unless this is not possible due to the manufacturer's specifications.

4.5.1.2 *Ductwork Connection.* Ductwork should be connected to the unit under test using a flexible gasket or connector. All flexible duct connections shall be maintained to retain flexibility and to contain the sound within the duct. The length of the flexible connection shall not contribute to the transmission loss of the ductwork.

4.5.1.3 *Construction of Test Ductwork.* The test duct wall transmission loss characteristics required vary with the type of rating test being conducted (casing radiated being the most stringent), the surface area of test duct in the test space, and the relative sound levels in the test duct versus the test unit radiation level into the test space. For this reason, it is difficult to quantify the wall transmission loss characteristics. However, experience conducting tests with typical products has shown that the following duct construction methods provide reasonable results. It should also be noted that when testing products with low sound emissions, test set up diagnostic tests may need to be conducted to confirm that adequate test duct wall transmission loss characteristics exist.

The Acoustic Test Duct shall have walls with high transmission loss construction and shall not have internal absorptive lining. The test ductwork shall be any of the following:

4.5.1.3.1 A minimum of 1.2 mm thick sheet metal stiffened by a minimum of 19 mm thickness gypsum board attached by sheet metal screws on 152 mm centers and bonded to the exterior of the duct

4.5.1.3.2 Round sheet metal or PVC duct with a minimum of 4.88 kg/m^2 limp exterior acoustical barrier

4.5.1.3.3 A minimum of 19 mm plywood. For high aspect ratio ducts, it may also be necessary to stiffen the 19 mm plywood.

4.5.1.3.4 Other configurations may be used if shown by test to provide equivalent transmission loss, and other acoustic characteristics, when compared to the above construction methods.

4.5.2 *Duct Static Pressure Taps.* Static pressure taps shall be in accordance with either ANSI/AMCA Standard 210/ASHRAE 51 or ASHRAE 37.

4.5.3 *Acoustic Test Ducts and Acoustic Duct Elbow.* For testing of ducted discharge or inlet, straight Acoustic Test Ducts are recommended. However, the standard allows for the use of an Acoustic Test Duct Elbow due to facility or set-up limitations. The use of an Acoustic Test Duct Elbow, its description, and the corrections applied shall be stated in the test report. If elbows are needed, the corrections given in Appendix C shall be used. The Acoustic Test Duct shall meet the construction requirements from Section 4.5.1.3.

4.5.4 *High Transmission Loss Duct Construction*. A special duct construction that limits the contribution of duct radiated sound to the component sound shall be used as illustrated in Figures 7 through 10. Acoustical duct lagging or thicker/ higher density duct walls are typically required. Sound Intensity can be used to determine the relative contribution of the duct radiation to the unit radiation. Alternatively, successive iterations of sound power measurements can be conducted with additional lagging to determine the adequacy of the ducts. No adjustments to the component sound power are allowed for contamination from duct radiation.

4.5.5 *Acoustic Baffle*. A barrier shall be constructed to terminate the duct and extend beyond the sound intensity measurement surface as defined in Section F5.1. A typical construction would be 19 mm ply-wood with stiffeners.

4.6 *Test Instrumentation and Facilities (Reverberation Rooms).* This section defines the reverberation room to be used for sound power testing.

4.6.1 *Reverberation Room Instrumentation.* The reverberation room instrumentation shall meet or exceed the requirements as stated in AHRI Standard 220.

4.6.2 *Reverberation Room Qualification.* The reverberation room used in testing shall be qualified, and shall meet the qualification requirements, as specified in AHRI Standard 220 for the One-third Octave Bands from 50 Hz to 10,000 Hz. Additionally, the reverberation room shall meet all the requirements as specified in AHRI Standard 220.

4.6.3 *Reference Sound Source (RSS).* The Reference Sound Source shall be calibrated in accordance with AHRI Standard 250.

4.6.4 *Test Unit Size.* For reverberation room testing, the total volume of the test unit, including ductwork, shall not exceed 5 % of the volume of the reverberation room.

4.6.5 *Use of Windscreen.* During testing, a windscreen may be used on the microphone. The effect of the windscreen on the microphone response shall not be more than ± 1 dB for frequencies of 50 to 4 000 Hz or ± 1.5 dB for frequencies from 4,000 to 10,000 Hz. Sound measurements shall not be made with air velocities over the microphone exceeding 2 m/s.

4.6.6 *Airflow Limitation.* For sound test measurements made within a reverberation room, it is recommended that the airflow of the test unit, m^3/min, not exceed, numerically, the room volume, m^3.

4.7 *Test Instrumentation and Facilities (Sound Intensity).* The requirements for test equipment and facilities for Sound Intensity are defined in Appendix F.

4.8 *Test Method Measurement Reproducibility.* Sound Power Levels obtained from either reverberation room or intensity measurements made in conformance with this standard should result in measurement standard deviations which are equal to or less than those in Table 1. For the reverberation room Comparison Method this table represents the uncertainty that would result from using AHRI Standard 220 and a Reference Sound Source calibrated per AHRI Standard 250. For the intensity method, 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 -- Reproducibility in the Determination of Ducted Equipment Sound Power Levels

Octave Band Center Frequency, Hz	One-third-Octave Band Center Frequency, Hz	Maximum Standard Deviation (dB) of Reproducibility
63	50 to 80	4.0
125	100 to 160	3.0
250	200 to 315	2.0
500 to 4000	400 to 5000	1.5
8000	6300 to 10000	3.0

4.9 *Information to be Recorded.* The following shall be compiled and recorded for measurements that are made according to the requirements of this standard to document the ducted noise ratings provided by this standard:

4.9.1 Description of unit under test and descriptive photograph
4.9.2 One-third Octave Band Sound Power Levels with end corrections (if applicable) included, dB
4.9.3 One-third Octave Band Duct End Corrections, dB, and description of how duct was terminated in the test space
4.9.4 Duct internal height, width, and length dimensions, m

4.9.5 Acoustic test duct elbow octave band correction, dB (if used)

4.9.6 Acoustic test elbow duct internal height and width dimensions (if used), length and location of the elbow in the duct, m

4.9.7 Description of thermal conditions during test

4.9.8 Airflow m^3/s, duct static pressure kPa, fan speed rev/s, fan motor BHP for each test point

4.9.9 Sound component measured

4.9.10 Test date

4.9.11 Test method used

4.9.11.1 *Unit Under Test.* Description of Base Unit shall include the following information to clearly identify the unit under test:

4.9.11.1.1 Fan type, model, manufacturer and size

4.9.11.1.2 Cabinet wall construction and size

4.9.11.1.3 Motor manufacturer and size

4.9.11.1.4 Operating conditions (fan speed rev/s, airflow m^3/s, fan static pressure kPa, and air density kg/m^3)

4.9.11.1.5 Installation/mounting details

4.9.11.1.6 Description of Appurtenances

4.9.11.1.7 Description of other Sound Sources

4.9.11.1.8 Acoustic test duct dimensions, m

4.9.11.1.9 Acoustic test duct elbow dimensions, m

4.9.12 *Thermal Conditions During Test.*

4.9.12.1 Air temperature, ^{o}C

4.9.12.2 Relative humidity, %

4.9.12.3 Barometric pressure, kPa

4.9.13 *Instrumentation.*

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

4.9.13.2 Description (manufacturer, model and serial number) of Reference Sound Source used

Section 5. Sound Level Calculations

5.1 *General.* This standard utilizes an octave band sound power level rating system based on one-third octave band sound level test data, determined by a reverberation room test method or sound intensity test method. Ducted Sound Components (ducted discharge or ducted inlet) shall include Acoustic Test Duct End Corrections and the effects of the Acoustic Test Duct Elbow (if used), for either a reverberation room or sound intensity test. The non-ducted Sound Components (casing radiated, free inlet combined with casing radiated and free components) do not have the duct correction considerations that are employed in the ducted component cases.

5.2 *Determination of Component One-third Octave Sound Power Levels.* The measured one-third octave band sound pressure level data acquired in a reverberation room in accordance with Section 4 shall be converted to One-third Octave Band Sound Power Levels using the calculation procedures in Section 6 of AHRI Standard 220. For intensity measurements, Sound Power Levels are directly determined from the measurements in Appendix F. Adjustments for the Duct End Correction ($E_{1(n)}$), as outlined in Sections 5.2.1 and 5.2.2, and/or the Acoustic Test

Elbow ($E_{2(n)}$) as outlined in Section 5.2.3 shall be added to the calculated One-third Octave Band Sound Power Levels using Equation 3.

$$L'_{w\,(n)} = L_{w(n)} + E_{1(n)} + E_{2(n)} \tag{3}$$

Where:

$L'_{w\,(n)}$ = Test unit component Sound Power Level, dB, for the n[th] One-third Octave Band adjusted for the Acoustic Test Duct End Correction and the Acoustic Test Duct Elbow Correction, if required

$L_{w(n)}$ = Test unit component Sound Power Level, dB, for the n[th] One-third Octave Band, determined by the reverberation room or sound intensity test methods

$E_{1(n)}$ = Acoustic Test Duct End Correction for the n[th] One-third Octave Band for either a duct terminating flush with a wall or terminating free in space (see Sections 5.2.1 and 5.2.2). If no test duct is used for this component then $E_{1(n)} = 0$

$E_{2(n)}$ = Acoustic Test Duct Elbow Correction for the n[th] One-third Octave Band (see Section 5.2.3). If no test elbow is used for this component then $E_{2(n)} = 0$

5.2.1 *Calculation of the Acoustic Test Duct End Correction.* For ducted inlet or ducted discharge Sound Components tested in accordance with this standard, the Duct End Correction shall be added to each One-third Octave Band Sound Power Level. The addition of the Duct End Correction to the tested Sound Power Levels will provide the user with the sound power that would be transmitted into a non-reflecting duct system.

For a ducted discharge or ducted inlet tests, the value for the Duct End Correction depends on the duct termination in the test space. For an Acoustic Test Duct terminating flush, or less than $3{\cdot}D_e$ from any acoustically reflective surface, Equation 4 shall be used to calculate the Duct End Correction. For an Acoustic Test Duct terminating into the free space, greater than $3{\cdot}D_e$ from any reflective surface, Equation 5 shall be used to calculate the Duct End Correction. These expressions shall be used to calculate the Duct End Correction (for either a flush or free termination) at the center frequencies of each One-third Octave Band or Octave Band.

For a duct terminating flush or at a distance less than $3{\cdot}D_e$ from the test space wall, Acoustic Baffle or termination surface use Equation 4:

$$E_{1(n)} = 10\log_{10}\left[1+\left(\frac{0.7C_o}{\pi\, f\, D_e}\right)^2\right] \tag{4}$$

Where:

C_o	=	Speed of sound in air, ft/s
D_e	=	Diameter of a circular duct or the Effective Diameter of a rectangular duct (as shown in Equation 1), ft
$E_{1(n)}$	=	Acoustic Test Duct End Correction for the n[th] One-third Octave Band for a duct terminating flush
f	=	One-third Octave Band center frequency, Hz

For a duct terminating at a distance greater than or equal to $3{\cdot}D_e$ from a test space wall, Acoustic Baffle or termination surface use Equation 5:

$$E_{1(n)} = 10\ \log_{10}\left[1+\left(\frac{C_o}{\pi\ f\ D_e}\right)^2\right] \qquad 5$$

Note: Historically, the transition from flush to free space termination was defined as $1{\cdot}D_e$. Recent research (ASHRAE RP-1314, 2007) has shown that free duct termination effects are not fully exhibited for duct lengths shorter than $3{\cdot}D_e$.

5.2.2 *Acoustic Test Duct End Correction Limit.* When using the equations for Duct End Corrections in Section 5.2.1, if the calculated value for Duct End Corrections exceeds 14 dB, the value for $E_{1(n)}$ shall be limited to 14 dB.

Note: The calculated Duct End Corrections become numerically large for products with small effective duct diameters. This could overstate the Sound Power Levels at low frequencies for such small products. For this reason, sufficient information is to be presented with the sound rating data to allow users of this information to identify the value of $E_{1(n)}$ for a specific unit ducted component.

5.2.3 *Acoustic Test Duct Elbow Correction.* When using an Acoustic Test Duct Elbow (Section 4.5.3) Acoustic Test Duct Elbow Corrections $E_{2(n)}$ shall be applied to the ducted Sound Power Levels as shown in Equation 3 in Section 5.2. The Acoustic Test Duct Elbow Corrections shall be obtained in Appendix C.

5.3 *Determination of Component Octave Band Sound Power Levels.* One-third Octave Band Sound Power Levels determined for the various product Sound Components (ducted discharge, ducted inlet, casing radiated and free inlet combined with casing radiated) defined in Section 5.1 shall be converted to Octave Band Sound Power Levels for sound rating Ducted Equipment using the method employed in Equation (6).

The three One-third Octave Band Sound Power Levels whose frequencies fall within each of the Octave Bands are summed as:

$$L'_{wo(m)} = 10\log_{10}\left[\sum_{n=1}^{n=3} 10^{\left(\frac{L'_{w(n)}}{10}\right)}\right] \qquad 6$$

Where:

$L'_{w(n)}$	=	The end corrected Sound Power Level for the n^{th} One-third Octave Band from Equation 3, dB
$L'_{wo(m)}$	=	Sound Power Level for the m^{th} Octave Band, dB
n	=	One-third Octave Band of interest in the Octave Band

5.4 *Individual Unit Tests.* Individual ducted equipment may be tested at specific operating conditions, and the results reported according to procedures in Sections 4 and 5 of this standard. These tests are often conducted to check published sound ratings for individual units at application specific operating conditions. The results for individual sound tests shall be reported in Octave Band Sound Power Levels, or optional One-third Octave Band Sound Power Levels, together with the information listed in Section 4.9.

Section 6. Equipment Sound Ratings

6.1 *Mapped Sound Ratings.* The purpose of this standard is to establish a method of sound rating the indoor Sound Components of ducted equipment. The Mapped Sound Rating for the specific configuration of the Ducted Equipment shall be published, printed or provided in a selection program including all the applicable Sound Components. The mapped Sound Power Levels for each sound component are to be derived from the addition of appurtenance effects and other Sound Sources to the Base Unit for each unit configuration.

6.2 *Combining Sound Sources and Appurtenances for Mapped Sound Ratings.* All Ducted Equipment is acoustically described by conducting a series of mapped sound tests for the applicable equipment configuration Sound Components as described in Section 4.2. The mapped sound measurements can then be used to define the sound rating for any product rating condition. Mapped sound tests for each sound component are obtained by first mapping the supply fan in the Base Unit. The effects of Appurtenances and other Sound Sources are then added to the sound map of the Base Unit to provide the acoustic description of a given sound component. The set of applicable Sound Components provide a total acoustic description of the equipment based on the full range of possible operating conditions as defined by the manufacturer.

6.2.1 *Base Unit Supply Fan Rating.* A sufficient number of speed curves and test points along each speed curve of the supply fan in the Base Unit shall be evaluated to ensure that the difference between adjacent test points does not exceed 5 dB for any given One-third Octave Band. At a minimum, the base unit supply fan shall be tested along the highest and lowest speed curves across the full operational map as specified by the manufacturer. This same mapped approach shall be applied to characterizing the other source contributions of a return fan (see Appendix D). The rating of the Base Unit may be considered representative of the total unit operation sound if appurtenance and other sound source effects are shown not to contribute to the Sound Components under test.

6.2.2 *Appurtenance Effects to the Base Unit Rating.* A sufficient number of test points along the supply fan speed curves shall be evaluated to ensure that the acoustical effect of the Appurtenance on the Base Unit is understood. The appurtenance effects upon the base unit ratings shall be obtained from test data as specified in Section 4. The objective of the test is to determine if the Appurtenance can be represented by an averaged acoustical effect or if it shall be described as a mapped function of airflow velocity. As for the case of the Base Unit, the difference between adjacent test points shall not exceed 5 dB for any given One-third Octave Band.

Note: It may be desirable to test a supply fan and an appurtenance plenum as an assembly if they are supplied together in a product.

6.2.2.1 *Mechanical Airflow Control Device.* The effects of a mechanical airflow control device, for example, inlet guide vanes (excluding variable frequency drives) shall be defined as outlined in Appendix E.

Note: The mechanical airflow device is part of the product and not a separate control system for purposes of the test.

6.2.3 *Other Sound Source Effects on Base Unit Rating.* The effects of other Sound Sources shall be added to the combined results of the Base Unit and any appurtenance effects. The effects of the other Sound Sources are to be based on test data as specified in Appendix D. A sufficient number of operating conditions shall be evaluated to ensure that the acoustical effects of the other Sound Sources on the Base Unit and applicable Appurtenances are understood for each sound component being measured.

The degree of difficulty in accounting for the effects of other sources on the mapped rating of the Base Unit and its Appurtenances can vary significantly depending on the operational character and what controls the output of the other source. In the simplest of cases, other sources may operate independent of the supply fan map, be constant in their acoustical nature, and only have two states of operation; one being on and the other off. In this situation, the mapped sound levels for a given sound component can be developed and published for both with and without the operation effects of the other source on the base map. However, in the case where the other source has an operational map that is not independent of the supply fan map but interdependent (such as with return and exhaust fans) it becomes more difficult to account for its effects on the supply fan map. The effects of independent and the more difficult interdependent sources on the Base Unit are addressed in Appendix D.

6.2.3.1 *Refrigerant Circuit Sources.* Refrigerant circuit related Sound Sources are identified and defined only in reference to the thermal rating standard operation point for a given product and considered independent of the supply fan map (see Appendix D). The sound due to refrigerant circuit related sources operating at non-standard conditions defined by the manufacturer may be provided as optional information.

6.2.3.2 *Exhaust and Return Fans.* Due to the potential interdependent effects of the exhaust and return fan Sound Sources with the supply fan, they shall be evaluated at a sufficient number of test points and in the manner as specified in Appendix D.

6.2.3.3 *Burners*. The effects of the burner sound source shall be evaluated at the input rate and gas type specified on the nameplate.

6.2.4 *Predicted Sound Ratings for Untested Fan Operating Points and Unit Sizes.* With certain restrictions, sound ratings can be predicted for untested fan operating points and unit sizes.

6.2.4.1 *Sound Estimation for Untested Fan Operating Points.* The manufacturer may estimate Sound Power Levels and provide ratings for other fan (typically the supply fan, however a similar process can be applied to return and exhaust fans) operating conditions using an appropriate algorithm that is based on the Sound Power Levels determined by testing over the Base Unit's operational map. However, Sound Power Levels and ratings shall not be estimated for a Base Unit operating at conditions outside the tested region. The tested region is defined by the highest and lowest fan speeds, fan power limits, and system curves tested.

6.2.4.2 *Estimated Ratings for Untested Product Sizes or Appurtenances.* Tested product data may be used to estimate the Sound Power Levels and ratings of an untested size of the same product line as long as:

6.2.4.2.1 The fans are of the same geometric family

6.2.4.2.2 The cabinet size, Appurtenances, or geometric scaling from one product size to another does not invalidate "scaling laws" based on the fan similarities

6.2.4.2.3 The sound levels of the two unit sizes tested and used for interpolation do not differ by more than 5dB.

6.2.4.2.4 The manufacturer tests a sufficient number of product sizes in a given product line to assure an accurate method of prediction

6.3 *Minimum Data Requirements for Published Sound Ratings.* The following is a list of data required to document the noise ratings supplied per this standard:

6.3.1 Unit configuration, Base Unit, Appurtenances and other sources

6.3.2 Octave Band Sound Power Levels, dB

6.3.3 Acoustic test duct internal height, width and length dimensions, m

6.3.4 Acoustic test duct elbow internal height and width dimensions (if used) and location of the elbow in the Acoustic Test Duct, m

6.3.5 Fan speed, fan static pressure, airflow rate and fan motor power and appropriate units for each test point

6.3.6 Component under test as applicable ducted discharge, ducted inlet, casing radiated, free discharge or free inlet discharge combined with casing

6.4 *Published Sound Power Ratings.* All published sound power ratings shall be expressed in decibels rounded to the nearest whole decibel.

6.5 *Verification of Published Sound Ratings.* Any equipment selected at random and tested in a suitably qualified laboratory in accordance with this standard shall have a sound rating not higher than its published sound rating.

6.6 *Acoustic Test Duct End Correction Documentation*. If a component under test includes an end correction, a statement shall be included that an end correction was applied to the ratings. The end corrections applied shall be available upon request.

6.7 *Acoustic Test Duct Elbow Correction Documentation*. If a component under test includes an elbow correction, a statement shall be included that an elbow correction was applied to the ratings. The elbow corrections applied shall be available upon request.

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 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 shall not 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 the standard.

A1.1 AHRI Standard 220-2012, *Reverberation Room Qualification And Testing Procedures For Determining Sound Power Of HVAC Equipment*, 2012, Air-Conditioning, Heating, and Refrigeration Institute, 2111 Wilson Boulevard, Suite 500, Arlington, VA 22201, U.S.A.

A1.2 ANSI S12.5-2006/ISO 6926:1999 (R2011), *Acoustics - Requirements for the Performance and Calibration of Reference Sound Sources Used for the Determination of Sound Power Levels*, 2011, American National Standards Institute, 11 West 42nd Street, New York, NY 10036, U.S.A.

A1.3 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.

A1.4 ANSI/AMCA Standard 210/ASHRAE 51-2007, *Laboratory Methods of Testing Fans for Certified Aerodynamic Performance Rating*, 2007, American National Standards Institute, 11 West 42nd Street, New York, NY 10036, U.S.A.

A1.5 ANSI/ASA Standard S1.11-2004 (R2009), *American National Standard Specification for Octave-Band and Fractional-Octave-Band Analog and Digital Filters*, 2009, American National Standards Institute, 11 West 42nd Street, New York, NY 10036, U.S.A.

A1.6 ANSI/ASA Standard S12.12-1992 (R2012), *American National Standard Engineering Method for the Determination of Sound Power Levels of Noise Sources Using Sound Intensity*, 2012, American National Standards Institute, 11 West 42nd Street, New York, NY 10036, U.S.A.

A1.7 ASHRAE RP-1314, *Reflection of Airborne Noise at Duct Terminations*, 2007, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., 1791 Tullie Circle, N.E., Atlanta, GA 30329, U.S.A.

A1.8 ASHRAE Standard 37-2009, *Methods of Testing for Rating Unitary Air-Conditioning and Heat Pump Equipment*, 2009, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., 1791 Tullie Circle, N.E., Atlanta, GA 30329, U.S.A.

A1.9 *ASHRAEwiki*, *Terminology*, http://wiki.ashrae.org/index.php/ASHRAEwiki, 2012, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., 1791 Tullie Circle, N.E., Atlanta, GA 30329, U.S.A.

A1.10 Beranek, L.L. 1960, *Noise Reduction*, McGraw Hill, New York.

A1.11 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.

A1.12 ISO 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, Case Postale 56, CH-1211, Geneva 21 Switzerland.

A1.13 ISO 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, 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.

B1.1 AHRI Standard 430-2009, *Performance Rating of Central Station Air-handling Units*, 2009, Air-Conditioning, Heating, and Refrigeration Institute, 2111 Wilson Boulevard, Suite 500, Arlington, VA 22201, U.S.A.

APPENDIX C. ACOUSTIC TEST ELBOW CORRECTION (E_2) – NORMATIVE

C.1 For testing of ducted inlet or ducted discharges, straight Acoustic Test Ducts are recommended. However, the standard does allow the use of an Acoustic Test Duct Elbow, when needed, to facilitate testing. An example of a test elbow configuration is shown in Figure C.1. An Acoustic Test Duct Elbow Correction ($E_{2(n)}$), shall be made (in addition to the test Duct End Correction) to the sound data to account for the presence of the Acoustic Test Duct Elbow.

Table C.1 displays insertion loss values for unlined Acoustic Test Duct Elbows (Beranek 1960). An example of its application is shown in Table C.2.

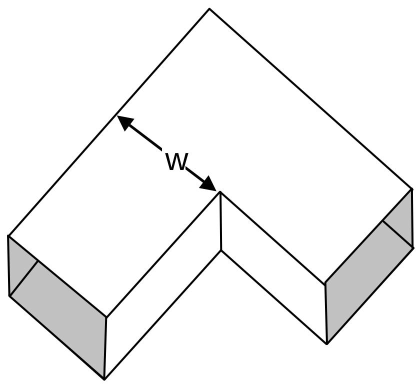

Figure C.1 - Insertion Loss of Unlined Acoustic Test Duct Elbows

Table C.1. Insertion Loss of Unlined Elbows[1]	
	Insertion Loss, dB
$fW < 48$	0
$48 \leq fW < 96$	1
$96 \leq fW < 190$	5
$190 \leq fW < 380$	8
$380 \leq fW < 760$	4
$fW > 760$	3
Note 1: f = center frequency, kHz, and W = width in the plane of bend, mm	

Table C.2 Examples of Test Elbow Insertion Loss, dB					
One-third Octave Band Frequencies, f (Hz)	One-third Octave Band Frequencies, f (kHz)	Duct Dimension, W, in Plane Of Bend , mm			
		500	750	1000	1250
50	0.050	0	0	1	1
63	0.063	0	0	1	1
80	0.080	0	1	1	5
100	0.100	1	1	5	5
125	0.125	1	1	5	5
160	0.160	1	5	5	8
200	0.200	5	5	8	8
250	0.250	5	5	8	8
315	0.315	5	8	8	4
400	0.400	8	8	4	4
500	0.500	8	8	4	4
630	0.630	8	4	4	3
800	0.800	4	4	3	3
1000	1.000	4	4	3	3
1250	1.250	4	3	3	3
1600	1.600	3	3	3	3
2000	2.000	3	3	3	3
2500	2.500	3	3	3	3
3150	3.150	3	3	3	3
4000	4.000	3	3	3	3
5000	5.000	3	3	3	3
6300	6.300	3	3	3	3
8000	8.000	3	3	3	3
10000	10.000	3	3	3	3

APPENDIX D. EFFECTS OF OTHER SOURCES - NORMATIVE

D.1 The degree of difficulty in accounting for the effects of other sources on the Mapped Sound Rating of the Base Unit and its Appurtenances can vary significantly depending on the operational character and what controls the output of the other source. In the simplest of cases, the other source may operate independent of the supply fan map, be constant in their acoustical nature, and only have two states of operation; one being on and the other off. In this situation, the mapped sound levels for a given sound component can be developed and published for both with and without the operation effects of the other source on the base map. However, in the case where the other source has an operational map that is not independent of the supply fan map but interdependent it becomes more difficult to account for its effects on the supply fan map. The effects of these more difficult sources on the Base Unit are addressed in Section D.2.

D.2 *Independent Sound Sources.* For the purpose of this standard, refrigerant circuit related Sound Sources are considered independent of the supply fan source and thus are identified and defined only in reference to the ISO thermal rating standard operation point for a given product. Other examples of independent Sound Sources are the airborne noise from variable frequency drive (VFD) ventilation fans, motor noise, gas burner combustion noise, and outdoor condenser fan noise. If a product is operated at the standard thermal rating conditions and the sound from the refrigerant circuit contributes 1 dB or less (in any One-third Octave Band) to the supply fan sound for a given sound component at that operating point, the supply fan (without the refrigerant circuit effects) can be used to describe the product at any other fan operating condition across the map. If there is a contribution to the supply fan spectrum at that point, the spectrum of the refrigerant circuit sound source shall be defined and added to the supply fan sound spectrum at all supply fan conditions for the given sound component. A similar contribution process is to be followed for any other independent sound source.

The sound spectrum for a refrigerant circuit related sound source is typically difficult to obtain due to contamination from the supply fan sound spectrum. To help avoid supply fan contamination to the refrigerant circuit related sound spectrum, the supply fan may be operated at a quieter operating point or turned off while artificially maintaining operation of the refrigerant circuit. Refrigerant circuit operation may also be artificially maintained by approximating the standard thermal rating conditions. This approximation can be obtained by artificially controlling the refrigeration circuit to match the compressor inlet and discharge saturation temperatures ($\pm$ 3^{o}C) that exist during a standard thermal rating test of the product. During refrigerant circuit operation, observe and record compressor inlet superheat. If necessary (and possible) adjust the superheat to avoid liquid slugging of the compressor(s) and associated noise.

D.3 *Interdependent Sound Sources.* Return or exhaust fans are classified in this standard as interdependent other Sound Sources since their operational maps and thus acoustic source characteristics are not independent of the supply fan map. The noise generated by return and/or exhaust fan in the return duct shall be determined as follows:

D.3.1 *Discrete Speed Fan or Multiple Discrete Speed Fan.* For a fan that is directly coupled to a motor shaft that has one or more speed taps, the sound map varies with fan speed. The fan speed depends on the discrete speed tap and the amount of speed slip between the stator and rotor fields. The speed slip increases as the load on the motor increases. This generates a sound map that is a curve for each discrete fan speed.

The sound spectrum in each One-third Octave Band shall be determined for each fan speed per the requirements of Section 4 at fan operating points determined by the airflow and return duct static pressure.

D.3.2 *Variable Speed Fans.* For a return or exhaust fan that can run at an infinite number of speeds depending on variations in sheave sizes or variations in the electrical input signal to the motor, the sound spectrum in each One-third Octave Band for each fan speed shall be determined per the requirements of

Section 4.3.1 at fan operating points determined by the airflow and return duct static pressure. For products where a supply fan is always used in conjunction with a return or exhaust fan it may be advisable to test both fans at the same time to reach additional operational points per the manufacture's defined control scheme that could not be reached testing the fans independently.

D3.3 The return duct noise shall be the combination of the noise generated from the supply fan in the return duct and the noise generated by the return or exhaust fan in the return duct at the respective running conditions of each fan.

APPENDIX E. SUPPLY FAN MODULATION DEVICE EFFECTS – NORMATIVE

E.1 *Modulation Device Insertion Effects.* This test identifies the acoustic effects of inserting a modulation device (such as inlet guide vanes at the fully open position) in the fan airflow. It does not measure the effects of actual modulation. Supply fan testing is conducted with the modulation device fully open (for guide vanes fully open at 90°) across the entire supply fan map.

E.2 *Modulation Device Modulation Effects.* This test provides representative modulated system curves for the product with a mechanical modulation device. This test is defined for various percentages of modulation of a modulation device along the same system curve as defined for the insertion effect. It can be conducted for two additional system curves, if desired. Modulation device insertion effects shall first have been defined, at a minimum, along a single constant system curve. The initial point of the system curve shall be on the highest fan speed curve with the test point (static pressure and volumetric flow) being mid-way between stall and full open flow. Tests shall be conducted at this point with the modulation device fully open. Additional points along the system curve are obtained by operating the supply fan at other speeds defined in the original supply fan map with the modulation devise a various degrees of closure. Additional tests are conducted at ¼, ½, ¾ and fully closed guide vane settings, applying the same system load line. Additional system lines may be tested, starting at a test point along the highest speed curve nearest the maximum efficiency point and at a more wide open point as defined by the manufacturer, if desired.

APPENDIX F. DETERMINATION OF SOUND POWER USING SOUND INTENSITY - NORMATIVE

F1. *Method for the Determination of Sound Power Using Sound Intensity.* Except where noted, sound tests utilizing the sound intensity method shall be conducted as described in ISO 9614-1 (grade 2) or ISO 9614-2 (grade 2).

F2. *General Requirements.*

F2.1 *Size of Noise Source.* The size and shape of the noise source are unrestricted and serve to define the measurement surface. The measurement surface, consisting of multiple sub-surfaces, shall totally enclose the noise source or duct opening under test. The basic concept is measurement of the Sound Intensity distribution around the equipment.

F2.2 *Character of Noise Radiated by the Source.* The signal shall be stationary in time, as defined in 3.13 of ISO 9614-1 (grade 2) and 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.

F2.3 *Time Averaging.* To minimize the random error in the measurement, it is required that the averaging time be long enough to give repeatable results. The minimum averaging time shall be 30 seconds per each square meter of measurement surface.

F2.4 *Measurement Uncertainty.* Refer to Section 4.8.

F3. *Acoustic Environment.*

F3.1 *Criteria for Adequacy of the Test Environment.* The temperature and humidity of the test environment shall be within the instrument manufacturer's stated limits. In addition, the test environment shall satisfy the requirements stated in 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. The background Sound Pressure Level shall be no greater than the direct sound from the equipment under test.

Care should 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 with a windscreen meeting the requirements of AHRI Standard 250 Section 5.10. Averaging times may be extended to improve the measurement results. Intensity measurements in airflow shall meet the requirements in Section F4.3.

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.

F4. *Instrumentation.*

F4.1 *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. Synthesized one-third octave band levels from narrow band analysis are not allowed.

For the calibration and field check of the instruments, see the requirements of 6.2 of ISO 9614-1 (grade 2) and 9614-2 (grade 2). The two values of $I_{(n)}$ for the field check should have opposite signs and the allowable difference in Sound Intensity Levels shall be less than 1.5 dB in all bands.

F4.2 *Instrumentation.* The Sound Intensity instrumentation shall be capable of measurements from the 50 Hz to the 10,000 Hz One-third Octave Band. The preferred sound intensity probe should consist of two ½" 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 F.1. A 50mm microphone spacer is typically used for the one-third octave band frequency range from 50 Hertz to 315 Hertz; a 12mm microphone spacer is typically used for the one-third octave band frequency range from 400 Hz to 10,000 Hz.

The Pressure-Residual Intensity Index (PRI) of the measurement instrumentation (microphone pair, spacer and analyzer) shall be recorded according to the procedure in 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 F4.3 is then used to check the quality of each sound intensity measurement. The procedure in Section F4.4 should also be used to quantify the high frequency correction at the 1,600 Hz through 10,000 Hz One-third Octave Bands using the 12-mm probe spacer.

F4.3 *Qualification of Sound Intensity Measurements.* To conform with this standard, the quality of each measurement shall meet the following requirements for each One-third Octave Band:

$$PI_{(n)} < PRI_{(n)} - K \qquad \text{F1}$$

Where:

K = 10 dB

$PI_{(n)}$ = Pressure-intensity index (mean-pressure level minus the intensity level) of the measurement for the nth One-third Octave Band, dB

$PRI_{(n)}$ = Pressure-Residual Intensity Index, determined by the phase calibration of the particular microphone pair, spacer and analyzer used for the measurement for the nth 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 mean-pressure level is less than the 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.

F4.4 *High Frequency Correction*. For measurements systems using 12 mm microphone spacers, the results of the performance verification in Section F4.5 may be used to determine a high frequency correction for each individual sound intensity probe and analyzer combination. The probe correction, $L_{wi(n)}$, is the one-third octave band level in decibels that is added to the sound power, determined by the intensity measurements, to equal the sound power of the Reference Sound Source (RSS). The high-frequency probe correction shall only be applied to the 1600 Hz through 10,000 Hz One-third Octave Bands.

F4.5 *Performance Verification by Comparison with a Reference Sound Source.* Periodically and within 30 days prior to a test, the performance of the sound intensity instrumentation system shall be verified by determining the sound power of a Reference Sound Source (RSS) according to ANSI S12.12, Section 5.8. The Reference Sound Source used for this verification shall have the characteristics required in AHRI Standard 250 and be calibrated in accordance with AHRI Standard 250 for the frequency range of 50 Hz to 10kHz. The measurement grid shall be as shown in Figure F1. The same sound intensity probe, windscreen and analyzer combination shall be used during the performance verification and all subsequent intensity measurements. The sound power, determined by intensity measurements with the high frequency correction as determined in Section F4.4, shall differ from the RSS value as determined by AHRI Standard 250 by no more than the levels shown in Table F.1.

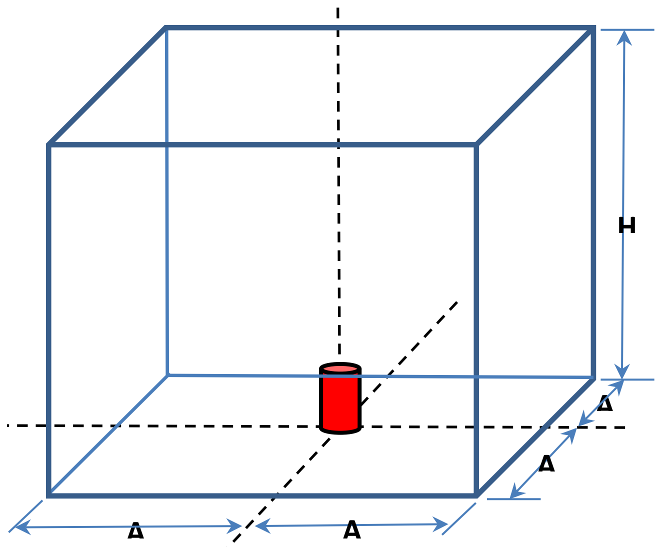

Figure F1. Performance Verification by Comparison with a Reference Sound Source Set-up

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 1 meter.

Table F.1 – 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

F5 *Measurement of Component Sound Intensity Levels.*

F5.1 *Measurement Surface*. The measurement surface shall be defined to 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. When scanning, the sub-surfaces should be small enough to facilitate the reach of the operator and to maintain even coverage with time. A suggested maximum size of each sub-surface is 1 m^2. The number of sub-surfaces shall be at least the larger of a) the surface area in square meters or b) eight. After a set of measurements is made, the average of the original set of measurement points or sub-surfaces shall be compared to a set with half the number of measurements to ensure the adequacy of the number of measurement points or sub-surfaces. This is especially true for tonal noise sources. This concept is called convergence index. The choice of measurement points or sub-surfaces shall be shown to result in a convergence index less than or equal to the following in Table F.2.

Table F.2 – Convergence Index

One-third Octave Band, Hz	Tolerance, dB
50 to 80	0.75
100 to 160	0.75
200 to 315	0.4
400 to 5000	0.4
6300 to 10000	0.65

The convergence index shall be calculated from the difference between two calculations of the surface Sound Intensity Level using N and N/2 sub-surface areas.

$$\delta_{(n)} = L_{Ia(n)} - L_{Ib(n)} \qquad \text{F2}$$

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.

F5.2 *Measurements Employing Discrete Points – ISO 9614-1 (grade 2).*

F5.2.1 *Initial Test.* Make measurements of normal Sound Intensity on an initial measurement surface. If this initial surface proves to be unsatisfactory, modify it according to the actions specified in Annex B of ISO 9614-1 (grade 2). The initial measurement surface shall be defined around the source under test.

Note: This surface should preferably 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 which may be required.

F5.2.2 *Calculation of Sound Power Level.*

F5.2.2.1 *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 the equation:

$$P_{(n)i} = I_{(n)i} S_i \qquad \text{F3}$$

Where:

$I_{(n)i}$ = Signed magnitude of the normal Sound Intensity component measured at position *i* on the measurement surface for the nth One-third Octave Band, W/ m^2

$P_{(n)i}$ = Partial sound power for sub-surface i for the n^{th} One-third Octave Band, W

S_i = Area of sub-surface i, m^2

Where the normal Sound Intensity Level $L_{I(n)i}$ for sub-surface i and the n^{th} One-third Octave Band is expressed as *XX* dB, the value of $I_{(n)i}$ shall be calculated from the equation

$$I_{(n)i} = I_0 \times 10^{xx/10} \qquad \text{F4}$$

Where the normal Sound Intensity Level $L_{I(n)i}$ for sub-surface i and the n^{th} One-third Octave Band is expressed as (-) *XX* dB, the value of $I_{(n)i}$ shall be calculated from the equation

$$I_{(n)i} = - I_0 \times 10^{xx/10} \qquad \text{F5}$$

In these equations, $I_0 = 10^{-12}$ W/m^2.

F5.2.2.2 *Calculation of the Sound Power Level of the Noise Source.* Calculate the Sound Power Level of the noise source in each frequency band from the equation:

$$L_{w(n)} = 10 \lg \sum_{i=1}^{N} \left(\frac{P_{i(n)}}{P_0} \right) + L_{wi(n)} \qquad \text{F6}$$

Where:

$L_{wi(n)}$ = High frequency compensation determined in Section F4.4 for the n^{th} One-third Octave Band, dB

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

N = Total number of measurement positions and sub-surfaces

$P_{i(n)}$ = Partial sound power for sub-surface i, calculated from Equation F.1 for the n^{th} One-third Octave Band, W

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

F5.3 *Measurements Employing Scanning ISO 9614-2 (grade 2).* The scanning procedure and the definition of the initial measurement surface shall be as described in 8.l and 8.2 of ISO 9614-2.

F5.3.1 *Calculation of Partial Sound Power.* Calculate a partial sound power in each frequency band for each sub-surface of the measurement surface.

$$P_i = \overline{I_{(n)i}} \cdot S_i \qquad \text{F7}$$

Where:

$\overline{I_{ni}}$ = Signed magnitude of the sub-surface average normal Sound Intensity measured on partial surface i on the measurement surface for the n^{th} One-third Octave Band, W/m^2

S_i = Area of sub-surface i, m^2

F5.3.2 *Calculation of Sound Power Level.* Calculate the sound power, P, of the source under test in each frequency band of interest.

$$P = \sum_{i=1}^{N} P_i \qquad \text{F8}$$

Where:

N = Number of sub-surfaces of the measurement surface

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

$$L_{w(n)} = 10 \lg \left(\frac{P_{(n)}}{P_0} \right) + L_{wi(n)} \qquad \text{F9}$$

Where:

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

$L_{wi(n)}$ = High frequency compensation determined in Section F4.4 for the n[th] One-third Octave Band, dB

$P_{(n)}$ = Source sound power for the n[th] One-third Octave Band, W

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

Note: When the intensity vector is negative, *P* is negative. In this case, the Sound Power Level, L_{wi}, is expressed as (-) XX dB.

F6 *Information to be Reported.* In addition to the information required in Section 4.9, the information to be reported shall be in accordance to Clause 10 of ISO 9614-1 (grade 2) and 9614-2 (grade 2) as applicable.