Sound Pressure, Sound Power and Air-Cooled Chillers

Form: 201.19-AG1 (1016)

APPLICATION GUIDE

INSTALL CONFIDENCE

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Introduction

Comparing and specifying sound performance on chillers can be daunting, even for an experienced engineer. There are different calculation methods and industry standards for air-cooled and water-cooled chillers, and sound data is not always presented consistently. Two of the most common questions are:

"Which sound data (power or pressure) should be used when selecting, comparing and specifying equipment?"

"Which industry standard is appropriate in a given scenario?"

This document attempts to answer some of these questions and is specifically focused on air-cooled chillers. For similar documents pertaining to other equipment including water-cooled chillers and other equipment, see Johnson Controls Engineering Supplements.

Sound Pressure and Sound Power

Sound Pressure is a measure of changes / fluctuations in atmospheric pressure due to a sound source. It is measured in Pascals (Pa). Sound pressure is dependent on distance from the source. Therefore, when specified, an associated distance must be included otherwise the pressure provided is rendered meaningless. Sound pressure can be measured directly.

Sound Power is the rate of sound energy emitted per unit time. (Energy radiates from a sound source and results in sound pressure). It is measured in Watts (W). Sound power is independent of distance and of the environment. Industry standards for air-cooled chillers recommend sound power as the method of comparison between chillers in part because it is *'inherent to the source'*. Sound power cannot be measured directly.

Both sound power and sound pressure can be presented in decibels (dB), either as overall or octave band levels. One could think of dB as *'a scale'* used to manage a large range of numbers. It can be used in reference to a host of quantities including sound pressure, sound power, vibration levels, etc. When an A-weighted filter is applied, dB(A) sound levels are obtained and these correlate reasonably well to human hearing.

Industry Standards

Industry standards are established to provide uniformity in determination and measurement methods amongst industry professionals. These might include the owner, architect, acoustician, consulting engineer, contractor, government regulators and equipment manufacturers.

Air-Conditioning, Heating and Refrigeration Institute (AHRI) Standards are used within the United States. Others adhere primarily to International Standards Organization (ISO). (In China, national standards are referred to as 'Guobiao or 'GB' Standards', many of which are adopted from other international standardizing parties).

Although AHRI, ISO and GB (with '/T') Standards are voluntary, they have been adopted by several bodies including equipment manufacturers. This is because they provide the end-user assurances of accuracy in the manufacturer's equipment performance. In addition, having equipment rated in a like manner allows for fair comparison between competing products.

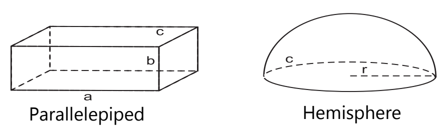
Sound Pressure Measurement and Sound Power Determination in Air-Cooled Chillers

Consider sound originating at a source. Within a small distance from the source, the sound waves are the *'nearfield'*. Outside this distance the waves are in the *'farfield'*. As would be expected, this distance depends on the size of the source and its characteristics, specifically wavelength. To date, behavior of sound in the *'farfield'* is better understood than its behavior in the *'nearfield'* where the presence of the source has a greater influence on sound behavior.

The two extremes that could define the *'farfield'* are the free-field and the reverberant field. In the free-field, sound radiates away from the source and is not reflected; the decay pattern is homogeneous. In the reverberant field, radiating sound encounters reflective boundary surfaces such as walls, ceilings and floors so that it is contained and builds up within the space. In practice, free-field conditions are obtained in a hemi-anechoic room in which only the floor is reflective. Reverberant field conditions are obtained in a room with appropriately located reflective surfaces.

Sound Pressure is measured using a microphone which can either be positioned at a fixed / discrete location or moving / traversing.

Sound Power is determined from sound intensity or sound pressure via measurement methods that make use of sound's behavior in controlled test environments that essentially simulate free or reverberant fields. The measurements are typically made over an imaginary surface that encloses the sound source. Shown below are two examples of measurement surfaces, a parallelepiped and a hemisphere.

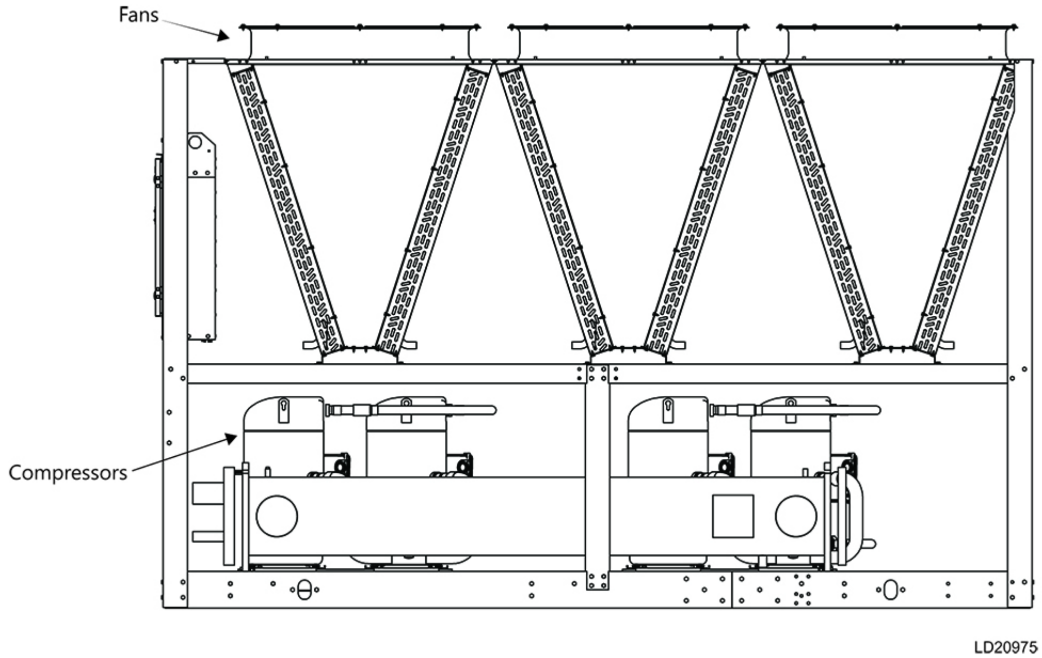


Surfaces on Which Sound Pressure is Measured

Determining sound power from sound pressure measurements based on free-field methods are developed on the premise that the receiver *'sees'* radiation from the sound source as '*well-behaved'* and with uniform decay.

Specifying the *'line'* where receiver perception of a sound source's behavior, as if in a free-field, remains a point of debate in the field of acoustics. However, general consensus is that free-field conditions are firmly established when the distance between the source and receiver is about twice the longest dimension of the source.

For an air-cooled chiller, an appropriate distance should then be such that its primary sound sources (compressors and condenser fans) can reasonably be allowed to blend so that they can be represented as a single source.



Schematic Diagram of Air-Cooled Chiller Primary Sound Source

In the laboratory test environment, although sound pressure measurements are taken on a surface that is fairly close to the air-cooled chiller, it is understood that free-field conditions are sufficiently well obtained with the inclusion of an appropriate correction factor in calculations. This factor mitigates the effects of sound build-up within the laboratory.

The various measurement methods for determining sound power are summed up in industry standards. Some details of these standards that can be applied to air-cooled chillers are summarized in the table below.

Industry Standards Pertaining to Determination of Sound Power of Air-Cooled Chillers (List not Exhaustive)

Standard		Test Environment	Microphone Position	Sound Pressure Measurement Surface	Relative Sound Power Level
a	ISO-3744	Free-field	Discrete	Parallelepiped	dB + 2
b			Traversing		
c	AHRI-370	Free-field	Discrete	Parallelepiped	dB
d		Reverberant field		As Per Standard	
e	JB/T4330	Free-field	Discrete	Parallelepiped	dB + 2
f	ISO-9614	Sound Intensity	Discrete	-	dB
g			Traversing	-	

Notes

1. Professional Standards... are developed and applied when no National GB Standard exists, but where a unified technical requirement is needed for a specific industry sector in China. Professional Standards are coded by industry sector. Source: https://www.standardsportal.org/usa_en/prc_standards_system/standards_used_in_china.aspx. JB/T4330 is the appropriate standard pertaining to air-cooled chillers.

2. As is evident in the table above, in the free-field test environment the sound power levels obtained from ISO-3744, AHRI-370 and JB/T4330, are not the same even though sound pressure is measured on identical parallelepiped surfaces in all three cases. This is because the area used in the calculation of sound power from the measured sound pressure levels is different.

   ISO-3744 and JB/T4330 assume the entire chiller is radiating sound so the calculation area is the parallelepiped. However in reality, individual sources (fans, compressors) are the sound contributors. AHRI-370 uses a calculation area that is an '*equivalent hemisphere*', whose area is obtained using dimensions of the parallelepiped and is such that sound power levels determined using AHRI-370 (free-field) and AHRI-370 reverberant field are equivalent. These sound power levels are then also consistent with those obtained using ISO-9614.

3. For the purposes of this paper, we will limit our focus to sound pressure measurements in a free-field.

Calculation of Sound Pressure from Sound Power for Air-Cooled Chillers

Customers routinely request sound pressure levels at a specific distance from an air-cooled chiller as well as the sound power level. This section discusses Johnson Controls' rationale in providing sound data.

Sound pressure decreases with increasing distance from the source as the source energy is distributed over an increasing area. It follows that distributing a given sound power over an area that is too large will result in sound pressure levels that are too low. Conversely, if this area is too small then sound pressure levels will be too high.

Consider the two *'distribution area' / radiation* models that are most widely used in sound measurement - a parallelepiped and a hemisphere. A parallelepiped at a given distance from a source has a larger area than that of a hemisphere of radius equal to that distance, and so the parallelepiped radiation model will yield lower sound pressure levels. As distance increases and the areas of both the parallelepiped and hemisphere increase, the difference in sound pressure levels calculated based on the two models decreases proportional to the difference in the two areas.

A crucial question then is, ***"Which radiation model is appropriate?"***

At Johnson Controls, we have found the answer is, ***"It depends***."

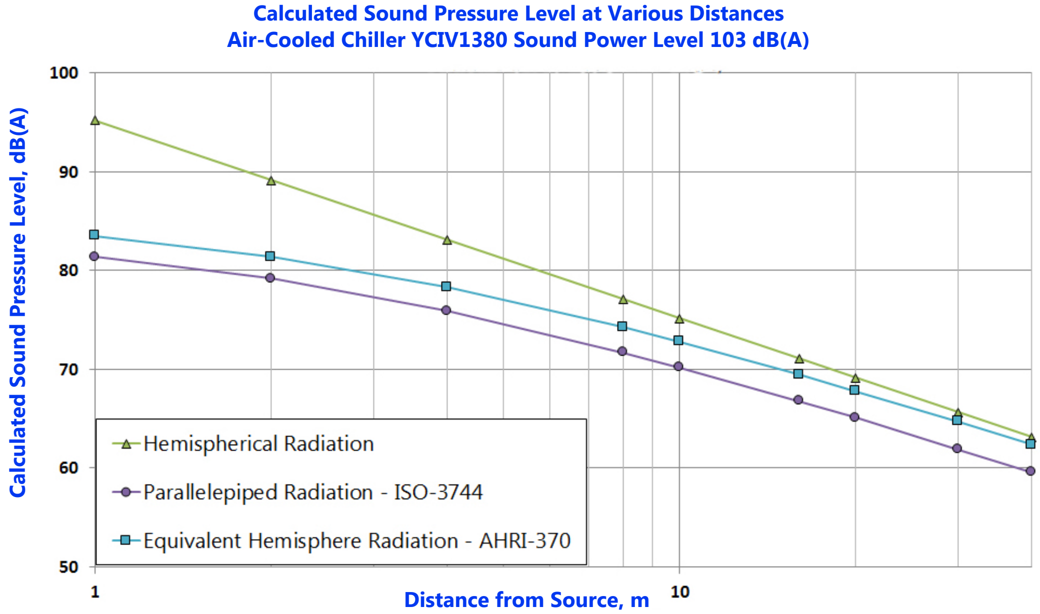
Actual field sound pressure level measurements performed by Johnson Controls, have shown that parallelepiped radiation model can be used when the distance between the chiller and receiver is either 33 feet, i.e., 10 meters or about twice the longest dimension for the chiller, (whichever is greater). The hemispherical radiation model in the same application overestimates sound pressure levels.

Still, we have found the hemispherical radiation model is preferred by experienced acousticians and applications engineers who opt to accommodate some margin of error. The fact that air-cooled chillers are invariably located fairly close to reflective surfaces (which effectively serve to increase sound pressure levels), strengthens the case for using the overestimated, *'conservative'* sound pressure levels during design. By similar argument, the *'conservative*' sound power levels are selected.

Closer to the source (less than 33 feet, i.e., 10 meters), Johnson Controls field measurements indicate the parallelepiped radiation model underestimates sound pressure levels and the hemispherical radiation model yields more accurate results.

Examples

Calculated sound pressure levels based on various radiation models for a Johnson Controls YCIV1380 Air-Cooled Chiller with a sound power level of 103 dB(A). See the figure below.

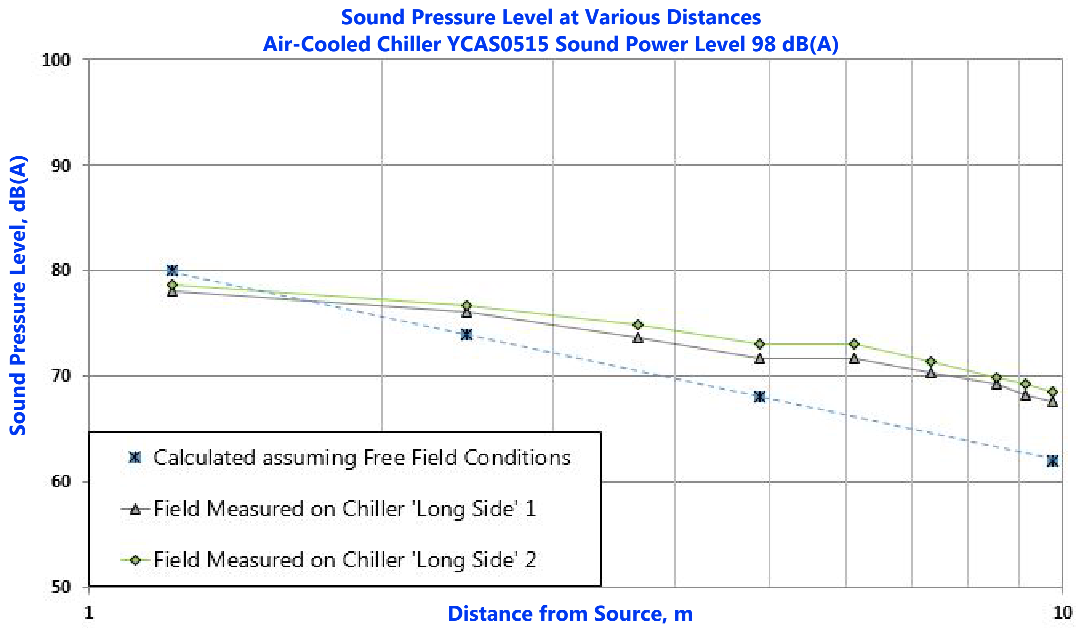


As indicated in the chart above, for this chiller, at about 33 feet, (i.e., 10 meters) there remains up to a 6dB(A) difference in sound pressure levels obtained from the various models. A difference of 6dB(A) is clearly perceptible.

At a certain distance from the source (132 feet, i.e., 40 meters in this example), the hemispherical radiation model is almost equal to the equivalent hemisphere radiation model used in AHRI 370. See *Notes on Page 6*.

At about 78 feet, i.e., 24 meters (which is twice the longest dimension of this chiller), sound pressure levels decay linearly for almost all models, indicating that the chiller is approaching a sound source that can be represented as a point. *YCIV1380 measures 11.96 meters x 2.24 meters x 2.38 meters* ***or*** *39.24 feet x 7.35 feet x 7.81 feet.*

Field measured sound pressure levels for a Johnson Controls YCAS0515 Air-Cooled Chiller with a sound power level of 98 dB(A) were obtained. See the figure below.



As indicated in the chart above, measured sound levels are higher than the sound levels predicted assuming free-field conditions. Although sound level for the YCAS0515 were measured only up to a distance of about 10 meters, the trend would be expected to continue even as a distance equivalent to twice the longest dimension of the chiller is approached. This is because the levels are largely influenced by the presence of reflecting surfaces that were within 20 feet / 6 meters of the chiller. *YCAS measures about 6.38 meters x 2.24 meters x 2.41 meters* ***or*** *20.92 feet x 7.35 feet x 7.91 feet.*

The examples above highlight differences in calculated sound pressure levels depending on radiation model and in measured sound pressure levels depending on field conditions.

This emphasizes the advantage of using sound power levels as the basis for comparison. *See Sound Pressure and Sound Power on Page 3.*

Key Takeaways

Sound Power is the recommended specification and comparison data set for air-cooled chillers.

Sound Pressure calculated at a certain distance from an air-cooled chiller using Sound Power data can vary widely. Therefore, specifying engineers must diligently document the associated calculation method and measurement distance.

Special Considerations

Although sound data published by Johnson Controls for air-cooled chillers is based on internationally recognized standards, Johnson Controls cannot assume responsibility for user-perceived satisfactory sound pressure levels in the field.

Noise from air-cooled chillers is often a concern when there are sensitive receivers (residences, outdoor gathering areas, etc) in the vicinity. The noise ordinances that are referenced typically outline limits for overall sound pressure levels for daytime and nighttime hours at a property line. In some cases, octave band sound pressure level limits are also included.

For a discussion of barriers as a means of minimizing sound pressure levels from exterior equipment such as air-cooled chillers, see Johnson Controls Engineering Supplements. However, in critical applications a suitable consultant should be engaged to review actual field conditions and equipment sound data, and provide appropriate recommendations.

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