Whitepaper

Selecting HVAC Equipment Above Rockfon Acoustic Ceilings so that Background Noise Requirements in Standards are Achieved

Building design standards and guidelines typically contain sound absorption requirements, such as minimum ceiling Noise Reduction Coefficient (NRC) or maximum reverberation time, so that occupants are acoustically comfortable and speech is either intelligible or private.[1] Many rooms and spaces have suspended acoustic ceilings overhead, mainly for their absorption performance and to ensure compliance with these room acoustic requirements.

Building design standards and guidelines also typically contain requirements for maximum background noise in occupied rooms due to heating, ventilating and air conditioning (HVAC) systems.[2] Acoustic ceilings can conceal HVAC systems and attenuate noise generated by devices in the plenum. Predicting the amount of attenuation provided by a suspended acoustic ceiling is straightforward and described in the *ASHRAE Handbook HVAC Applications* by the American Society of Heating, Refrigerating and Air Conditioning Engineers and the *AHRI Standard 885* by the Air Conditioning, Heating and Refrigeration Institute.[3]

Most acoustic ceiling panels available in the market provide roughly the same amount of attenuation of HVAC noise in the plenum in the frequencies of concern.[4] Given the similar performance of acoustic ceiling panels when controlling HVAC device noise, it is not necessary to specify a certain type of panel material, weight or sound isolation rating.[5] Neither Ceiling Attenuation Class (CAC) nor Sound Transmission Class (STC) correlate well to ceiling attenuation performance when the noise source is mechanical equipment located in the plenum above the ceiling.[6, 7] Instead, designers specifying Rockfon acoustic ceilings should use this three-step guide as it is based on the industry-accepted, prediction method in the *ASHRAE Handbook* and *AHRI Standard.*

3-Step Guide to Compliance

Step 1

Determine if a suspended acoustic ceiling is part of the building's design aesthetic and select the Rockfon stone wool ceiling panel based on Noise Reduction Coefficient (NRC), aesthetics, contribution to indoor air quality, environmental/energy impact or cost.

Step 2

Determine the maximum background noise level for each room type according to the applicable standard or the reference table below.[8]

Noise Criterion NC	Decibels A-Weighted dB(A)	Functions of Rooms and Spaces
30	35-40	Private offices, conference rooms, patient rooms, classrooms, lecture rooms
35	40-45	Courtrooms, hospital wards, medical procedure rooms
40	45-50	Open plan offices, lobbies, corridors and support spaces

Locate HVAC equipment over unoccupied or noisy areas such as corridors, storage rooms and lobbies. Avoid locating HVAC equipment over normally occupied rooms that have background noise requirements of NC-35/40-45 dB(A) or lower.

Step 3

When locating HVAC equipment over occupied rooms cannot be avoided, use figure 1 or 2 below based on the Rockfon ceiling panel selected in step 1 to determine the maximum sound power levels for the HVAC equipment in the plenum above. Select the appropriate device model, configuration and operating conditions so these maximum sound power levels are not exceeded.

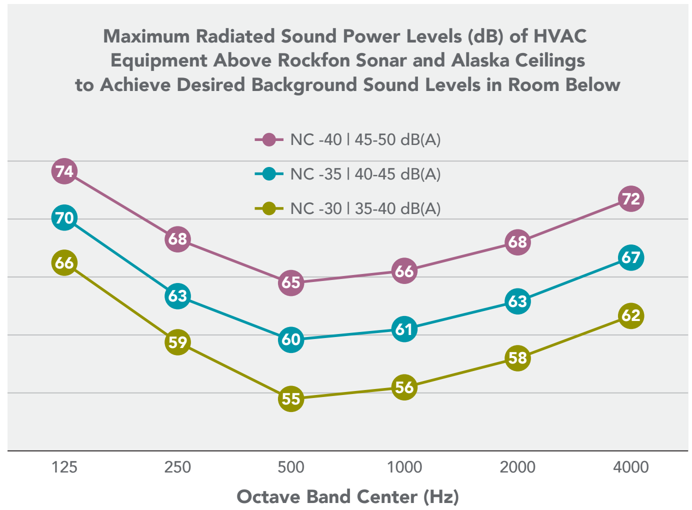


Figure 1[9] - Maximum radiated sound power levels (dB) for HVAC equipment above Rockfon Sonar® and Alaska® ceiling panels (> 0.50 psf) for three common background noise level limits in building design standards.

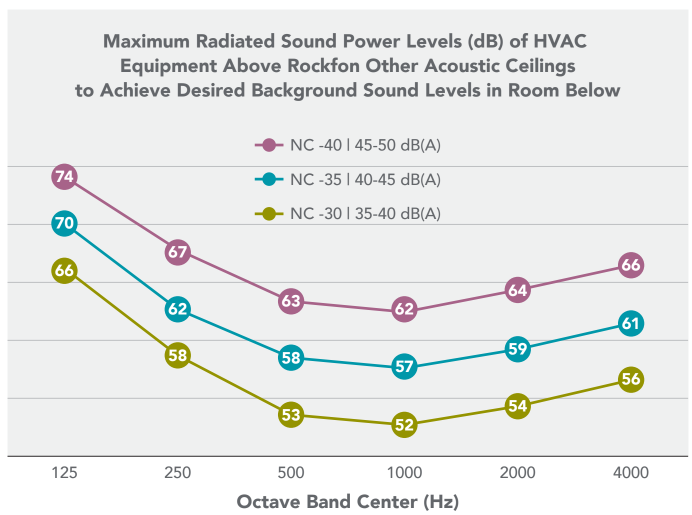


Figure 2[10] - Maximum radiated sound power levels (dB) for HVAC equipment above all other Rockfon ceiling panels (< 0.50 psf) for three common background noise level limits in building design standards.

Special Cases

If the maximum HVAC equipment sound power levels provided in figures 1 and 2 cannot be met:

1. Consider other HVAC equipment brands or models, or noise control options provided by the HVAC equipment manufacturer.
2. Contact Rockfon for other potential options above the ceiling that can increase the attenuation where the HVAC equipment is located.

Ceiling Attenuation Class (CAC)

CAC, measured according to ASTM E1414 and calculated per ASTM E413, is an acoustic metric that applies only to horizontal noise isolation of airborne sound between two adjacent rooms when the partition between the rooms stops at the height of the suspended acoustic ceiling, leaving a common plenum above the ceiling. CAC ratings of suspended acoustic ceilings cannot be used to predict background noise levels in rooms due to HVAC equipment noise from inside the plenum.[6] ASHRAE and AHRI standards show that the best overall attenuation of noise from HVAC equipment located in the plenum is provided by an acoustic ceiling with a high NRC and moderate weight even though its CAC rating is substantially lower than other ceiling types.[5]

Sound Transmission Class (STC)

STC, measured according to ASTM E90 and calculated per ASTM E413, is an acoustics metric that applies to noise isolation of airborne sound provided by building partitions such as walls, floors, doors, windows, roofs and other space dividing elements. STC ratings of suspended acoustic ceilings cannot be used to predict background noise levels in rooms due to HVAC equipment noise from inside the plenum.[7] ASHRAE and AHRI standards show that the best overall attenuation of noise from HVAC equipment located in the plenum is provided by an acoustic ceiling with a high NRC and moderate weight even though its STC rating is substantially lower than other ceiling types.[5]

Other Considerations

Many modern spaces are designed without ceilings, leaving the HVAC systems overhead visible. These designs must comply with the background noise requirements in the standards and guidelines. Therefore, ceilings are not required to control HVAC noise or to comply with the background noise requirements. Even if an acoustics ceiling is provided, it is advisable for the HVAC systems to comply with the background noise limits without the ceiling installed so that compliance is maintained if the ceiling is changed or removed in the future.

This guideline addresses only noise radiated off the HVAC device casing and transmitted through the ceiling below. Noise from the HVAC device may also be duct-borne and emitted into the room through the supply air diffusers and return air grilles. The mechanical engineer should control duct-borne noise, if necessary, with noise control devices such as duct silencers or duct lining. All noise paths/sources should be combined to ensure the background noise limit is not exceeded.

Technical Notes

1. Examples Include:

a. *WELL Building Standard* by the International WELL Building Institute (IWBI), Sound Concept, Feature S04 Reverberation Time and Feature S05 Sound Reducing Surfaces

b. *FGI Guidelines for Hospitals* by the Facilities Guidelines Institute, Table 1.2-4 Minimum Design Room-Average Sound Absorption Coefficients

c. *Acoustical Performance Criteria, Design Requirements, and Guidelines for Schools, Part I: Permanent Schools* by the American National Standards Institute and the Acoustical Society of America (ANSI/ASA S12.60), Table 1 Limits on A- and C-Weighted Sound Levels of Background Noise and Reverberation Times in Unoccupied Furnished Learning Space

2. Examples Include:

a. *WELL Building Standard* by the International WELL Building Institute (IWBI), Sound Concept, Feature S02 Maximum Noise Levels

b. *FGI Guidelines for Hospitals* by the Facilities Guidelines Institute, Table 1.2-5 Maximum Design Criteria for Noise in Interior Spaces Caused by Building Systems

c. *Acoustical Performance Criteria, Design Requirements, and Guidelines for Schools, Part I: Permanent Schools* by the American National Standards Institute and the Acoustical Society of America (ANSI/ASA S12.60), Table 1 Limits on A- and C-Weighted Sound Levels of Background Noise and Reverberation Times in Unoccupied Furnished Learning Space

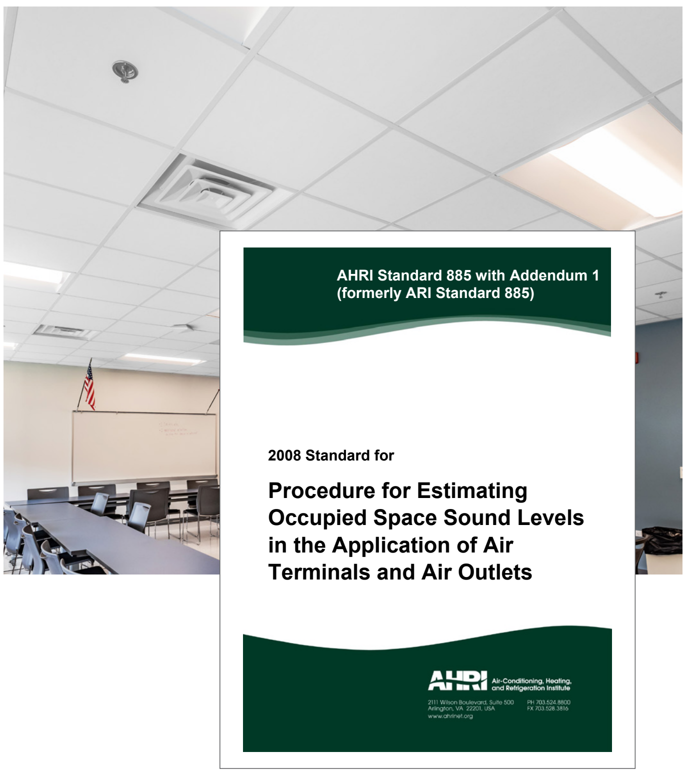
3. Refer to:

a. *2008 AHRI Standard 885 (with Addendum 1), Procedure for Estimating Occupied Space Sound Levels in the Application of Air Terminals and Air Outlets* (free pdf download). Refer to Appendix D Sound Path Factors:

- Sections D1.6 Ceiling/Space Effect
- Table D14 Uncorrected Ceiling/Space Effect Attenuation Values
- Table D15 Ceiling/Space Effect Examples

b. *2019 ASHRAE Handbook HVAC Applications*, Chapter 49 Noise and Vibration Control (purchase here) Refer to:

- Section 2.8, subsection Sound Transmission Through Ceilings
- Table 43 Ceiling/Plenum/Room Attenuation in dB for Generic Ceiling in T-Bar Suspension Systems



4. The *ASHRAE Handbook HVAC Applications*, when discussing the attenuation performance of various ceiling panels, states, "experiments have shown that, for ceiling panels supported in a T-bar grid system, differences among ceiling panel types are small." This is evidenced by the similar attenuation values in Table 43. For example, the first six ceiling types in the table include 5/8" thick mineral fiber panels weighing 0.50 to 1.0 psf, 5/8"-2" thick fiberglass ceiling panels weighing 0.1 psf to 0.6 psf and 1/2" thick gypsum board panels weighing 1.8 psf. These panels represent the full range of acoustic ceiling panel materials, thicknesses and weights. (Note that the original study that led to the values in Table 43 was conducted in the late 1990s, before Rockfon's stone wool ceiling panels became available in North America.) Note that in the 125 Hz through 500 Hz octave bands, the attenuation provided by all these ceiling panels varies little, 1 dB in the 63 Hz band, 2 dB in the 125 Hz band, 3 dB in the 250 Hz band and 4 dB in the 500 Hz band. Also note that the ceiling panel that provides the most attenuation overall is the one made of fiberglass and weighs only 0.6 psf. The panels made of heavyweight gypsum board were one of the worse performing ceilings, providing less noise attenuation in the room below, despite having the highest weight. Table 43 in the *ASHRAE Handbook HVAC Applications* contains the same information as Table D14 in AHRI Standard 885. The information in both these standards was derived from ASHRAE research project 755 conducted by the National Research Council of Canada (NRCC). (See also Technical Note #5.)

5. To better understand the claims, data and prediction method in the ASHRAE and AHRI standards, one must become familiar with the foundational study *ASHRAE RP-755* conducted by the National Research Council Canada (NRCC) (free download). "ASHRAE RP-755 was initiated to investigate the transmission of sound through different ceiling types with the intent of providing more reliable design information to deal with sound transmission through ceilings close to HVAC devices."

The average total attenuations [sound power (Lw) of the HVAC device above the ceiling to sound pressure (Lp) at listening height inside the room below] for the ceiling types shown in Table TN-5.1 are provided in Figure TN-5.2 (Figure 3.1 in ASHRAE RP-755).

AHRI 885 Type #	RP-755 Code	Description*	Thickness	Weight (psf)	NRC	CAC	STC
1	A895	Mineral Fiber	5/8"	1.00	0.45	34	18
2	A775B	Mineral Fiber	5/8"	0.50	0.50	31	17
4	FGvin	Glass fiber, perforated vinyl face	2"	0.63	1.10	28	14
5	FGTL	Glass fiber, perforated vinyl face, metal foil backing	2"	0.63	1.10	30	16
3	A2910	Glass fiber, random fissured	5/8"	0.10	0.70	–	–
6	G13	Gypsum board, vinyl-faced	1/2"	1.80	0.00	39	19

** More information about the ceiling panels in table TN5.1 can be found in ASHRAE TC2.6, Final Report RP755, Tables 3-1 (page 5) and 9-1 (page 59)*

Table TN5.1 Compiled information for each ceiling type studied in *ASHRAE RP-755* and reported in *ASHRAE Handbook HVAC Applications and AHRI Standard 885.*

To understand the results in Figure TN5-2, one must understand the three main factors that determine how much attenuation an acoustic ceiling will provide:

a. **Absorption** The extent that the tiles absorb reflected sound in the plenum and room.

b. **Malleability** The extent that the surface of the tile can conform to the irregularities of the ceiling grid and prevent noise leaks between the panel face and the grid flange.

c. **Weight** The extent that the tiles decrease the noise transmitting through the tiles.

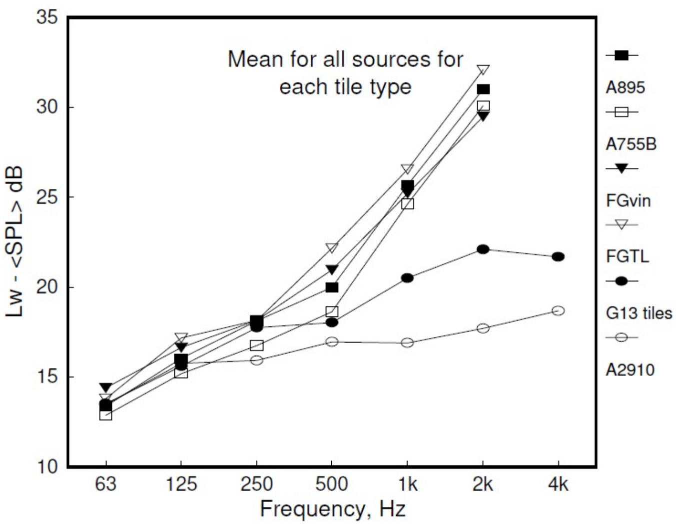


Figure TN-5.2 Average attenuations for acoustic ceiling panels in a suspended grid when the noise sources are HVAC equipment in the plenum and located close to the ceiling. Refer to Table TN5.1 for detailed information about the ceiling panels.

ASHRAE concludes, "experiments have shown that, for ceiling panels supported in a T-bar grid system, leakage between the panels and the grid is the major transmission path." This is evidenced by the low attenuation provided by the heavy gypsum board tiles (Type 6/G13) in the upper three octaves in Figure TN-5.2. The rigid material spans the high points in the supporting grid flanges, leaving gaps elsewhere through which noise leaks. Additionally, the gypsum board provides no absorption in the plenum or room. Even lower in attenuation performance is the very lightweight Type 3/A2910 fiberglass panel. While it has the malleability to decrease leaks at the grid, it has low absorption and very low weight. The highest overall attenuation is achieved by a fiberglass panel which is soft and seals the leaks at the grid, has very high absorption and a moderate weight. It has the right combination of all three factors. RP-755 concludes the following:

a. If the atypical gypsum board tiles and very lightweight glass fiber panels are excluded, the remaining and more standard acoustic ceiling panels made of either mineral fiber or glass fiber, between 5/8" and 2" thick, weighing between 0.5 psf and 1.00 psf and having absorption ratings (NRC) between 0.45 and 1.10, have very similar overall attenuation performance.

b. When all the tiles are considered, including the two lowest performing ones, the attenuation performances for all ceilings are very similar in the most important lower four octave bands. The performance difference is 1 dB in the 63 Hz octave band, 2 dB in the 125 Hz band, 3 dB in the 250 Hz band and 4 dB in the 500 Hz band. While the performance difference for the more standard ceiling tiles is higher in the upper three bands, higher attenuation in these bands is not likely to be beneficial since sound power levels of HVAC equipment do not typically increase in these upper bands.

c. Since most normal tiles provide about the same attenuation, there is little point in creating a test procedure to rate the effectiveness of ceiling tiles as attenuators of sound from air terminal devices. No measurement standard for this case has been developed since these conclusions were made.

6. The transmission loss of all the ceiling panels in *ASHRAE RP-755* (except A2910) was measured per ASTM E1414 (the test method used for the calculation of CAC per ASTM E413) and compared to the values of the measured ceiling attenuations in Figure TN-5.2. The differences in the test methods are shown in Figure TN-6.1 (Figure 13-4 in *ASHRAE RP-755*). If ASTM E1414 was an accurate predictor of ceiling attenuation, all values would be zero. If all ceilings had the same values, even if they were not zero, a simple transfer function between E1414 and actual ceiling attenuation could be derived.

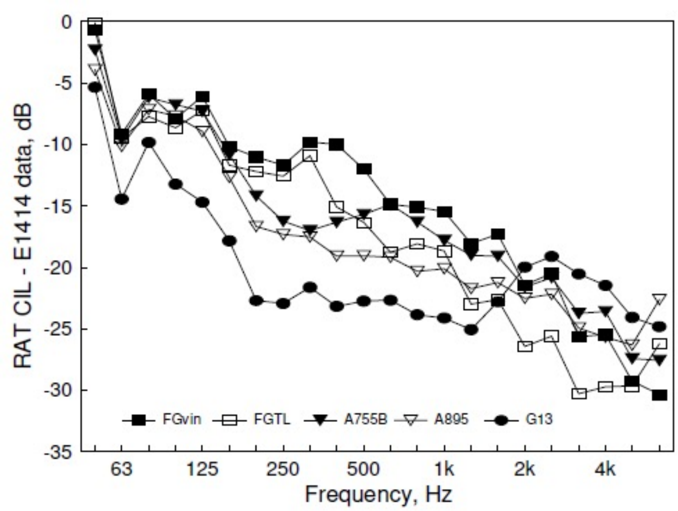


Figure TN-6.1 Measured ceiling attenuations of Figure TN-5.2 minus measured E1414 (CAC) values. Negative values indicate overestimation by E1414. Large differences between ceilings mean E1414 measurements are not usable for predicting ceiling attenuation.

All the values are negative because ASTM E1414 is a double-pass test setup (the noise passes through the ceilings twice) and the case being investigated is a single-pass situation. E1414 greatly overestimates the ceiling attenuation, giving negative values as high as 30 dB. However, ASHRAE/NRCC concludes, "in these figures, the actual value of the difference is not too important; it is the range of the data at any one frequency that matters. If the range were reasonably small, then the test procedure could be used to predict levels in a room under a ceiling/plenum system that contain a noisy device."

In Figure TN-6.1, there are large differences (10-15 dB) between the ceiling panel types when test method E1414 is used. The performance of the heavy gypsum board panel is overestimated the most because the gaps between the panels and grid matter less in a double-pass test method. Additionally, E1414 normalizes the beneficial effects of absorption provided by some of the ceiling panels. The result is higher transmission loss values and CAC ratings. NRCC and ASHRAE conclude:

a. "A substantial amount of sound transmission data is available for different ceiling types measured according to ASTM E1414 (CAC) in a two-room facility. Despite considerable work in the area, no acceptable method has been developed for estimating the random-incidence single-pass transmission loss from these double-pass data."

b. The ceiling panels with the highest attenuation performance in Figure TN-5.2 had some of the lowest CAC ratings (30 and 28) while the gypsum board panels with the highest CAC rating (39) provided one of the lowest attenuations (refer to Table TN-5.1).

c. "The E1414 test is not useful for this situation."

7. The transmission loss of all the ceiling panels in *ASHRAE RP-755* (except A2910) was measured per ASTM E90 (the test method used for the calculation of STC per ASTM E413) and compared to the values of the measured ceiling attenuations in Figure TN-5.2. The differences in the test methods are shown in Figure TN-7.1 (Figure 13-1 in *ASHRAE RP-755*). If ASTM E90 was an accurate predictor of ceiling attenuation, all values would be zero. If all ceilings had the same values, even if they were not zero, a simple transfer function between E90 and actual ceiling attenuation could be derived.

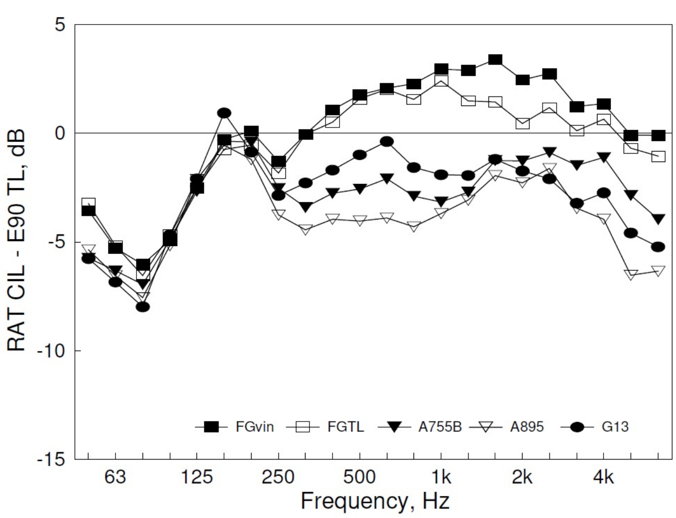


Figure TN-7.1 Measured ceiling attenuations of Figure TN-5.2 minus measured E90 (STC) values. Negative values indicate overestimation by E90. Positive values indicate underestimation by E90. Large differences between ceilings mean E90 measurements are not usable for predicting ceiling attenuation.

At 250 Hz and below, ASTM E90 overestimates ceiling attenuation for all ceiling panel types (negative values), but all ceiling panels basically perform the same. Above 250 Hz, ASTM E90 also overestimates the ceiling attenuation provided by the harder and more rigid panels, such as mineral fiber and gypsum board. Conversely, ASTM E90 underestimates the ceiling attenuation for high NRC ceiling panels, such as those made of glass fiber.

The reasons that ASTM E90 cannot be used to predict actual attenuation of acoustic ceilings when the noise source is a mechanical device in the plenum is two-fold; 1. it assumes a remote, nondirectional and decoupled sound source in a diffuse environment and 2. it normalizes the beneficial effects of the absorptive properties of some of the ceiling panel types. HVAC devices are directional sources in typically non-diffuse plenums and are so close to the ceiling that coupling occurs (refer to RP-755 and ASTM E-90).

Using ASTM E90 to predict the attenuation of an acoustic ceiling when the noise source is HVAC equipment above and close to the ceiling will result in up to 8 dB overestimation below 250 Hz, overestimation of up 7 dB above 250 Hz for heavier and more rigid panels and underestimation up to 3 dB for lighter more absorptive ceiling panel types. Like ASTM E1414 (CAC), ASTM E 90 (STC) is not useful in this situation.

8. The background noise requirements provided in step 2 are from the *ASHRAE Handbook, HVAC Application (2019)*, Table 1 Design Guidelines for HVAC-Related Background Sound in Rooms. If your building must comply with a different building standard or guideline, use those values instead. (Also see Technical Note #2.)

9. The values in this graph for Rockfon's heavier panels (> 0.5 psf) were derived using the following method per the *2019 ASHRAE Handbook HVAC Applications and AHRI Standard 885*:

a. Most building design standards require that most rooms have background noise levels of NC-30 (35-40 dBA), NC-35 (40-45 dBA) or NC-40 (45-50 dBA). Octave band values for these Noise Criterion curves were taken from Table 13 in *AHRI Standard 885*.

b. The 'Environmental Adjustment Factor' in Table C1 in *AHRI Standard 885* was added to the octave band background noise levels in step 'a' above. This is a minor correction in only low bands to account for how sound power of HVAC devices is measured in a free field versus actual plenum conditions.

c. The 'Uncorrected Ceiling/Space Effect Attenuation Values' per Table D14 in *AHRI Standard 885* for Rockfon stone wool panels were added to the sum of steps 'a' and 'b' above to get the maximum permissible sound power levels for the mechanical equipment in the plenum. Single-pass transmission loss for Rockfon stone wool panels weighing more than 0.5 psf (Alaska® and Sonar®) was measured per ASTM E336 (modified) and a space/room effect was applied using a volume of 3,600 c.f., and source to receiver distance of 5.5 feet (representing worse a case condition of a person standing directly under the HVAC device).

In greatly smaller rooms, the provided maximum sound power levels of the HVAC devices could be slightly high. It is more likely that the room is larger, the source to receiver distance is larger and the sound power levels could be even higher than given in the graph. In other words, the values in the graph are conservative in most cases.

10. The values in this graph for Rockfon's lighter panels (< 0.5 psf) were derived using the following method per the *2019 ASHRAE Handbook HVAC Applications* and *AHRI Standard 885*:

a. Most building design standards require that most rooms have background noise levels of NC-30 (35-40 dBA), NC-35 (40-45 dBA) or NC-40 (45-50 dBA). Octave band values for these Noise Criterion curves were taken from Table 13 in *AHRI Standard 885*.

b. The 'Environmental Adjustment Factor' in Table C1 in *AHRI Standard 885* was added to the octave band background noise levels in step 'a' above. This is a minor correction in only low bands to account for how sound power of HVAC devices is measured in a free field versus actual plenum conditions.

c. The 'Uncorrected Ceiling/Space Effect Attenuation Values' per Table D14 in *AHRI Standard 885* for Rockfon stone wool panels were added to the sum of steps 'a' and 'b' above to get the maximum permissible sound power levels for the mechanical equipment in the plenum. Single-pass transmission loss for Rockfon stone wool panels weighing less than 0.5 psf (most panels except Alaska and Sonar) was measured per ASTM E336 (modified) and a space/room effect was applied using a volume of 3,600 c.f., and source to receiver distance of 5.5 feet (representing worse a case condition of a person standing directly under the HVAC device).

In greatly smaller rooms, the provided maximum sound power levels of the HVAC devices could be slightly high. It is more likely that the room is larger, the source to receiver distance is larger and the sound power levels could be even higher than given in the graph. In other words, the values in the graph are conservative in most cases.

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