ENGINEERING UPDATE

MAY 2014 - **VOLUME 14**

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SPECIFYING SOUND POWER LEVELS INSTEAD OF NOISE CRITERION FOR TERMINAL UNIT APPLICATIONS

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Terminal unit sound performance is often a poorly understood concept, frequently misapplied or compared between manufacturers. Without a clear understanding of how sound is obtained and identified in manufacturer literature, selecting an appropriate terminal unit can be a daunting, complicated and frustrating process.
With such knowledge, designers are able to select and specify products that meet the design goals of the project in a clear and concise manner.

Sound Pressure and Sound Power

Sound power is the total sound energy of an object independent of any environmental influences.
A manufacturer measures the sound power produced by the terminal unit in accordance with industry accepted standards. Sound power levels can then be used to predict the sound pressure in a specific environment where factors such as distance, ceilings, carpet and furnishings affect the loudness of the environment experienced by the occupant. Sound pressure is determined by subtracting attenuation factors from known sound power levels.

The performance of a space heater is a great analogy.

The heater's output is measured in Watts.
The temperature measured in the room will vary with distance from the heater, and the construction of the room in which the heater is located. Changes to wall insulation, floor and ceiling construction, and equipment or furniture located in the space will alter the temperature in the room, but the output of the heater is unchanged. Sound power is the unalterable acoustic energy of the terminal unit. What the occupant hears (sound pressure) can be likened to the room temperature in the space heater analogy. Sound pressure is greatly affected by the installed conditions of the terminal unit or other potential noise sources.

In the occupied space served by an HVAC system, there are many potential sources of noise – the air handling unit, exhaust fans, room air devices, mechanical equipment, and terminal units. This discussion will be limited to terminal units as the noise source. The sound energy created by these sources travels along many paths to the receiver, as shown in Figure 1. As the sound travels to the receiver, the sound energy will be absorbed, reflected or transmitted.

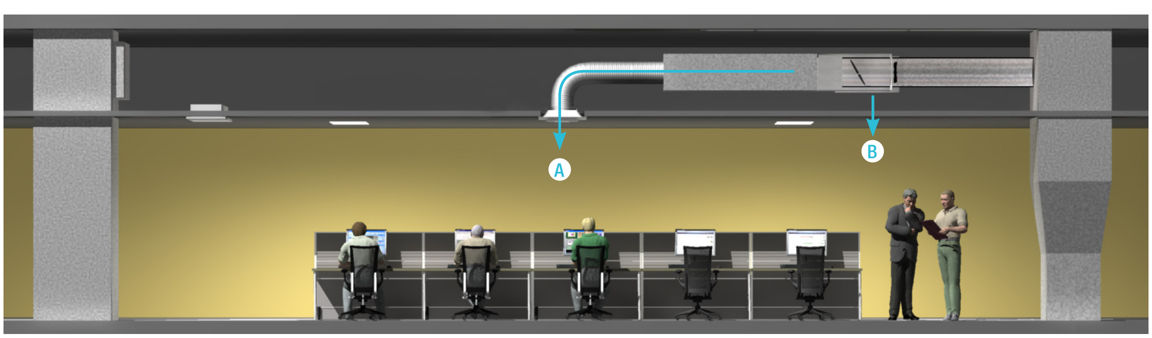

Figure 1: A - Duct-borne path (discharge sound), where sound from the terminal unit passes through the duct-work into the occupied space.
B - Airborne path (radiated sound) where sound from the terminal unit radiates directly to the receiver.

This system attenuation has a significant impact on the net sound levels achieved in the occupied space. Because of these variables, it is essential that an acoustic analysis is performed to consider all significant transmission paths, especially in critical applications where low noise levels are required.

Noise Criterion

Noise Criteria (NC) is a single number rating derived from sound pressure levels in all eight octave bands, and is intended to predict an occupant's response to the overall sound level. For terminal units, the critical octave bands for evaluating sound performance range from 125 to 4000Hz. To determine the NC rating value, sound pressure levels are plotted with a family of criterion curves shown in Figure 2. The level which intersects the highest curves determines the overall NC rating.

Industry Standards and Catalog Data

Sound performance data for terminal units is provided in two manners: sound power levels and a Typical Selection Guide showing NC ratings. The sound power levels are tables of the laboratory tested discharge and radiated sound power levels. This data shows the "raw" octave band sound power levels of the terminal units in the second through seventh octave bands with no attenuation allowances. The terminal sound data is obtained in accordance with ASHRAE Standard 130 and the AHRI 880 certified ratings program.

The NC ratings shown in the Typical Selection Guide are representative of the expected sound level for a specific installation. The NC rating is determined by the application of standardized attenuation values defined by AHRI Standard 885-2008 Appendix E. These attenuation values are based on specific assumed installed conditions and should not be used for designing specific spaces, unless those spaces exactly match the assumed conditions. The sole appropriate purpose for these NC level ratings is a relative comparison of one unit to another. However, in order to make a fair comparison of product NC ratings from different manufacturers, a careful review of the attenuation allowances must be made to ensure they are consistent.

Standardized Attenuation Factors for Radiated Sound

The ceiling/space effect for radiated sound from Appendix E of AHRI 885 are shown in Figure 3. These deductions apply to a piece of equipment located in the ceiling space,

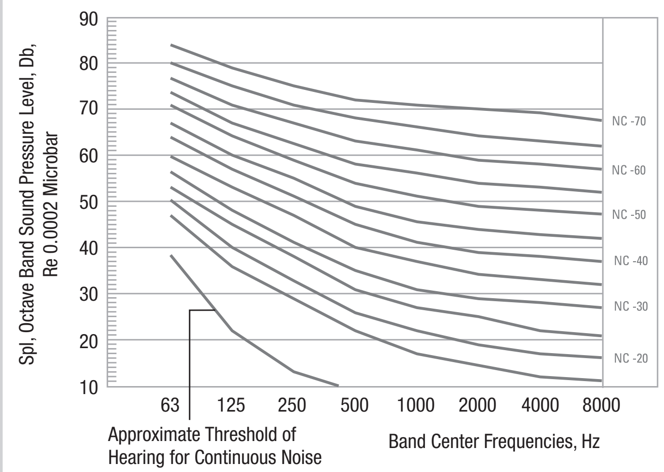

Figure 2: Noise Criteria Curve

and account for the combined effects of the absorption of the ceiling tile, plenum absorption and room absorption. The following installed conditions are assumed:

- 5/8" tile, 20 lb/ft^3 density
- The plenum is at least 3 ft (0.9 m) deep
- The plenum space is either wide (over 30 ft [9 m]), or lined with insulation
- The ceiling has no significant penetration directly under the unit

NC	Octave Band Mid Frequency					
	2	3	4	5	6	7
Type 1, Mineral Fiber Tile	16	18	20	26	31	36

Figure 3: Ceiling/space effect, dB (AHRI Standard 885-2008, Appendix E, Table E1)

Standardized Attenuation Factors for Discharge Sound

The discharge sound attenuation factors defined in AHRI 885-2008 Appendix E are shown in Figure 4 for several sizes of terminal boxes.

	Octave Band Mid Frequency					
	2	3	4	5	6	7
Small Box	24	28	39	53	59	40
Medium Box	27	29	40	51	53	39
Large Box	29	30	41	51	52	39

1. Small Box (8 in. x 8 in. [0.2 m x 0.2 m]) <300 cfm [0.14 m^3/s]
2. Medium Box (12 in. x 12 in. [0.3 m x 0.3 m]) 300 to 700 cfm [0.14 to 0.33 m^3/s]
3. Large Box (15 in. x 15 in. [0.4 m x 0.4 m]) > 700 cfm [0.33 m^3/s]

Figure 4: Terminal sound power, dB (AHRI Standard 885-2008, Appendix E, Table E1)

A very important consideration that dramatically affects the resulting sound levels is the attenuation provided by duct liners. As one might expect, different liners attenuate differently. Refer to Figures 5, 6, and 7 for attenuation values for fiberglass, solid metal and fiber free foam liners. Keep in mind, however, that it is recommended that the designer use the attenuation factors for solid metal for all liner types other than one inch fiberglass.

For a detailed explanation of the individual attenuation factors, refer to AHRI 885 or the ASHRAE Applications Handbook chapter on Noise and Vibration Control.

A Note on End Reflection

Duct end reflection occurs at the termination of a duct where there is a large change in cross sectional area, and a significant amount of low frequency sound is reflected back into the duct work. The amount of end reflection varies with the size and type of duct, with greatest impact at low frequencies and small discharge duct sizes. AHRI regulations required manufacturers to catalog discharge sound power levels with duct end reflection corrections by January 1st, 2013. The resulting published sound power levels are higher than previously published, and possibly higher than other manufacturers who have not yet updated their data. Discharge sound power levels tested in accordance with AHRI Standard 880-2011 include the end reflection correction. When comparing data between manufacturers, it is essential to ensure that the end reflection correction is consistently applied.

Specifying for Protection Against Liability

Effective sound specifications and schedules specify the maximum allowable sound power levels in the critical octave bands to ensure that all manufacturers provide comparable performance.

Large box, >700 cfm [330 L/s]						
Octave Band Mid Freq, Hz	2	3	4	5	6	7
	125	250	500	1000	2000	4000
Lining Reduction (1 in. fiberglass, 15 x 15 in. duct)	2	3	9	18	17	12
Power Splits (3 diffusers)	5	5	5	5	5	5
End Reflection (8 in. duct)	9	5	2	0	0	0
Flex Duct Reduction (8 in. duct)	6	10	18	20	21	12
Environmental Adj. Factor	2	1	0	0	0	0
Room Attenuation 2400 ft^3	5	6	7	8	9	10
Total Attenuation	29	30	41	51	52	39
Reference • AHRI Standard 885-2008, Appendix E, Discharge Sound Attenuation Factors						

Figure 5: Attenuation factors for dual density fiberglass

Large box, >700 cfm [330 L/s]						
Octave Band Mid Freq, Hz	2	3	4	5	6	7
	125	250	500	1000	2000	4000
Lining Reduction (solid metal liner, 15 x 15 in. duct)	0	0	0	0	0	0
Power Splits (3 diffusers)	5	5	5	5	5	5
End Reflection (8 in. duct)	9	5	2	0	0	0
Flex Duct Reduction (8 in. duct)	6	10	18	20	21	12
Environmental Adj. Factor	2	1	0	0	0	0
Room Attenuation 2400 ft^3	5	6	7	8	9	10
Total Attenuation	27	27	32	33	35	27

Figure 6: Adjusted attenuation factors for solid metal liner

Large box, >700 cfm [330 L/s]						
Octave Band Mid Freq, Hz	2	3	4	5	6	7
	125	250	500	1000	2000	4000
Lining Reduction (fiber free foam liner, 15x15 in. duct)	0	1	0	2	3	2
Power Splits (3 diffusers)	5	5	5	5	5	5
End Reflection (8 in.duct)	9	5	2	0	0	0
Flex Duct Reduction (8 in. duct)	6	10	18	20	21	12
Environmental Adj. Factor	2	1	0	0	0	0
Room Attenuation 2400 ft^3	5	6	7	8	9	10
Total Attenuation	27	28	32	35	38	29

Figure 7: Adjusted attenuation factors for fiber free foam liner

An NC specification can be an acceptable sound specification if, and only if, the assumed attenuation values, by room or zone, are also specified. An acoustical analysis must be completed to determine the project specific attenuation values – the values cannot be assumed. Returning to the space heater analogy, the desired temperature range of the space is assumed, but it is the designer's responsibility to determine the loads and required heating or cooling capacity to ensure the comfort of the occupant. A terminal manufacturer does not know the final installed conditions of the terminal unit, therefore sound power levels are the only way to ensure the acoustic design goals are met and accurately compare sound data from multiple manufacturers.

Conclusion

The best way to ensure an acoustically successful project is to specify the maximum sound power levels of the equipment.

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PRODUCT FEATURE: PRICE INTRODUCES 80/20 MIXING BOX TO DIRECT FIRED PRODUCT LINE FOR US MARKET

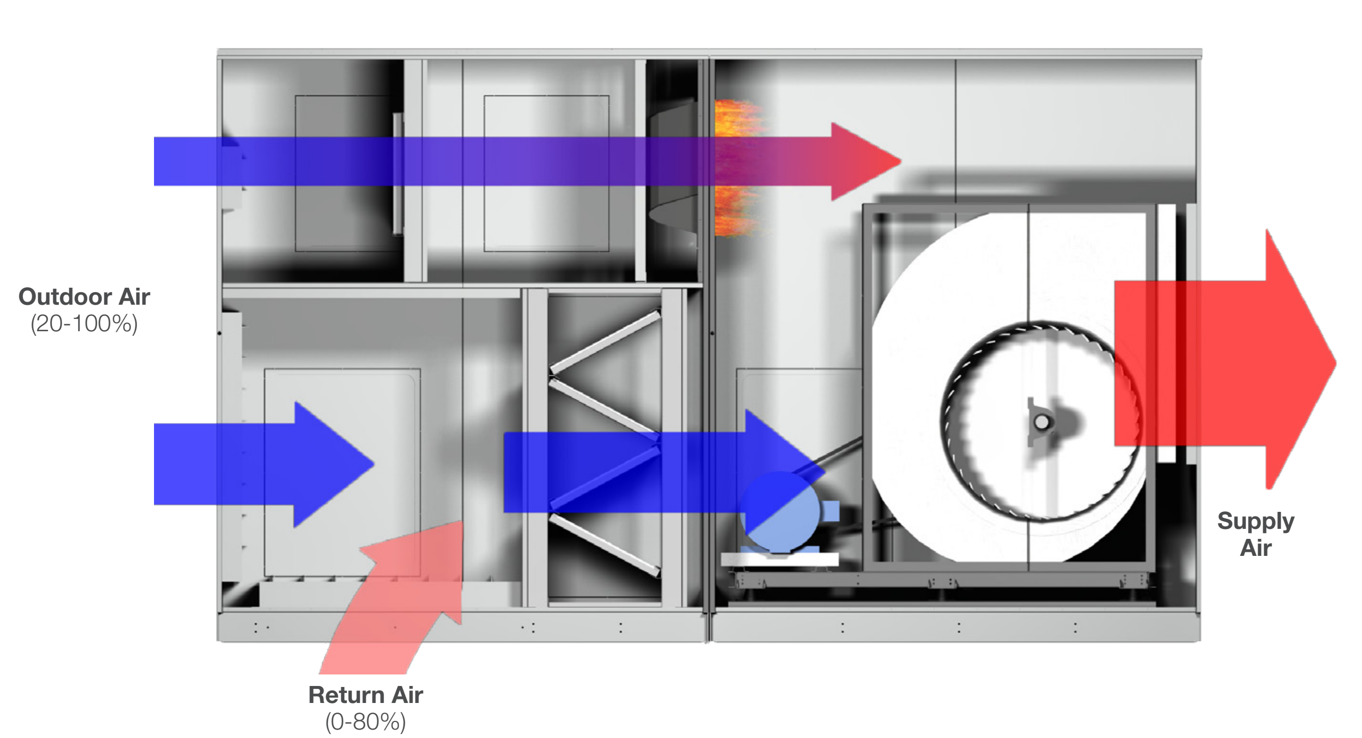

Figure 1: Shows the air flow path through an AW-D model with the mixing box. Twenty percent of the outdoor air is separated and passes through its own filter bank and then across the burner. This design avoids return air passing through the burner and improves indoor air quality, since return air may have some minor products of combustion in it. If return air is passed through the burner for a second time it can create contaminants and lower the air quality.

By Hugh Crowther, P.Eng – Executive Vice President, Product Management and Technology

As Price Industries expands its mechanical product offering into the US market, special features are being added to our lines to meet the US needs.

Price is pleased to announce the 80/20 mixing box option has been added to the AW-D direct fired gas heat products. We are now completing the final testing with ETL.

The mixing box blends outdoor air with return air. Eighty percent of the supply air comes from the mixing box, so the unit can operate between 100% outdoor air (mixing box set to all outdoor air) and 20% outdoor air (mixing box set to all return air).

Adding a mixing box to a gas heat unit offers several advantages to the system designer:

- Constant supply air volume to the space ensures the desired number of air turnovers and helps manage stratification issues

- The modulating mixing box allows the amount of outdoor air being introduced to the building to be adjusted as required. This can be a significant energy savings
- The constant air flow over the burner provides reliable operation

The percentage of outdoor air can be managed by several methods:

- The percentage of outdoor air can be increased as exhaust fans in the building are turned on
- Building pressurization can be used to increase or decrease the percentage of outdoor air
- CO2 monitoring can be used to increase or decrease the percentage of outdoor air
- Drybulb or enthalpy controllers can be used to adjust the outdoor air flow above minimum as a form of free (economizer) cooling

For more information on Price's extensive Make-Up Air, Custom Rooftop, and Energy Recovery solutions, please visit www.priceindustries.com or contact your local sales representative.

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TECH TIP: IMPACT OF CEILING TYPE ON TERMINAL UNIT RADIATED SOUND

By Jerry Sipes, Ph.D., P.E. – Vice President of Engineering, Atlanta

In a previous Tech Tip – Terminal Unit Liner Acoustical Considerations – I discussed the impact that liner selection can have on radiated and discharge sound from terminal units. The article discussed the impact on sound caused by selecting a solid metal liner to prevent fiberglass particles from being entrained in the discharge air stream.

Many times I have seen ceilings either removed from rooms or changed to a cloud type to add the perception of volume to the space. Many design engineers do not consider the impact on the room sound levels when a ceiling is removed. And most designers do not consider the impact of changing both liner and ceiling type and the resultant change in the overall room sound levels.

As you are aware, to obtain an NC rating for a terminal unit, the discharge and radiated sound pressure levels obtained by testing in a reverberant sound chamber are converted by taking the sound power data and applying the attenuation factors from Appendix E, in the AHRI Standard 885 "Procedure for Estimating Occupied Space Sound Levels in the Application of Air Terminals and Air Outlets". In the online AHRI certification database, most manufacturers only rate their standard construction terminal which uses a fiberglass liner. So when a design engineer selects a different liner, the catalog data for many suppliers may not take into account this shift in NC values. For more on this, please see the previously mentioned Tech Tip – Terminal Unit Liner Acoustical Considerations.

The Appendix E attenuation factors that are used to estimate NC levels for terminal units include attenuation for a suspended acoustical ceiling (see **Table 1**). A common mistake made by design engineers is that they fail to account for the lowered attenuation of sound when the ceiling type is either changed to a solid surface, such as drywall, or when the ceiling is removed (or becomes a 'cloud').

I looked at the impact that ceiling type has on the occupied sound levels and compiled the following tables for the gain or loss in the calculated NC value for the radiated sound based on no ceiling, mineral fiber acoustical ceiling, and drywall ceiling. I kept the same room physical characteristics as the basis used in the Appendix E attenuation factors and just changed the ceiling type. That is to say, the terminal is mounted five feet above the occupant who is standing in a 2,400 ft³ space.

Table 1: Typical Sound Attenuation Values, dB (from AHRI Standard 885, Appendix E)

Diffusers: Deduct 10 dB in all Octave Bands to compute diffuser NC						
VAV Terminals: Radiated Sound Ceiling Plenum Noise Sources: Total deduct from Sound Power to Predict Room Sound Pressure (Includes Environmental Effect), dB						
Assumes, 3 ft [0.9 m] deep plenums with non-bounded sides						
	Octave Band Mid Frequency, Hz					
	125	250	500	1000	2000	4000

Table 2: SDV14 Terminal with Standard 1" thick Fiberglass Liner, NC Value by Ceiling Type

NC Value determined using AHRI Standard 885, Appendix E attenuation factors	Estimated Room Radiated NC by Ceiling Type		
	Mineral Fiber	Drywall Ceiling	No Ceiling (Terminal Exposed)
30	30	24	43

The size 14 single duct terminal shown in **Table 2** was selected with a volume flow rate of 2,400 cfm at a differential static of 1.25 inches w.c. across the damper. As you can see, removing the ceiling and selecting a terminal using the standard attenuation factors will result in a louder space than anticipated. A rise of 7 NC is enough to generate sound complaints. Changing the ceiling type can have a very large impact on the occupant perception of how much sound is being generated by the terminal units. In this case, the removal of the ceiling raises the space NC values by 13 and although the resulting NC is below 45, this gain in NC may result in occupant complaint.

In fan powered terminals, combining the liner change and change of ceiling treatment can have a much larger impact than anticipated, particularly if the design engineer calls for all NC values in the submittal to be based on the attenuation factors in Appendix E of the AHRI 885 Standard.

Table 3 shows a fan powered terminal, model FDCA 3010, with 1,090 cfm fan and primary valve volume flow rate at a differential static of 1.25 inches w.c. across the primary air valve damper. Since liner type has a large impact on the amount of radiated sound from a fan powered terminal due to the return air opening, liner types are also varied and reported.

When a design engineer uses a non-fiberglass liner, and/or non-mineral fiber ceiling type, they should consider specifying the specific attenuation factors that are to be used for calculating the NC values as the default values can easily lead to a space with unexpected sound levels.

Table 4 shows the radiated sound power deductions for various ceiling types. It is suggested that the design engineer place the appropriate radiated sound power deductions for the project ceiling type and require that NC values on submittals be calculated using the specified values.

For more information on this and other aspects of terminal unit selection, please see the Price HVAC Handbook or contact the Price Applications Engineering Team.

Table 3: FDCA3010, NC by Ceiling and Liner Type

Liner Type (1" thick)	NC value determined using Appendix E attenuation factors	Estimated Room Radiated NC by Ceiling Type		
		Mineral Fiber	Drywall Ceiling	No Ceiling (Terminal Exposed)
1.5 lb/ft^3 fiberglass	33	33	27	46
FoilBoard	34	34	27	47
FiberFree	36	36	28	49
Solid Metal	36	36	30	49

Table 4: Radiated Sound Power Deductions for various ceiling types

Ceiling Type	Density (lb/ft^3)	Thickness (inch)	Weight (lb/ft^2)	Octave Band Mid Frequency, Hz					
				120	250	500	1000	2000	4000
Mineral Fiber*	20	0.63	1	18	19	20	26	31	36
Mineral Fiber	10	0.63	0.5	17	18	19	25	30	33
Glass Fiber	4	1.97	0.6	18	16	17	17	18	19
Gypsum Board Tiles	43	0.51	1.8	18	19	18	21	22	22
Solid Gypsum Board	43	0.51	1.8	23	26	25	27	27	28

*Ceiling type used in AHRI 885-2008, Appendix E