TRANE®

providing insights for today's hvac system designer

Engineers Newsletter

volume 47–4

Understanding VAV

Sound Standards

Acoustics are an important and often overlooked topic in HVAC&R. Many pieces of equipment in these systems generate sound, including chillers, air handlers, rooftops, and variable air volume (VAV) boxes. In this Engineers Newsletter, we are going to provide an overview of acoustics related to VAV boxes.

Fundamentals of Acoustics

When discussing sound, you will see a variety of terms and phrases, including sound pressure, sound power, A-weighted, noise criteria (NC), room criteria (RC) and many more. When discussing indoor acoustics, NC and A-weighted sound values are used.

Sound pressure and power Sound pressure, sometimes written as L_p, refers to the pressure disturbances created as sound waves pass through air. The human ear responds to these sound pressure disturbances. Obstructions in the sound path between the source and receiver affect sound pressure.

Sound power, L_W, is the magnitude of acoustical energy created by the sound source. Unlike sound pressure, distance and obstructions do not affect sound power.

Noise Criteria (NC) NC values are likely the most common single-number descriptor used to define indoor sound quality. Building owners may require specific NC levels for spaces. NC curves slope downward from left to right to reflect the human ear's increasing sensitivity at higher frequencies. Lower NC values indicate quieter spaces. The following procedure determines NC given sound pressure levels in a range from 63 to 8000 Hz:

1. Plot the sound pressure levels for each octave band on an NC chart.
2. Identify the highest NC curve intersected by the plotted sound pressure level. This curve identifies the NC rating.

Figure 1 shows sample sound pressure levels on an NC chart. In this example, the 63 Hz octave band determines the rating of NC 40 because this is the highest NC curve intersection. Sound in the higher frequency ranges drops off quickly.

A-weighting Weighting curves developed by Fletcher and Munson and published in 1933 have been used to compensate for the human ear's varying sensitivity at different frequencies. The "A" weighting curve, often written as dBA, is most often used because it best approximates human hearing at low sound pressure levels where hearing protection is not necessary.

To calculate an A-weighted value:

1. Subtract A-weighting curve values, in decibels, from the corresponding octave band sound pressure level for each octave band (63 to 8000 Hz).
2 Use logarithmic addition to sum the

adjusted sound pressure levels for all eight octave bands. The resulting value represents the A-weighted sound pressure level to be expressed with "dBA" as the unit of measure, e.g. 41 dBA.

The entire procedure is explained in detail and with an example in the "Acoustics in Air Conditioning" Applications Engineering Manual published by Trane.

VAV box acoustics

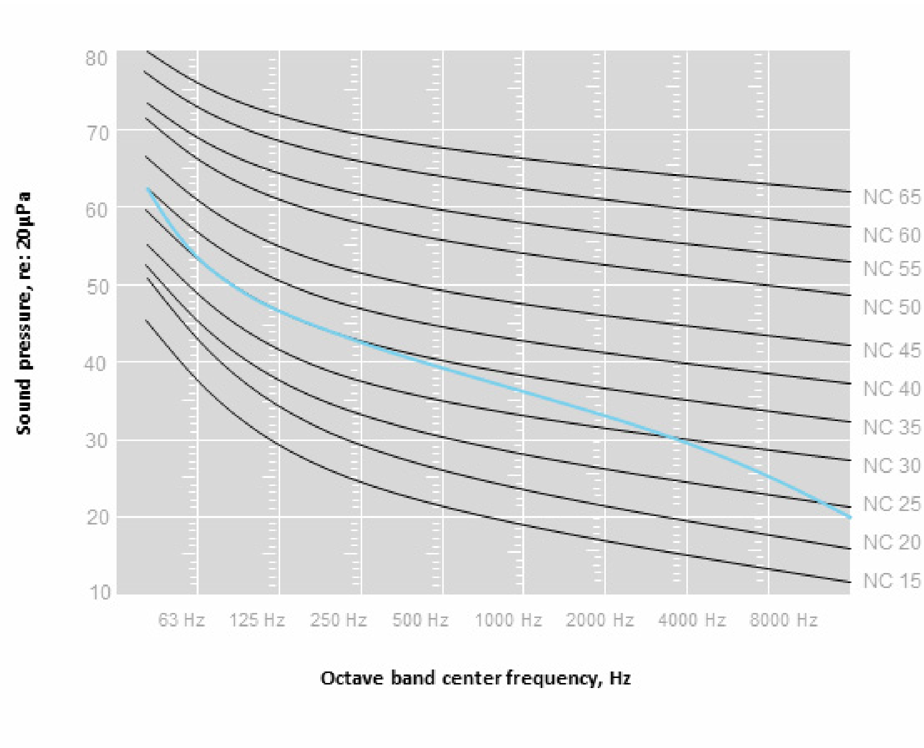
Conditioned air is supplied from an air handler or rooftop unit to spaces to maintain space temperature in a multiple-zone VAV system. VAV boxes installed downstream of the supply fan, are used to vary the supply of conditioned air to the spaces. The VAV box contains an airflow-modulation device (air valve), controls, and depending on system application, possibly a heating coil, filter, and small terminal fan. The air passing through a VAV box generates sound.

VAV box sound standards

There are currently two major sound standards for VAV acoustics in North America: ANSI®/AHRI® Standard 880 and ANSI/AHRI Standard 885. Representatives from AHRI-member companies participate in standard development, which results in industry agreed-upon standards. AHRI publishes its standards online and free to view. Go to www.ahrinet.org to view these standards.

AHRI Standard 880 AHRI Standard 880-2017 "Performance Rating of Air Terminals" establishes test requirements, rating requirements, and minimum data requirements for air terminal devices.to determine VAV box sound power. These devices may include pressure-dependent air valves, pressure-independent air valves, fans with on/off or speed control, heating elements, and diffusers. The standard does not apply to air registers or diffusers and grilles without an air valve.

Figure 1. Plotted sound pressure levels on an NC chart



For rating purposes, all manufacturers are required to test with a differential static pressure of 1.5 inches H_2O and 100% airflow. This ensures that sound data from one manufacturer can be compared equally to another because the data was collected at the same rating conditions, if the data was collected with the same version of Standard 880. If different versions of the standard were used, two sets of data may not be directly comparable due to the addition of duct end corrections (see page 3).

Discharge sound power refers to the sound that leaves a VAV box. In sound predictions, the discharge sound power is used to help predict the sound levels inside a space because of supply air passing through the VAV box, flexible duct, and diffusers into the space.

Radiated sound power escapes the VAV box casing. This sound will affect indoor sound pressure levels unless attenuated by acoustic ceiling tiles, for example. It is becoming more common for commercial buildings to be built without acoustic ceiling tiles. With HVAC equipment open to the occupied space, designers must be more aware of radiated sound to ensure acceptable sound pressure levels in the occupied spaces. A mitigating option would be to locate the VAV box over a non-critical area.

Standard 880 requires that sound power levels from octave band center frequencies 125 through 4000 Hz be presented in documentation like catalogs and selection reports. Alternatively, this may be written in octave bands from 2 through 7 (125 to 4000 Hz). Octave band 1 at 63 Hz is omitted from the standard because air terminals do not generate significant sound at this frequency. Manufacturers are allowed to publish data beyond the required sound bands.

Table 1 shows an example 700-cfm shut-off VAV box tested in accordance with AHRI Standard 880. Both discharge and radiated sound power are shown.

In a parallel fan powered VAV installation, a small terminal fan in the VAV box recirculates air from the plenum when heat is needed. In a series fan powered VAV installation, the terminal fan operates continuously. Additional tests with the fan on and off are required for fan-powered VAV boxes because the fan generates additional sound and, depending upon the configuration, may not run the entire period of operation.

Parallel fan-powered VAV box sound power data is presented for terminal fan-only operation and standard cooling operation (where the terminal fan is not operating) as shown in Table 2. Series fan powered VAV box sound power is presented for terminal-fan operation only and terminal fan plus primary airflow operation as shown in Table 3.

Footnotes generally accompany the table of data indicating which version of Standard 880 was used for testing and relevant commentary on the VAV box and/or tests.

Duct end corrections The Standard 800 committee added "duct end corrections" to the standard beginning in 2011 in an effort to account for open-ended duct terminations into large rooms. This can be referred as "end reflection loss." This gives testers the ability to account for the sound that should enter a test chamber to be measured but does not. Instead, some low-frequency plane waves rebound back into the duct and are not measured. In an installation, this phenomenon is usually desirable as it reduces the amount of sound transmitted to the space through the supply air path.

Certified sound Manufacturers may choose to participate in AHRI's VAV box Certification Program. Annual independent verification of randomly sampled VAV boxes ensures manufacturer's performance claims are accurate within tolerance limits set by both Standard 880 and the Certification Program. The VAV box operating characteristics evaluated include discharge and radiated sound power (for the damper and, in the case of fan-powered boxes, the fan), wide-open damper pressure drop, and fan motor power consumption.

Once approval is received, manufacturers are able to use the AHRI VAV Certification Mark to show compliance.

While certification applies to one operating point and cooling-only VAV boxes, manufacturers typically publish data that covers the entire operating range of their products, including the effects of options like reheat, VAV box lining, and alternate housing geometries.

AHRI Standard 885 ANSI/AHRI Standard 885-2008 "Procedure for Estimating Occupied Space Sound Levels in the Application of Air Terminals and Air Outlets" uses sound power taken in accordance with Standard 880 to estimate sound pressure in the occupied space. This industry-

Table 1. Discharge and radiated sound power for a 700-cfm shut-off VAV box.

Octave (Hz)	125	250	500	1000	2000	4000
Discharge	71	71	63	59	58	60
Radiated	57	54	53	45	42	36

Table 2. Discharge and radiated sound power for a 700-cfm parallel fan powered VAV box.

Octave (Hz)	125	250	500	1000	2000	4000
Discharge - valve only	66	63	60	57	54	49
Radiated - valve only	64	58	53	47	42	35
Discharge - fan only	66	59	59	55	50	48
Radiated - fan only	69	62	60	56	52	49

Table 3. Discharge and radiated sound power for a 700-cfm series fan powered VAV box.

Octave (Hz)	125	250	500	1000	2000	4000
Discharge - fan and 100% primary airflow	68	62	59	55	54	52
Radiated - fan and 100% primary airflow	74	69	66	63	61	63
Discharge - fan only	64	56	58	54	52	51
Radiated - fan only	60	57	56	53	50	49

developed method gives the user a procedure to compute space sound pressure using hand-calculations or a spreadsheet.

In many presentations of VAV box sound data, a space NC level is printed. The attenuation values printed in Table E1 of Normative Appendix E "Typical Sound Attenuation Values", often called transfer functions, are used as deducts to compute the space sound pressure. Each deduct is subtracted from the VAV box sound power value in the same octave band to determine sound pressure. Then, the NC-level is computed using the sound pressure and published for both discharge and radiated sound. The result is two unique and different NC values for a single VAV box.

This appendix and the attenuation values used within are not used to estimate sound pressure for actual installations. The attenuation values were developed with a number of assumptions, such as the size of a room being served by the VAV box, the plenum depth, and acoustical ceiling type materials. **It is for these reasons that the NC level printed in a catalog or selection report should not be expected in the actual installation.** Instead, the NC level gives designers another tool to compare VAV boxes from a sound perspective because each VAV box NC level is computed using the same criteria. To predict an NC level in the actual space, an acoustic model would need to be created using software like the Trane Acoustics Program (TAP™) or a system mock up.

Separate attenuation values are provided for the discharge and radiated sound paths. Over the course of several publications, these attenuation values have changed, complicating matters. For example, the discharge sound pressure from a medium sized VAV box serving 700 cfm would be reported as NC 35 when tested in accordance with ARI Standard 885-1998 and NC 31 when tested with Standard 885-2008. For the same box, the radiated sound pressure would be reported as NC 26, NC 27, or NC 22 depending on the acoustical ceiling tile material being used, if tested with Standard 885-1998 version. If Standard 885-2008 were used, only NC 27 would be reported. See pages 5-7 for a comparison of the attenuation values and their results from the two most recent versions of Standard 885.

The evolution of AHRI Standard 885 Sound Attenuation Values

The sound attenuation values (transfer functions) found in AHRI Standard 885 have been changed over the course of several publications. Discharge attenuation values have been provided in the standard from 125 to 8000 Hz while radiated attenuation values have been provided from 125 to 4000 Hz.

In the 1998 publication, there were three options for discharge attenuation values based upon VAV box size and airflow:

ARI Standard 885-1998 – Table E1 – Discharge Attenuation values

	125	250	500	1000	2000	4000	8000
Small Box (8 x 8 in.) <300 cfm	25	28	38	53	58	31	28
Medium Box (12 x 12 in.) 300-700 cfm	27	26	39	51	53	33	26
Large Box (15 x 15 in/) >700 cfm	29	30	40	51	51	35	29

In the 2008 update, the discharge attenuation values were largely republished with changes highlighted:

ARI Standard 885-2008 – Table E1 – Discharge Attenuation values

	125	250	500	1000	2000	4000	8000
Small Box (8 x 8 in.) <300 cfm	24	28	39	53	59	40	28
Medium Box (12 x 12 in.) 300-700 cfm	27	29	40	51	53	39	30
Large Box (15 x 15 in/) >700 cfm	29	30	41	51	52	39	32

In the 1998 publication, there were three options for radiated sound:

ARI Standard 885-1998 - Table E1 - Radiated Attenuation Values

	125	250	500	1000	2000	4000
Type 1 - Glass Fiber	19	19	21	25	29	35
Type 1 - Mineral Fiber	18	19	20	26	31	36
Type 1 - Solid Gypsum Board	23	26	25	27	27	28

In the 2008 update, only the mineral fiber option was left with no changes to the individual octave band attenuation values. Because the octave band attenuation values were not changed for mineral fiber, a strict 1998-to-2008 comparison with mineral fiber should yield no changes.

ARI Standard 885-2008 - Table E1 - Radiated Attenuation Values

	125	250	500	1000	2000	4000
Type - Mineral Fiber	18	19	20	26	31	36

The evolution of AHRI Standard 885 Sound Attenuation Values, continued

As a result, system designers must be very careful to ensure like-for-like comparisons when using Standard 885 and the resulting NC level derived from Appendix E. Three different VAV boxes were compared using 1998 and 2008 attenuation values. The resulting sound pressure and NC values are below.

First, a small, 150-cfm VAV box with a 4-inch inlet was evaluated with both versions:

	125	250	500	1000	2000	4000	NC
Discharge sound power	75	74	61	58	55	53	
...if ARI 885-1998: Small Box (8 x 8 in.) <300 cfm were used:	50	46	23	5	-3	22	NC 36
...if ARI 885-2008: Small Box (8 x 8 in.) <300 cfm were used:	51	46	22	5	-4	13	NC 36

	125	250	500	1000	2000	4000	NC
Radiated sound power:	52	52	50	43	39	33	
...if ARI 885-1998: Type 1 - Glass Fiber were used:	33	33	29	18	10	-2	NC 23
...if ARI 885-1998: Type 2- Mineral Fiber were used:	24	33	30	17	8	-3	NC24
...if ARI 885-1998: Type 3- Solid Gypsum Board were used:	29	26	25	16	12	5	NC 18
...if ARI 885-2008: Type - Mineral Fiber were used:	34	33	30	17	8	-3	NC 24

Next, a medium sized VAV box with an 8-inch inlet serving 700 cfm is considered:

	125	250	500	1000	2000	4000	NC
Discharge sound power:	71	71	63	59	58	60	
...if ARI 885-1998: Medium Box (12 x 12 in.) 300-700 cfm were used:	44	45	24	8	5	27	NC 35
...if ARI 885-2008: Medium Box (12 x 12 in.) 300-700 cfm were used:	44	42	23	8	5	21	NC 31

	125	250	500	1000	2000	4000	NC
Radiated sound power:	57	54	53	45	42	36	
...if ARI 885-1998: Type 1 - Glass Fiber were used:	38	35	32	20	12	1	NC 26
...if ARI 885-1998: Type 2- Mineral Fiber were used:	39	35	33	19	11	0	NC 27
...if ARI 885-1998: Type 3- Solid Gypsum Board were used:	34	28	28	18	15	8	NC 22
...if ARI 885-2008: Type - Mineral Fiber were used:	39	35	33	19	11	0	NC 27

The evolution of AHRI Standard 885 Sound Attenuation Values, continued

Finally, a large VAV box with a 10-inch inlet serving 1100 cfm is considered:

	125	250	500	1000	2000	4000	NC
Discharge sound power	75	70	67	66	61	57	
...if ARI 885-1998: Large Box (15 x 15in.) >700cfm were used:	46	40	27	15	10	22	NC 28
...if ARI 885-2008: Large Box (15 x 15in.) >700cfm were used:	46	40	26	15	9	18	NC 28

	125	250	500	1000	2000	4000	NC
Radiated sound power:	63	59	54	47	39	32	
...if ARI 885-1998: Type 1 - Glass Fiber were used:	44	40	33	22	10	-3	NC 28
...if ARI 885-1998: Type 2- Mineral Fiber were used:	45	40	34	21	8	-4	NC 28
...if ARI 885-1998: Type 3- Solid Gypsum Board were used:	40	33	29	20	12	4	NC 23
...if ARI 885-2008: Type - Mineral Fiber were used:	45	40	34	21	8	-4	NC 28

In the medium-sized VAV box, the reported discharge sound pressure is different when using the dissimilar attenuation values.

Using NC does present some challenges. Due to the nature of the procedure, different sound spectrums can result in the same NC level. For example, a sound spectrum dominated by low frequency sound could result in NC 40 shown as the blue sound spectrum in Figure 2 (next page). Middle frequency sound dominates the second sound spectrum, in red, which results in a different human response but the same NC level.

Final Thoughts

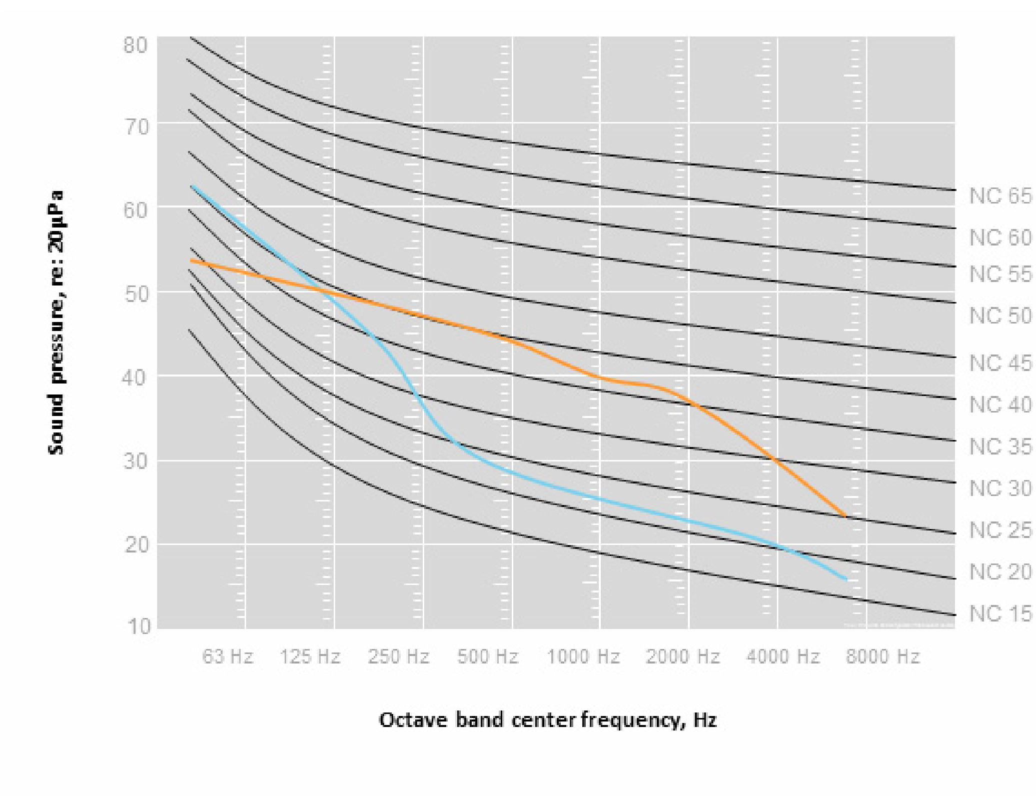
VAV boxes serve as both sound attenuators and regenerators in HVAC systems. The industry has provided two separate sound standards that pertain to VAV boxes: AHRI Standard 880 to determine and present sound power and AHRI Standard 885 to compute space sound pressure and show space NC level with a specific VAV box and representative space parameters.

In general, radiated and discharge sound power is provided for VAV boxes without terminal fans. Boxes with terminal fans will have radiated and discharge sound with and without the fan operating. Sound power is a property of the VAV box and sound pressure is the result of installation and the various paths sound takes to reach the space or receiver.

Published NC levels are based upon example installations where room sizes and materials are assumed and not specific to the actual project. Two catalog NC values—one for discharge sound and another for radiated—are provided. These values, when printed in a catalog or selection software, should be used only for comparison. When comparison does occur, it is important to ensure like-for-like comparison in the radiated and discharge material and parameters.

By Eric Sturm, Trane. To subscribe or view previous issues of the *Engineers Newsletter* visit trane.com/EN. Send comments to ENL@trane.com.

Figure 2. NC chart with two different sound spectrums resulting in the same NC level



Resources

Trane Resources

Guckelberger, D. and B.Bradley. *Acoustics in Air Conditioning* application manual. ISS-APM001-EN. April 2006.

Trane. "Fundamentals of HVAC Acoustics" *Air Conditioning Clinic*. TRG-TRC007-EN. February 2018.

Trane. "Achieving Acoustical Standards in the Classroom." Classroom Acoustics White Paper. EDU-SLB026-EN. December 1, 2013, www.www.trane.com/content/dam/Trane/Commercial/global/markets/k12/improvingstudentperformance/schoolacoustics/EDU-SLB026-EN_072414.pdf

Industry Resources

Air-Conditioning, Heating, and Refrigeration Institute. 2011. *AHRI® Standard 880-2011: Performance Rating of Air Terminals (I-P).* Arlington, VA: AHRI.

Air-Conditioning, Heating, and Refrigeration Institute. 2017. *AHRI Standard 880-2017: Performance Rating of Air Terminals (I-P).* Arlington, VA: AHRI.

Air-Conditioning, Heating, and Refrigeration Institute. 1998. *AHRI Standard 885-1998: Procedure for Estimating Occupied Space Sound Levels in the Application of Air Terminals and AIr Outlets.* Arlington, VA: AHRI.

Air-Conditioning, Heating, and Refrigeration Institute. 2008. *AHRI Standard 885-2008: Procedure for Estimating Occupied Space Sound Levels in the Application of Air Terminals and AIr Outlets.* Arlington, VA: AHRI.

Air-Conditioning, Heating, and Refrigeration Institute. Variable Air Volume Terminals Certification Program Operations Manual. AHRI.

ASHRAE®. 2017. ASHRAE Handbook—Fundamentals, Chapter 8 (Sound and Vibration). Atlanta, GA: ASHRAE.

ASHRAE. 2015. ASHRAE Handbook—Fundamentals, Chapter 48 (Noise and Vibration Control). Atlanta, GA: ASHRAE.

Articles

Fletcher, H. and W.A. Munson. "Loudness, Its Definition, Measurement and Calculation." The Journal of the Acoustical Society of America 5, 82; October 1933.

Analysis Software

Trane Acoustics Program (TAP™). Program details and trial software available at www.trane.com/TAP

Join your local Trane office for the 2019 Engineers Newsletter LIVE!

Mark your calendar!

Small Building System Control. Recent innovations provide more options to consider for controls in smaller buildings. This program will compare different configurations of packaged rooftop systems, describe the technologies available to control each system type, and demonstrate how to specify the controls to meet the needs of your customer.

Chilled-Water Coil Design for ASHRAE 90.1-2016. The 2016 version of ASHRAE Standard 90.1 requires chilled-water cooling coils be selected for at least a 15°F ΔT. This ENL demonstrates the process for selecting coils and control valves to meet this new requirement. illustrates coil configuration impact on part-load coil performance, and discusses the impact on chiller plant design operation.

Air and Waterside Economizing Reviews air- and waterside economizing advantages, drawbacks and considerations when using one versus the other. ASHRAE Standard 90.1 requirements and exceptions will also be discussed.

Design Considerations for Hydronic Heating Systems. Investigates various methods of providing efficient hydronic heating, including the use of heat-recovery chillers, heat pumps, and boiler systems.

Contact your local Trane office for dates and details.

Earn PDH credit - no charge and on-demand!

NEW Online Courses Available!

View all courses at **www.trane.com/ContinuingEducation**

High-Performance Air Systems examines the properties of high-performance air systems and provides guidance on their design. Topics include right-sizing and proper component selection, duct design guidelines, system control strategies, selection for part-load efficiency and much more.

Demand Response in Commercial Buildings discusses the relevant improvements that load shifting and demand response can provide, with examples of the types of utility and funding programs that are available.

TRANE®

*Trane,
A business of Ingersoll Rand*

For more information, contact your local Trane office or e-mail us at comfort@trane.com