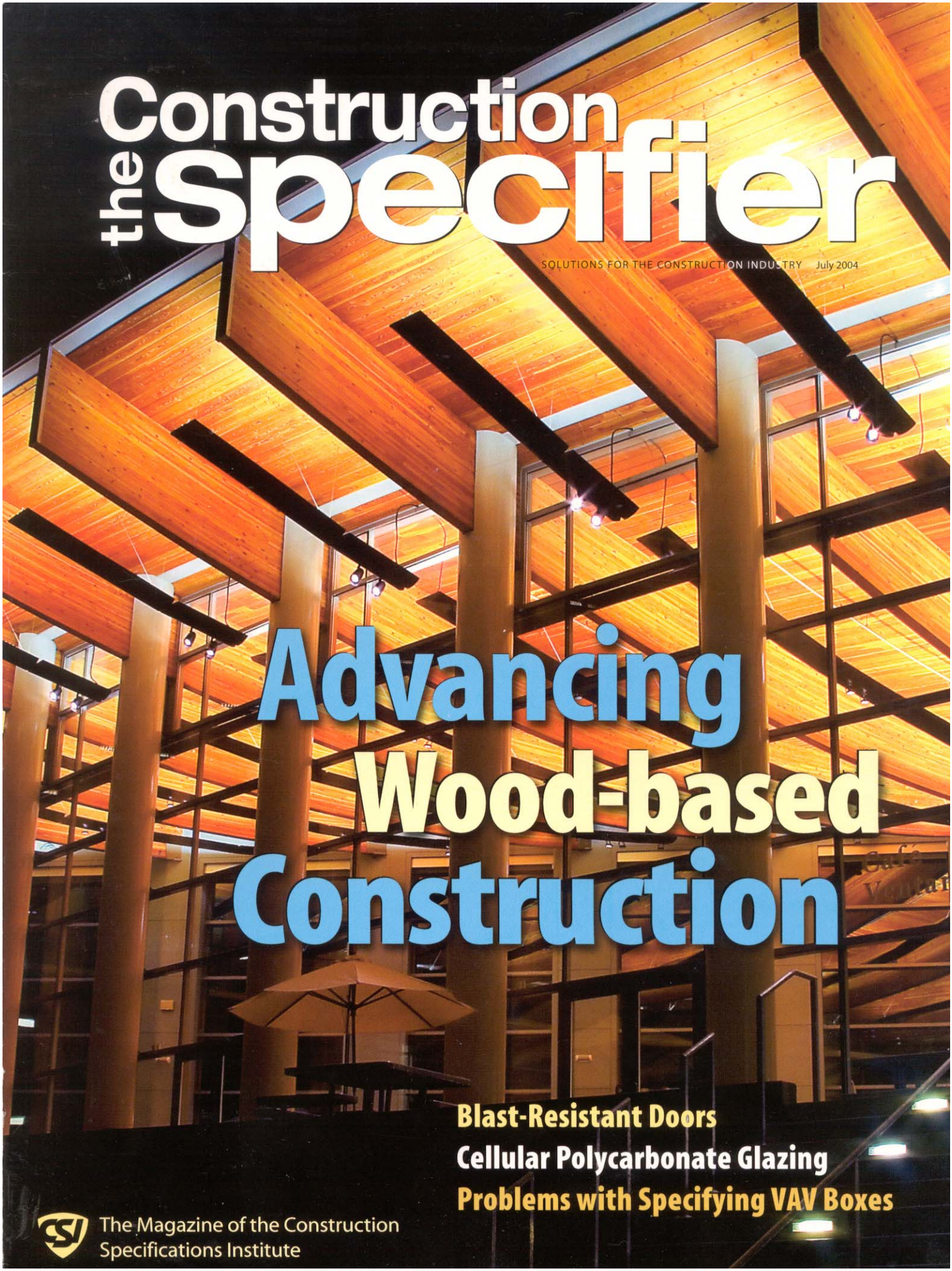


Construction the specifier

SOLUTIONS FOR THE CONSTRUCTION INDUSTRY July 2004

Advancing Wood-based Construction

Blast-Resistant Doors

Cellular Polycarbonate Glazing

Problems with Specifying VAV Boxes

The Magazine of the Construction Specifications Institute

The Problems with Specifying VAV BOXES

by Daniel Int-Hout

One thing is certain when it comes to writing the specification for variable air volume (VAV) boxes (also known as air terminal units): when the wording is vague, the product used is usually what the low-bid contractor feels like supplying, which is not necessarily what the architect/engineer (A/E) desires.

A VAV box varies the quantity of conditioned (typically cooled) air from a central source delivered to a control zone in response to a thermostat. Several types of these units exist, including some with an additional fan to mix plenum air with central source (primary) air.

One of the problems is many A/Es do not read their own variable air volume specifications, which opens the door to inconsistencies and misinformation. Computers compound the problem by allowing specifications to be cut and pasted, thereby ensuring vague requirements and obsolete references are handed down for generations. In other cases, specifications require design elements and settings contrary to accepted design principles.

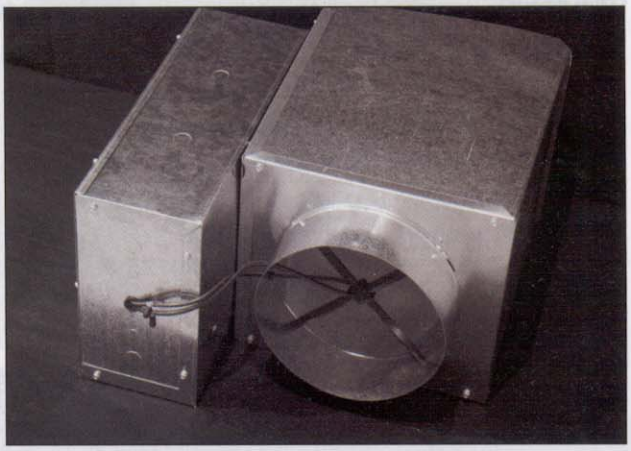
When a specification is clearly flawed, a VAV terminal supplier has three choices:

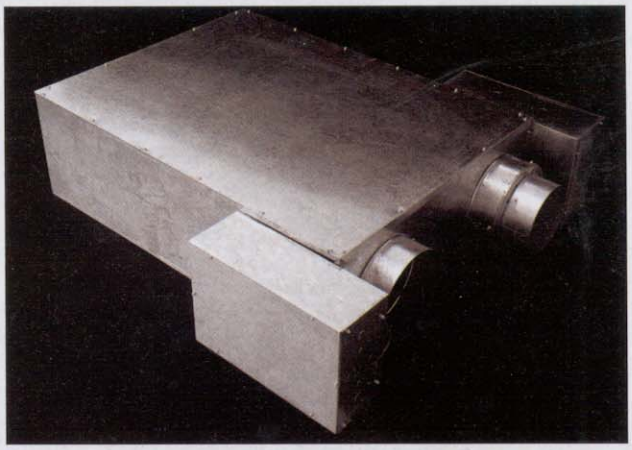
- he can go ahead and bid the project with what he assumes the A/E means, hoping his submitted data is approved;
- he can call the A/E and point out the deficiencies in the document; or
- he can choose not to bid the project because of the problems involved.

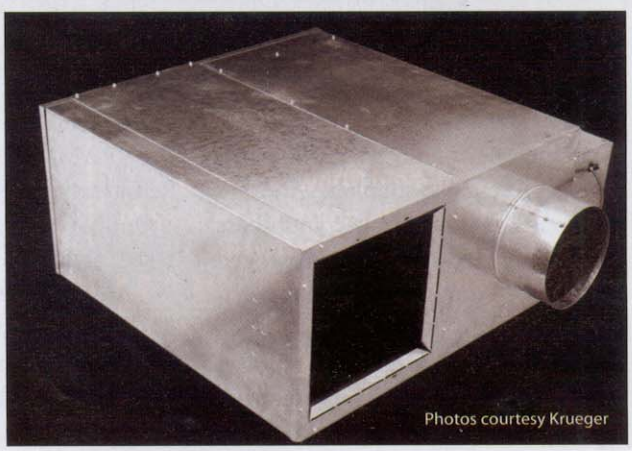
Although this article details the problems with specifying VAV boxes for HVAC systems, the general rules discussed below could apply to the selection of other systems intended for non-residential construction/retrofit projects.

Are specifications current?

Sometimes, the flaws in an A/E's VAV box specification stem from an inability to keep current. Every so often, HVAC







Photos courtesy Krueger

Figure 1

ARI 885-98	Octave bands					
Discharge < 0.41 m^3/s (300 cfm)	2	3	4	5	6	7
Environmental effect	2	1	0	0	0	0
Duct lining, 1.5 m (5 ft), 203 x 203 x 25 mm (8 x 8 x 1 in.)	2	6	12	25	29	18
End reflection	9	5	2	0	0	0
Power division (0 outlets)	0	0	0	0	0	0
1.5-m (5-ft), 203-mm (8-in.) flex duct	6	10	18	20	21	12
Space effect	5	6	7	8	9	10
Total attenuation	24	28	39	53	59	40

ARI 885-98	Octave bands					
Discharge 0.14 m^3/s to 0.33 m^3/s (300 cfm to 700 cfm)	2	3	4	5	6	7
Environmental effect	2	1	0	0	0	0
Duct lining, 1.5 m (5 ft), 305 x 305 x 25 mm (12 x 12 x 1 in.)	2	4	10	20	20	14
254-mm (10-in.) end reflection	9	5	1	0	0	0
Power division (2 outlets)	3	3	3	3	3	3
1.5-m (5-ft), 203-mm (8-in.) flex duct	6	10	18	20	21	12
Space effect	5	6	7	8	9	10
Total attenuation	27	29	40	51	53	39

ARI 885-98	Octave bands					
Discharge > 0.33 m^3/s (700 cfm)	2	3	4	5	6	7
Environmental effect	2	1	0	0	0	0
Duct lining, 1.5 m (5 ft), 381 x 381 x 25 mm (15 x 15 x 1 in.)	2	3	9	18	17	12
End reflection	9	5	2	0	0	0
Power division (3 outlets)	5	5	5	5	5	5
(5 ft., 8 in.) flex duct	6	10	18	20	21	12
Space effect	5	6	7	8	9	10
Total attenuation	29	30	41	51	52	39

ARI 885-98	Octave bands					
Radiated	2	3	4	5	6	7
Mineral tile space/ceiling effect	16	18	20	26	31	36
Environmental effect	2	1	0	0	0	0
Total dB reduction	18	19	20	26	31	36

suppliers and contractors see companies that went out of business in the 1980s listed as acceptable suppliers. Another important reason for keeping specs current revolves around referenced standards. Outdated standards, such as Air Diffusion Council (ADC) 1062, *Certification*, have long been replaced by American Society for Heating, Refrigerating, Air-Conditioning Engineers (ASHRAE) and Air-Conditioning and Refrigeration Institute (ARI) models.

One VAV box supplier was recently asked about meeting a requirement for ASHRAE 36B-62—an acoustical specification last updated in 1972 before being dropped by ASHRAE in favor of American National Standards Institute/Acoustical Society of America (ANSI/ASA), S 12.1, *American National Standard Guidelines for the Preparation of Standard Procedures for the Determination of Noise Emission from Sources*, in the late 1970s. (See also International Organization for Standardization [ISO] 3741, *Acoustics - Determination of sound power levels of noise sources using sound pressure - Precision methods for reverberation rooms*, which should be referenced instead.

Remnants of pneumatic control specifications are often left behind in direct digital control (DDC) specifications. The most commonly mistaken requirement is for a damper to fail open or closed, which is a simple pneumatic selection issue. A normal DDC actuator costs about $30, but a fail closed/open electronic actuator often costs several times this amount—which is seldom actually required or intended. Some A/Es also erroneously seek air consumption requirements in DDC control specifications.

VAV terminal reheat issues

Often, supplemental heat is added to the primary airflow to satisfy local heating demand needs. Sufficient airflow is needed in heating mode to provide adequate mixing and ventilation. When discharge temperatures exceed 32 C (90 F), temperature stratification is likely, and ventilation may short circuit to the ceiling-located return. ASHRAE Standard 62, *Ventilation for Acceptable Indoor Air Quality* (Addenda N), now requires a 25-percent increase in ventilation rate when discharge temperatures exceed stated limits and low diffuser velocities do not result in sufficient diffuser air projection (throw).

Several issues are often unclear when it comes to electric heating coils:

1. Is there sufficient discharge static pressure in the design? At least 25 Pa (0.1 in.) backpressure is

often required to trip the flow safety sensors in the electric heater.

2. When 480-V, three-phase electric power is used, is a neutral lead supplied? Heaters can be wired for either three- or four-wire 480-V, but it must be known beforehand. Fan boxes, however, require the neutral lead for 277-VAC fan motors, or else a very large transformer has to be provided at each unit.
3. Are the types of contactors and number of stages—or is a proportional heat control—clearly specified?

For hot water coils, the schedule typically lists both British thermal units (Btu/hr and gallons-per-minute (gpm). A manufacturer, however, probably cannot meet both, unless the requirement is determined using his selection program. The rules-of-thumb A/Es use to determine heat transfer are often idealized, and actual tested performance is usually different. Surprisingly, experience shows the gallon-per-minute requirement is typically the required one, as we are told "the pumps have already been selected based on these values."

Unit linings

A VAV terminal can be lined 15 different ways, including foil-faced insulation and several varieties of double-wall construction (depending on both intended use and an owner's concerns over exposed glass fiber insulation). The appropriate selection cannot be made without really understanding the acoustical and cost implications. While the liner type in a single duct box with little insulation does not have much acoustical effect, its impact on a large-series fan terminal can be as much as an increase of 12 NC (noise criteria). Likewise, a double-wall requirement can more than double a large VAV box's cost, with little actual benefit over other liners for safety or cleanability. Meantime, closed-cell foam linings can offer considerable cost savings, reduce acoustical impact, and meet all safety requirements. The liner specification should identify situations when the different liner types may be warranted.

Fan-powered terminals

Fan-powered terminals are generally equipped with permanent split capacitor (PSC) motors. Electronically commutated motors (ECMs) increase a VAV box's cost, but can result in a return on investment in two years or less (67 percent less energy use), depending on utility rates and flow settings. Another ECM advantage is its built-in microprocessor controller, which can be integrated into (and controlled from) the controls system logic, and tuned for air delivery in its installed condition. This means it can be adjusted to deliver air within five-percent accuracy after being installed in the system.[1]

Figure 2

	2	3	4	5	6	7
Suggested room sound pressure	125	250	500	1000	2000	4000
High speech privacy	57	53	48	43	37	31
Low speech privacy	52	49	44	37	32	20
RC 40	60	55	45	40	35	33
NC 40	55	50	44	41	39	38
NC 35	52	45	40	36	34	32

Inlet sensors

In terms of inlet sensors, most VAV units combine a linear/ring airflow-sensing grid, or two grids (provided by a VAV box manufacturer) crossed with a damper actuator and controller (provided by a controls manufacturer). Stated accuracy of these sensors is typically five percent of rated flow. An oft-specified five-percent accuracy requirement of reading would, at minimum flow, require 0.02-percent accuracy, which is simply unachievable. The expected accuracy in the field with a test and balance hood is probably ±20 percent.

Figure 3

Recommended, based on ARI 885-98, with 1.5-m (5-ft) duct lining

			Maximum Radiated Sound Power Level, db, at Band No. and Center Freq., Hz]						
All sizes	All inlets	Fan and 100-percent primary	(2) 125	(3) 250	(4) 500	(5) 1000	(6) 2000	(7) 4000	(per ARI) 885-98
Minimum			70	64	60	62	65	68	NC 35
Maximum speech privacy			75	72	68	69	68	67	RC 42(N)
Maximum			78	74	65	66	66	69	RC 40(N)

			Maximum Discharge Sound Power Level, db, at Band No. and Center Freq., Hz]						
All sizes	All inlets	Fan and 100-percent primary	(2) 125	(3) 250	(4) 500	(5) 1000	(6) 2000	(7) 4000	(per ARI) 885-98
Minimum			80	75	80	87	85	70	NC 35
Maximum speech privacy			85	83	88	94	88	69	RC 42(N)
Maximum			88	85	85	91	86	71	RC 40(N)

Figure 4

Recommended, based on ARI 885-98, no duct lining

			Maximum radiated sound power level, db, at Band No. and Center freq., Hz]						
All sizes	All inlets	Fan and 100-percent primary	(2) 125	(3) 250	(4) 500	(5) 1000	(6) 2000	(7) 4000	(per ARI) 885-98
Minimum			70	64	60	62	65	68	NC 35
Maximum speech privacy			75	72	68	69	68	67	RC 42(N)
Maximum			78	74	65	66	66	69	RC 40(N)

			Maximum discharge sound power level, db, at Band No. and Center Freq., Hz]						
All sizes	All inlets	Fan and 100-percent primary	(2) 125	(3) 250	(4) 500	(5) 1000	(6) 2000	(7) 4000	(per ARI) 885-98
Minimum			78	71	71	69	68	58	NC 35
Maximum speech privacy			83	79	79	76	71	57	RC 42(N)
Maximum			86	81	76	73	69	59	RC 40(N)

More trouble spots to consider

Another problem occurs when required accessories are not clearly identified or mistakenly required:

Silencers

Duct silencers are seldom effective in the small size required for VAV terminals, especially in the critical 125-Hz to 250-Hz bands. They are rated at 0.6 x 0.6-m (2 x 2-ft) sizes, and smaller units are less effective in critical low frequencies.

Transformers

The form of high voltage supplied to non-fan-powered VAV units is often unspecified, but low-voltage control transformers are. This often requires several time-delaying queries between the supplier's representative, installing mechanical contractor, and electrical/controls contractor to determine the type of low voltage transformer to supply.

Filters

Filters are frequently specified for fan terminals, then discarded after construction. Experience shows filters are seldom changed after installation because they are located in the return air plenum and often difficult to access (they may, in fact, be very hard to find). With plenum air already being filtered by the primary air system (at least in theory), filters have been shown to be unnecessary.

Hanger brackets

When required for a project, hanger brackets (which are used to help the installing contractor) should be clearly spelled out in the specification. In many cases, however, an installing contractor simply drives self-tapping screws through a metal hanger strap into a unit. Vibration isolation is almost never specified, or required, for these type units.

Disconnects
When field installed, the unit cannot be Underwriters Laboratories (UL) Inc.-listed, as UL requires factory high-voltage testing.

Some words on acoustical requirements

Acoustics cause a lot of confusion in many VAV specifications. Often, the specs merely list a maximum noise criteria (NC) value as the design criterion for the intended space. A VAV terminal supplier, however, cannot guarantee space sound levels without knowing a number of acoustical parameters, including inlet static pressure, lining length, ceiling type, plenum depth, and so forth.

The lack of a clear "design inlet static pressure" is a major impediment to supplying accurate acoustical information. Often, only a minimum static pressure is listed, and the only time this pressure is realized is when the system has insufficient air pressure. Most often stated around 60 Pa (0.25 in.wg), actual system operating pressures are more often nearer 250 Pa (1.0 in.wg).

As the equipment supplier cannot control installation details, what is required is just the opposite: a "not-to-exceed" sound power specification value based on space acoustic needs (not some manufacturer's data).

Many times, a specification requires an independent laboratory to perform a mock-up sound test specific to the building design, but no such labs are presently set up to perform this type of testing.

The Air-Conditioning and Refrigeration Institute (ARI) is now requiring manufacturers with certified data to calculate NC values using the tables provided in Appendix E of ARI 885-98, *Procedure for Estimating Occupied Space Sound Levels in the Application of Air Terminals and Air Outlets.* This standard provides the most current

application factors for converting rated sound power to a predicted room sound pressure level, and can provide a repeatable and comparable method of both predicting and specifying sound levels.

ARI 885 provides a number of equations and tables available elsewhere, but puts them all in one document along with some unique tables. It also includes examples and diagrams to make the process easier to use and understand. The calculations have been repeatedly verified in tests and mock-ups, and should be accurate within 3 dB in most properly defined applications.

Historically, most sound levels were both specified and reported as either NC or dBA (the value for the average of all sound frequencies weighted against a standard curve). As a result, dBA is essentially useless as a sound descriptor or diagnostic. Although the NC rating is better than dBA, it has some shortcomings—especially as a speech privacy predictor. The use of RC (room criteria) has been proposed as a better descriptor for determining noise acceptability in open-plan offices, and has been substituted for NC in recent ASHRAE handbooks.

In middle frequencies, NC and RC result in similar ratings, but the latter has the advantage of additional letters to describe high- (H) and low frequency rumbling (R), and vibration (V) characteristics. Unfortunately, when used to rate the performance of VAV terminals—or any predominantly low-frequency device—significant differences between products can be masked by this rating scheme. As a result, VAV box manufacturers will likely continue to rate products in NC units. (See Figure 1, page 62.)

Speech privacy

Speech privacy is a condition in which an occupant sitting at his desk can hear adjacent conversations, but does not understand enough to be distracted by them. Surveys of various building occupants show preferred background sound levels for achieving speech privacy do not correspond well with NC curves, and are the basis of the change to RC ratings (RC 40 is an ideal open-plan office requirement). Distraction due to poor acoustics and a lack of acoustical privacy are two of the highest complaints from occupants today.

The table in Figure 2 shows five different room sound spectra. The high- and low-speech privacy spectra reflect survey data taken during the development of open office acoustical criteria. An RC 40(N)[2] is the mean level meeting this criteria (NC 35 and NC 40 spectra are also listed). See Figure 2, page 63.

Specifying sound levels

A "not-to-exceed" sound power specification value can be accomplished by starting with a desired room sound pressure level, then adding the expected acoustical deductions to that value, creating a maximum allowable sound power requirement.

When one starts with a room sound-pressure curve from

Additional Information

Author

Daniel Int-Hout is the chief engineer at Krueger, where he is responsible for presenting technical data and advanced application engineering for the company's grilles, registers, and diffusers, as well as VAV air terminals. He has been in the air distribution research and design business since 1973, and has a Master's degree in Business Management from Central Michigan University. Int-Hout has written over 30 technical papers and articles on VAV system performance, acoustics, air diffusion, controls, and occupant comfort, and can be reached via e-mail at dint-hout@krueger-hvac.com.

MasterFormat No.

15840–Air Terminal Units

UniFormat No.

D3040–Air Distribution Systems

Key words

Division 15
Acoustical Society of America
Air-Conditioning and Refrigeration Institute
Air Diffusion Council
American National Standards Institute
American Society of Heating, Refrigerating, and Air-Conditioning Engineers
Direct digital control
Electronically commutated motor
Noise criteria
Permanent split capacitor
Room criteria
Variable air volume
Underwriters Laboratories Inc.

Abstract

Variable air volume (VAV) terminal units continue to cause problems in mechanical specifications, particularly when design professionals employ outdated specs referencing long-dead standards. The key to success is remaining current and analyzing all aspects of the job to ensure all system components integrate properly and achieve the desired performance.

Figure 2, and applies ARI 885 Appendix E's standard assumptions (Figure 1), one can develop a standard acoustical specification with a high expectation of the space actually meeting the required sound levels. When no duct lining is allowed—as is the case in healthcare facilities and other applications—the ARI 885 tables must be slightly modified. Figures 3 and 4 suggest specifications for both lined and unlined duct applications.

By employing values from Figures 3 and 4 (page 64), and listing the required design inlet static pressure, an A/E can provide a specification based on the most current data—free from any commercial/product bias—with a high probability of achieving an acceptable acoustical environment.

Conclusion

Unclear or technically unsound specifications cause confusion, time delays, and worse—non-performing projects. Often, the cost of alleviating these problems exceeds the initial equipment cost. A poorly described project still receives bidders, but it is expensive and time-consuming to fix poor specifications.

A/Es need to work with knowledgeable suppliers before a project is released to ensure specifications are clear and technically responsive to the design. Allowing the supplier to create proprietary specifications is not the answer. Clear and technically informed specifications identify the supplier best able to meet the project's real needs at the lowest cost to the owner.

Notes

[1] Although often specified, no mechanical anti-backward rotation device is available in the industry. Electronic strategies can be ordered, but a single line of code in the building management system avoids this problem more easily.

[2] N = neutral spectrum.