DUCTWORK, ENERGY-CONSERVATION

AND THE HVACR PROFESSIONAL

Ten reasons why building HVACR systems do not perform the way they should and steps that can be taken to make sure they do.

BY DAVE MCFARLANE

In both new and existing building projects, numerous issues directly affect energy usage, sound and comfort levels, which is why HVACR contractors and sheet-metal journeymen play such a major role in a building's final comfort and energy efficiency.

Several problem areas are recurring themes in construction projects, including the examples—and several possible corrections—reviewed in this article.

Informed HVACR professionals who understand the applicable standards will perform the installation up to specifications or notify the engineer before performing work that could create a potential problem. This will reduce problems—which may include an adversarial relationship between the design engineer and the service pro—once the project is completed.

Problem areas

Ductwork is not reinforced for the proper SMACNA pressure classifications. SMACNA's duct-construction standards designate how to properly fabricate and install ductwork, duct accessories and air-handling equipment. These standards are so prevalent that most construction documents and specifications say, in effect, "Install ductwork to SMACNA standards."

However, that familiarity with the term "SMACNA standards" has led engineers, contractors and sheet-metal journeymen to forget to examine *current* SMACNA standards—which have been continually upgraded and improved. For example, the current standard is the SMACNA 3rd Edition, dated 2005, yet many engineers and contractors specify and install ductwork as they did 25 years ago.

SMACNA pressure classifications now specify ductwork reinforcing for specific duct pressures measuring 0.5–10 in. The design engineer must specify the system's design static pressure. If the design engineer does not specify an exact static pressure but instead states, "Install ductwork to SMACNA standards," SMACNA-standards compliance requires ductwork built to a 1-in. pressure class, with the exception of ductwork upstream of a VAV box, which should be constructed to 2-in. pressure.

These images show how ductwork can be blown out or (as shown in the inset) collapse due to inadequate reinforcement.

The design professional's lack of clarification or the installing contractor's failure to follow the required pressure classifications specified are the main reasons ductwork collapses or blows apart, as shown above. This potential problem can be eliminated if the installing contractor verifies that reasonable ductwork pressure has been specified and that the current SMACNA pressure classifications are followed in the field.

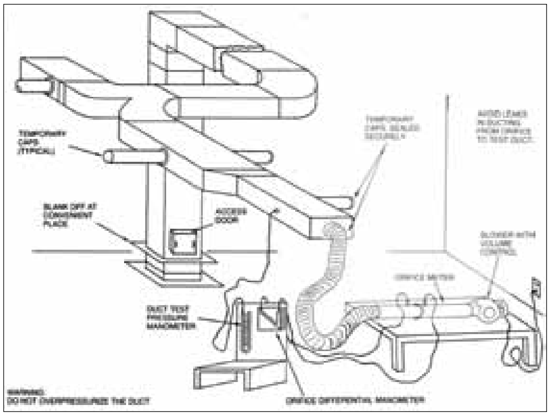
Failure to adequately seal ducts. Air inside a supply duct under positive pressure will leak from any system penetration—from snap-lock seams to out-of-wall penetrations—unless the system is properly sealed. This leakage causes two problems. First, some areas at the end of the run may have an air-flow shortfall, which can cause overheating in the summer or the inability to heat in the winter. And second, although there are some cases when the fan can supply enough air to overcome the leakage rate and meet the room requirements, in these situations, excessive fan energy is typically used to provide the required flow. The fan energy increases as the cube of the air leakage increases. For example, if a system has 10% leakage and the fan design was originally 20 hp, the new motor required to overcome the 10% loss will be 20 hp x (1.13) = 26.6 hp—the owner is paying for an additional 6.6 hp of fan operation for the life of the building.

SMACNA specifies that if ductwork is not sealed, leakage rates of 25% on ductwork sized 2-in. or more can be expected. SMACNA Seal Class A, B and C define the degree of sealing required: Seal Class C means that all transverse joints (slip, drive and TDC) connections need to be sealed; Seal Class B means that all longitudinal seams (Pittsburgh and snap-lock) and all joints as listed above need to be sealed; and Seal Class A—the most stringent—means that all wall penetration (damper rods, screws and duct accessories) must be sealed in addition to all seams and joints as defined above.

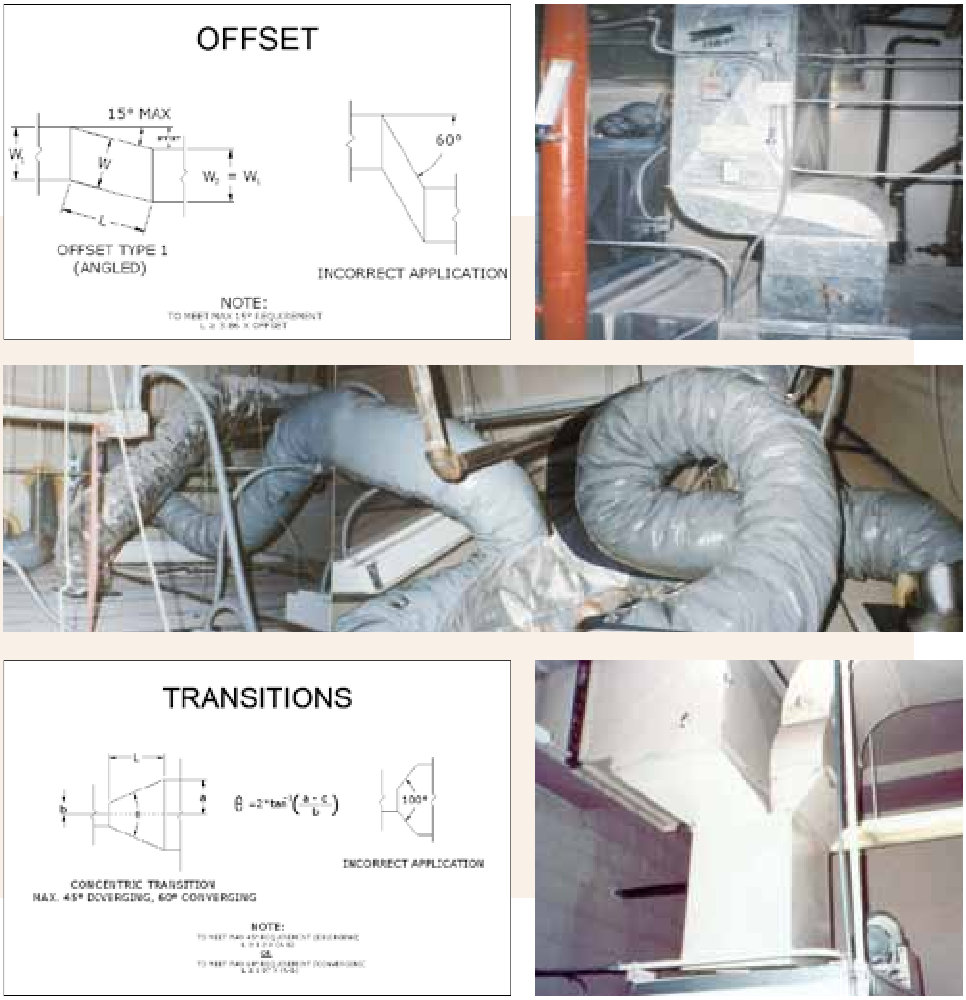
Failure to seal return and exhaust ducts. Air will leak *into* ductwork via the same openings described with the seal classes. When excessive leakage occurs in exhaust ducts, it sometimes is impossible to obtain the required exhaust air at the needed location. In many cases, exhaust air flow at the fan is 15% over design, and the exhaust flow at the register or hood location is 20% under design because air is leaking into the duct systems along the duct route, not at the specified exhaust point. This can lead to stuffy, stagnant rooms or laboratory exhaust systems that are not performing as required. System operating costs also increase.

Failure to adequately pressure-test ductwork. Ductwork pressure-testing determines how well ducts are constructed to prevent air leakage. A closed section of ductwork is pressurized to a known level. Leakage at a specific pressure is calculated by measuring the amount of air that is then blown into the closed duct system.

SMACNA defines duct-leakage rates as Leakage Class 24, 12 or 6—meaning that at 1 in. of test pressure, ducts can be expected to leak 24, 12 or 6 cfm/sq ft of duct surface. Know that the mere presence of duct-sealing material on a joint or seam does not guarantee proper sealing has been achieved. Once the installing contractor has leak-tested several sections of ductwork and has adequate documentation that the duct-sealing procedures being used are keeping leakage within the specified ranges, the frequency of sealing can be reduced. This is why proper ductwork-leakage testing, as shown below in Figure 1, is so important.



« Figure 1 This illustration shows the proper way to set up an apparatus to pressure-test a system for duct leakage. Such tests are necessary to make sure that all seams and joints are properly sealed and connected.



›› **Figure 2** **These examples illustrate improper system-installation processes that result in restricted air flow, the need for more energy to operate equipment and, in some cases, more noise resonating from the ductwork.**

Failure to understand duct-construction standards in the fabrication/installation process. While SMACNA standards are almost always used as a project reference, proper techniques are not always understood by both engineers and contractors—as the examples in Figure 2 illustrate. Design engineers often fail to allow sufficient room to install properly sized transitions or offsets. In many cases when there is insufficient room, journeymen overlook the applicable standard and install transitions or offsets that are choked or lack proper slope.

When SMACNA standards for fitting are not followed, the entire system has imposed restrictions that the fan must overcome. In some cases, the addition of several improper fittings can cause air-flow noise and in adequate air flow to occupied spaces.

Failure to properly install turning vanes. Whether to or from the fan, air flowing in ducts encounters the same restrictions. If air velocity in ducts is more than 1,000 fpm, then vanes are required. While most contractors understand the importance of installing vanes in supply ducts, return and exhaust ducts *also* require turning vanes.

Duct velocities approaching 2,500 fpm will cause increased pressure drops in fittings and ductwork and may create noise. Duct velocity can be calculated by dividing the design air flow in a duct at any location by the area of the duct in that location. For example, a fan rated at 6,000 cfm with the duct size at the fan discharge measuring 24 in. x 12 in., the velocity is 6,000 cfm ÷ 288 sq in. (24 in. x 12 in.) ÷ 144 sq in. per sq ft = 3,000 fpm. Velocities exceeding 2,500 fpm and the possible repercussions should be reported to the engineer. It is much easier to solve a potential problem by increasing duct size before the duct is installed.

The detrimental impact on fan capacity caused by fan-system effect is a problem not fully understood by the design industry. Fans are tested with a specific amount of straight duct connected to the inlet or discharge. When installation conditions differ from the test installation—and they likely will—the fan suffers a capacity reduction (system effect).

Figure 4 shows that air flow leaving a fan does not reach a uniform flow profile for several duct diameters from the fan discharge. The distance required to reach uniform flow is dependent on the velocity of the air—the higher the duct velocity, the greater the distance is required before uniform flow is attained. Therefore, any item installed before 100% effective length is attained reduces the fan's capacity.

All duct accessories (fire dampers, control dampers, sound attenuators, etc.) are tested with uniform flow conditions to determine their design pressure drop. But if any of these components are installed in a portion of ductwork where the flow is not uniform, the actual pressure drop always will be greater than the design pressure drop. When system-imposed pressure drops are not counted in design calculations, fans have

> **System effect is a phenomenon that cannot be measured, but it is real and one of the reasons many fans cannot develop the required capacity shown in manufacturers’ catalog data.**

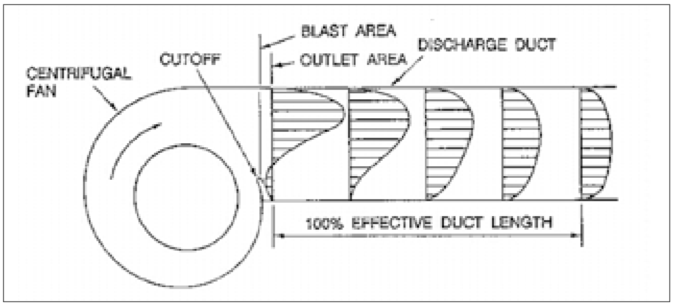


Figure 3 This diagram shows the fan outlet air velocity profile and why it is important not to install any branches or connections before air reaches a uniform profile in the duct.

greater static pressure than calculated and fail to generate the required air flow. Elbows installed in the zone of non-uniform air flow also create a system-imposed pressure drop.

AMCA has documented the various additional pressure drops that should be added to the calculated pressure drops. System effect is a phenomenon that cannot be measured, but it is real and one of the reasons many fans cannot develop the required capacity shown in manufacturers’ catalog data. The owner and design engineer will benefit if the contractor or journeymen closely look at fan inlets and discharges during shop-drawing approval or the field-measuring phase of the project. If any duct accessory or elbow has been installed within the first 4–6 duct diameters from the fan inlet or discharge, the design engineer should be informed of the potential problem.

Drawings without dimensional sizes can be improperly interpreted—resulting in undersized ductwork being installed. This problem is usually seen on VAV-box inlets where duct sizes are omitted from the drawings. When inlet sizes are not shown on the drawings, the installing contractor invariably installs ductwork sized for the VAV-box inlet size.

In many instances the VAV inlet is sized for velocities that exceed 2,500 fpm. While this velocity is satisfactory for the 6-in. inlet length of a VAV box, noise and duct problems (when velocities approach 2,500 fpm) will, again, surface on the ducts leading to the VAV box. The problems are compounded when extended lengths of inlet duct and numerous elbows are installed. Inlet static pressure to the VAV box can be reduced to the point that the box becomes starved for air. To compensate for this, the fan speed is increased and the owner pays excessively for energy over the life of the project merely because one or two VAV inlets are undersized.

Most specifications require four duct diameters of straight duct before the inlet to a VAV box, but duct drawings do not allow sufficient room for the installation. When sufficient lengths of straight ducts are not installed, the airflow sensors on a VAV box do not read properly. This causes the VAV box to hunt and make the VAV controller difficult to control. Unstable control can cause both noise and the fan to operate at static pressures that are higher than they need to be.

What mistakes can cost

The following side-by-side comparison of two buildings reveals what the aforementioned oversights can lead to.

Assume each 100,000-sq-ft, five-story office building with the same heating and cooling capacity has the following components:

Occupied 16 hours/day 6 days/week $0.10 kWh $12-kW demand

	BUILDING 1	BUILDING 2
Air Flow (Duct Leakage)	105,000 cfm	115,000 cfm
SYSTEM EFFECT FAN DISCHARGE		
Elbow Placement	0.5 in.	1.5 in.
Sound Attenuator Placement	0.25 in.	0.75 in.
Ductwork Restrictions	2.5 in.	3.5 in.
Missing Turning Vanes	1.0 in.	1.75 in.
Total System Pressure	4.25 in.	7.5 in.
DETERMINING HORSEPOWER hp = cfm x SP / (6,356 x fan efficiency)		
Horsepower	105,000 x 4.25 ÷ 6,356 x 0.65 = 108 hp	110,000 x 7.5 ÷ 6,356 x 0.65 = 200 hp

Now, lets look at how the difference in efficiency increases cost to the building owner:

Fan Operation: 16 hours/day; 6 days/week
Electrical Cost: $0.10 / kWh
200 hp – 108 hp = 92 hp
92 hp x 0.746 kWh/hp = 68.6 kWh
68.6 kWh x 16 hours/day x 6 days/week x 52 weeks/year = 342,500 kWh/year
342,500 kWh/year x $0.10/kWh = $ 34,250/year of extra kW usage

Increase in demand charge:
200 hp – 108 hp = 92 hp
92 hp x 0.746 kWh/hp = 68.6 kWh x 1 hour = 68.6 kW demand
68.6-kW demand x $12 x 12 months/year = $ 9,878/year
Total Cost/year = $34,250 + $9,878 = $41,000

The potential savings to eliminate restrictions and reduce static pressure over the 25-year life of the project is more than $1,000,000.

Dave McFarlane is President of McFarlane, headquartered in Grand Forks, ND. In addition to working as a Design Engineer responsible for designing and building HVACR, process and heat recovery projects, he is a NEBB-certified professional and has authored and given presentations on numerous TAB-related topics. He can be reached via e-mail at dmcfarlane@mcfarlane-e3.com.