Choosing Ductwork

The kind of ducts you use and the number and types of turns they make dramatically affect HVAC-system performance

by John O'Connell and Bruce Harley

Think of air whooshing through ductwork as people rushing to work on a freeway. It doesn't take an accident to slow things to a crawl. Get thousands of cars traveling together at 60 mph, and watch what happens when the road curves.

Now suppose the highway has a 90° turn in it. Or picture an abrupt T-intersection where everyone must decide which way to go. Or think what would happen if one lane disappeared or if the road were filled with ruts and bumps.

Elbows, turns and intersections in ducts have the same effect on air. Every time there's an exit, the air slows down. Whenever there's a hill, air molecules pile up on each other and slow down, spreading the effect back down the line. If the ductwork is flexible, the ribs in the duct slow the air movement, just the way bumps in a road slow traffic.

This resistance is called static pressure. The type of ductwork that you use, the smoothness of its interior surface, and the number and severity of the turns and reductions the ducts make create this resistance. If ductwork is the appropriate type and size, and is as straight as possi-

It bends easily, but at a price. Flexible ductwork, such as this insulated, foil-covered duct, is good for getting up and over a joist or around a corner. However, the ridges inside the duct slow air so much that it shouldn't be used for straight runs.

ble, air moves with less resistance, and the air-delivery system performs better and with greater energy-efficiency.

Ducts to avoid, starting with flexible ducts—Although it's not possible to install all straight runs of round metal ductwork—which is the most effective method of moving air—it is possible to keep resistance to a minimum. One way to do that is to discourage contractors and homeowners from installing flexible duct.

Every straight foot of flex duct is equivalent to 2 ft. of rigid, which means the static-pressure penalty is twice as great with flexible duct. That's because the inside surface of flexible duct has the same effect on air as a rough road has on traffic. Add all the curves, uphill climbs and exits to a flex-duct system, and you can understand why it's difficult to get the performance you need from flex duct.

Originally designed to make short, vibration-dampening connections between branch ducts and register boots, flexible duct is now improperly used as an alternative to rigid ductwork. It is an attractive product. It bends easily (hence the name), goes around corners and travels up and over joists. It's inexpensive, installs quickly and easily, and is available covered with insulation and a vapor barrier (photo facing page).

Even when used appropriately, however, flexible duct should be used as little as possible in air-delivery systems. And in reality, flexible duct often is not used appropriately. For instance, cramming it into a tight comer results in drastic airflow reductions. It is tempting to stretch flex duct too far. If it is, the strain may eventually cause the nylon straps that hold it to give way, resulting in a disconnection. If the disconnection is in an unheated attic or crawlspace, it might go unnoticed, which would mean a lot of warm, moist air pumped into a cold space. The outcome could be condensation, moisture and rot.

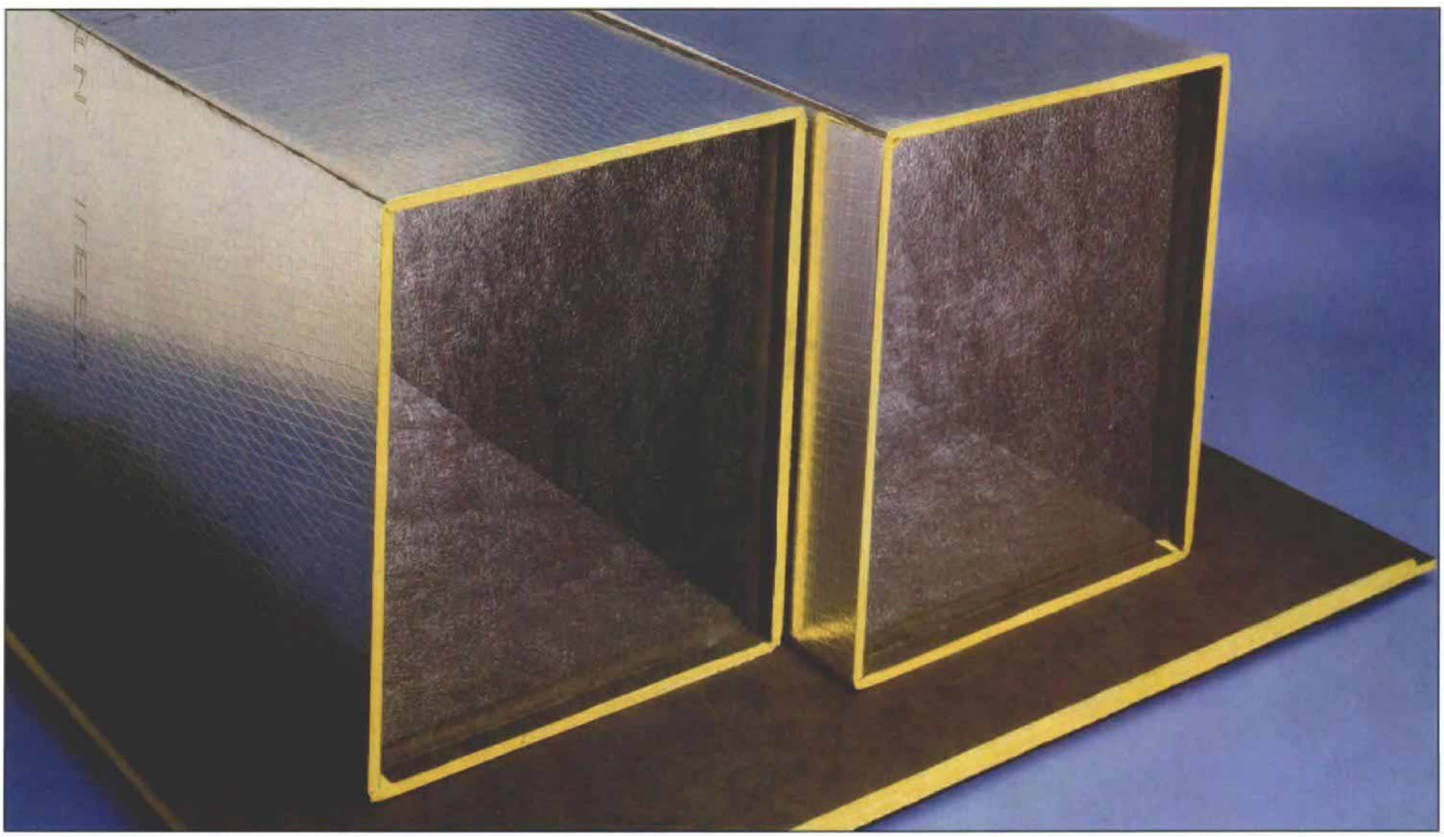
Also, if a lot of flexible duct is used in a system, the fan motor may need to be much bigger than would be necessary if rigid duct were used. In any case, the result would be either a system that can't deliver the air required or a fan that is oversize and, thus, costly to run.

Flex duct is useful in some circumstances—There are only a few situations where flex duct is worth the penalty. We use short pieces to get up and out of joist bays, to connect branch lines to register boots or to get around some particularly tight corners.

Many equipment manufacturers recommend using a short piece of flexible duct or canvas boot connector where ductwork enters the heating or air-conditioning unit to break any vibration that might occur. Rigid-metal duct often transfers vibration through a system.

Some manufacturers also recommend using insulated flex duct in unconditioned spaces. They're concerned about condensation inside the metal ducts, which can lead to mold, mildew and bad air. They assume that the contractor won't remember to insulate the ducts in those spaces.

However, when use of flexible duct is considered necessary, it serves most efficiently if it's stretched to its fullest reasonable length. According to *ASHRAE Fundamentals* (one of a five-volume series of handbooks published by the American Society of Heating, Refrigerating and Air-Conditioning Engineers; 404-636-8400), flex duct at 30% compression increases the friction rate fourfold. If you absolutely need to use flex duct in a long run, make it one size larger than



Duct board is rigid fiberglass faced with foil. Preinsulated ducts made of duct board are generally leakier than rigid-metal ducts and puncture more easily. The seams are prone to failure unless assembled under clean shop conditions.

Photo this page: Courtesy of CertainTeed indicated and stretch it to full length—but don't pull it too tight.

Duct board and building cavities aren't the solution, either—Duct board is made of high-density fiberglass that has a foil-scrim kraft (FSK) facing, which is sort of an aluminum-foil version of rip-stop nylon (photo p. 99). Duct board is typically put together with FSK adhesive tape, which is prone to failure unless it's installed in clean factory or shop conditions.

Although it appears easy to create tight, preinsulated ducts using duct board, most of these systems are actually leaky once installed. Furthermore, the board's aluminum surface, which is the primary air barrier, punctures easily.

Stud spaces and joist bays are not duct runs, either, and should never be used as such-even for returns. First, they are nearly impossible to seal and to insulate properly. Second, introducing moist air to the framing of a house can't possibly be a good idea, as you can imagine. Blower-door tests indicate that many building cavities communicate with outdoor air much better than one might expect. In fact, many floor-cavity returns draw the majority of their air from the outside. Air traveling through a system tends to draw air with it through holes, leaks and seams.

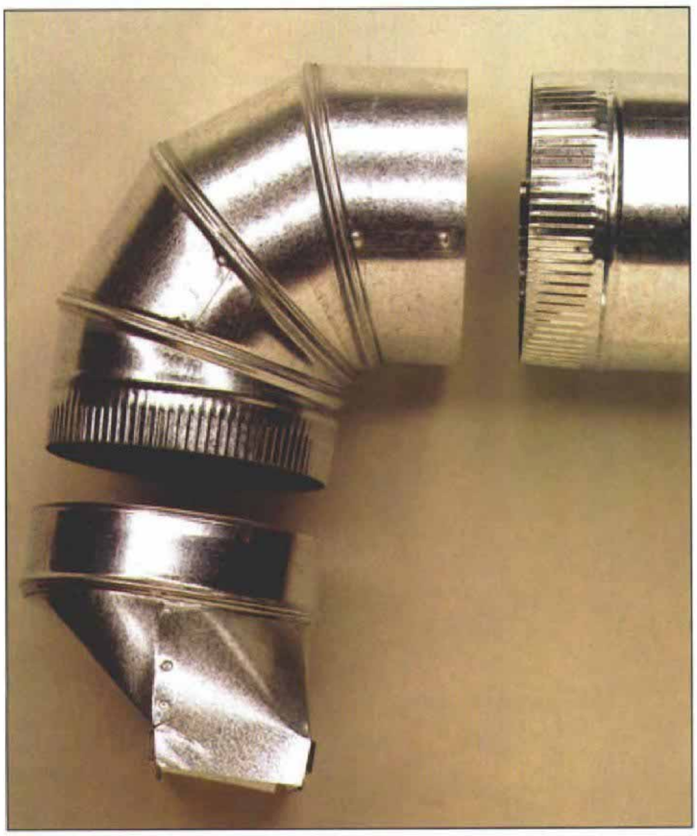
The duct of choice is metal—Rigid-metal duct is the product of choice for air-delivery systems. Rigid ducting is the sturdiest and offers the least amount of static resistance (photo bottom right). Rigid metal also is resistant to accidental puncture.

By the time you've made the decision to use rigid-metal ductwork, you've already chosen the type and size of heating equipment you'll need and created a detailed line drawing that shows where the ductwork goes. From this, you can measure the length of duct runs and count the number and the types of pieces you'll use to put it all together, remembering to keep it as straight as possible.

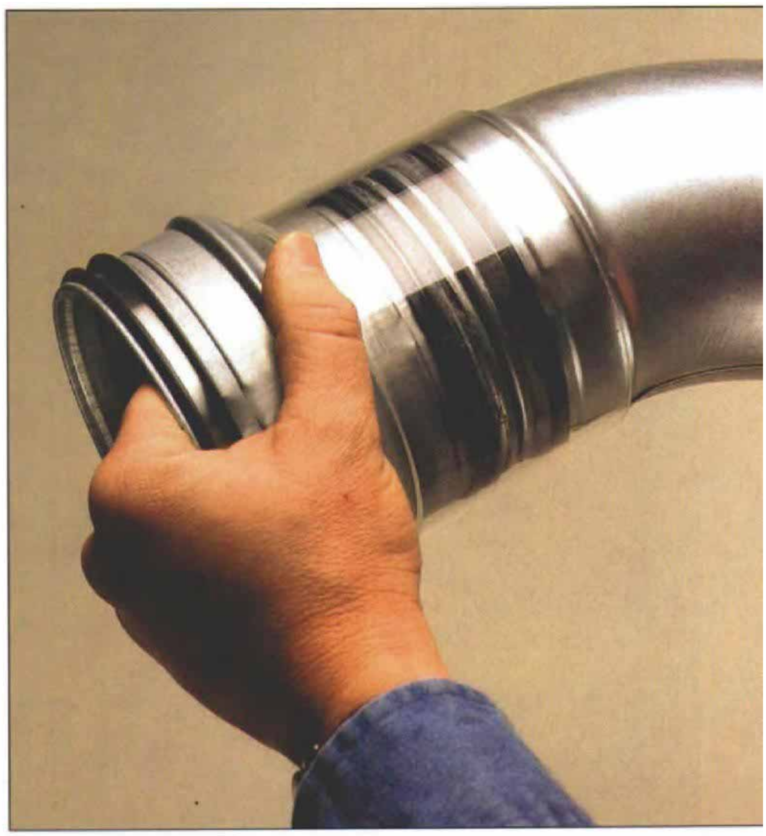
Sizing the ductwork to the heating unit is a much more complicated process than we can get into in this article. Ductwork for heating and cooling systems must be designed based on room-by-room heat/cooling load calculations. Without this information, there is no way to know how much air needs to be delivered to each room. Part of the process of determining duct size entails figuring the total equivalent length (TEL) of each duct run in the system. Calculating the TEL of a duct run will give you a good understanding of what happens when you combine all those ducts and fittings (photo bottom left). For instance, a 90° square-to-rectangular elbow has an equivalent length of 35. This means that the resistance offered by this fitting is the same as the resistance of 35 ft. of straight duct. Once you get familiar with some of these numbers, it becomes easy to understand the penalties for a lot of corners, Ts and elbows, and easy to understand why particular rooms may not get the airflow that had been expected.

When you add up the equivalent lengths for all the comers, elbows, etc., you then can measure all the straight runs, which are called actual lengths. By adding the equivalent lengths of the fittings to the actual lengths of the straight runs, you get the TEL.

The size of the ductwork in a house is based on the longest TEL, according to the Air-Conditioning Contractors of America manual (ACCA; 202-483-9370). This means that some smaller duct runs may be oversize. This is fine in a ranch house. However, in a two-story house



The best bet for ductwork. Round, rigid-metal ductwork is the best choice for delivering air throughout a house. However, these fittings—a 90° elbow and a round-to-rectangular transition—create resistance to the airflow and should be used judiciously.



Metal duct that doesn't need sealing. This ductwork made by Lindab (203-325-4666) is called SPIROsafe. Each fitting comes with a double rubber gasket at each end. The plastic sleeve connecting the two in the photo is for demonstration purposes.

or in a more complicated floor plan, you may have to size the ducts separately for each floor.

Needless to say, the longer the TEL, the more the ductwork resists air movement and the larger the blower has to be. And larger blowers cost more to buy and to operate.

Oversize ductwork is usually less of a problem than undersize ductwork. However, you don't want to oversize it greatly, especially in a low-velocity system such as a typical residential-ventilation system. It is important to go through the process of sizing your ducts correctly. Too big can be as bad as too small. In ducts that are too big, the fan blower does not have the ability to pressurize the entire system. Most of the air will exit the first available hole or grille, resulting in discomfort for rooms farther down the line.

Dos and don'ts of metal ducts–There are ways to use even rigid-metal ductwork incorrectly. Avoid excessively long runs and unnecessary turns and curves. In some cases long runs can be minimized by findings better location for the equipment. Using rigid duct gets you thinking in straight lines and eliminates a tendency to go up, over and around.

When making corners, try to use longer smooth curves as opposed to 90° pieces (photo bottom right). And remember that Y-joints are less resistant than Ts. When installing a ventilation system, put the supply or the exhaust port high on the wall as opposed to the ceiling to eliminate a 90° turn in addition to a length of straight duct.

Finally, sealing and insulating ducts is extremely important if you want the system to perform as designed. Leaky ducts reduce equipment capacity, can cause backdrafting of combustion byproducts and generally cause air to flow in unintended directions. When a system is on, a leaky duct system can cause the air-leakage rate of the building to increase. Sealing and insulating ducts is more than we can get into in this article, however, and is worth an article of its own.

As usual, a little up-front work goes a long way–The most efficient way to deliver air is through a straight run of round metal ductwork, so layout planning is helpful. If possible, try to work with the builder before framing begins. If you get the builder to appreciate the issues that you face either as a contractor or as a homeowner, the duct layout and system performance will be better.

For example, a good approach to improving the performance of duct systems in two-story houses is sending branch lines for the second-story rooms up through a center wall and then out through the floor to perimeter floor registers. This layout reduces equivalent lengths and duct size and eliminates some attic and exterior wall runs. This can be accomplished only if you can get the framer to put in a 2x6 interior wall somewhere and have the second-story joists lined up with it. Having the utility room located centrally may help to reduce duct runs. Working with the builder to plan for chases to carry ducts to distant parts of the house is also helpful in system setup. □

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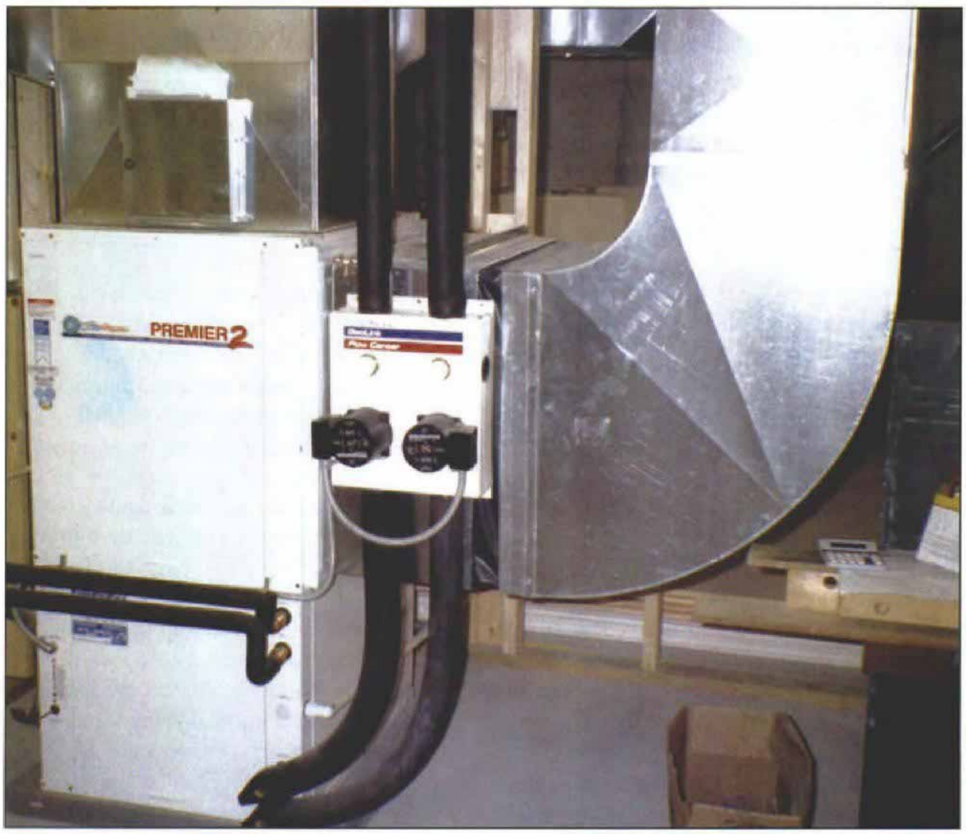

A curve is more efficient than a 90° turn. Air moves more efficiently through the large curve in this return duct than it would have if the installers had used a right-angle, or squared-off, fitting to bring air back to the heating, unit.

Photo right this page: John O'Connell