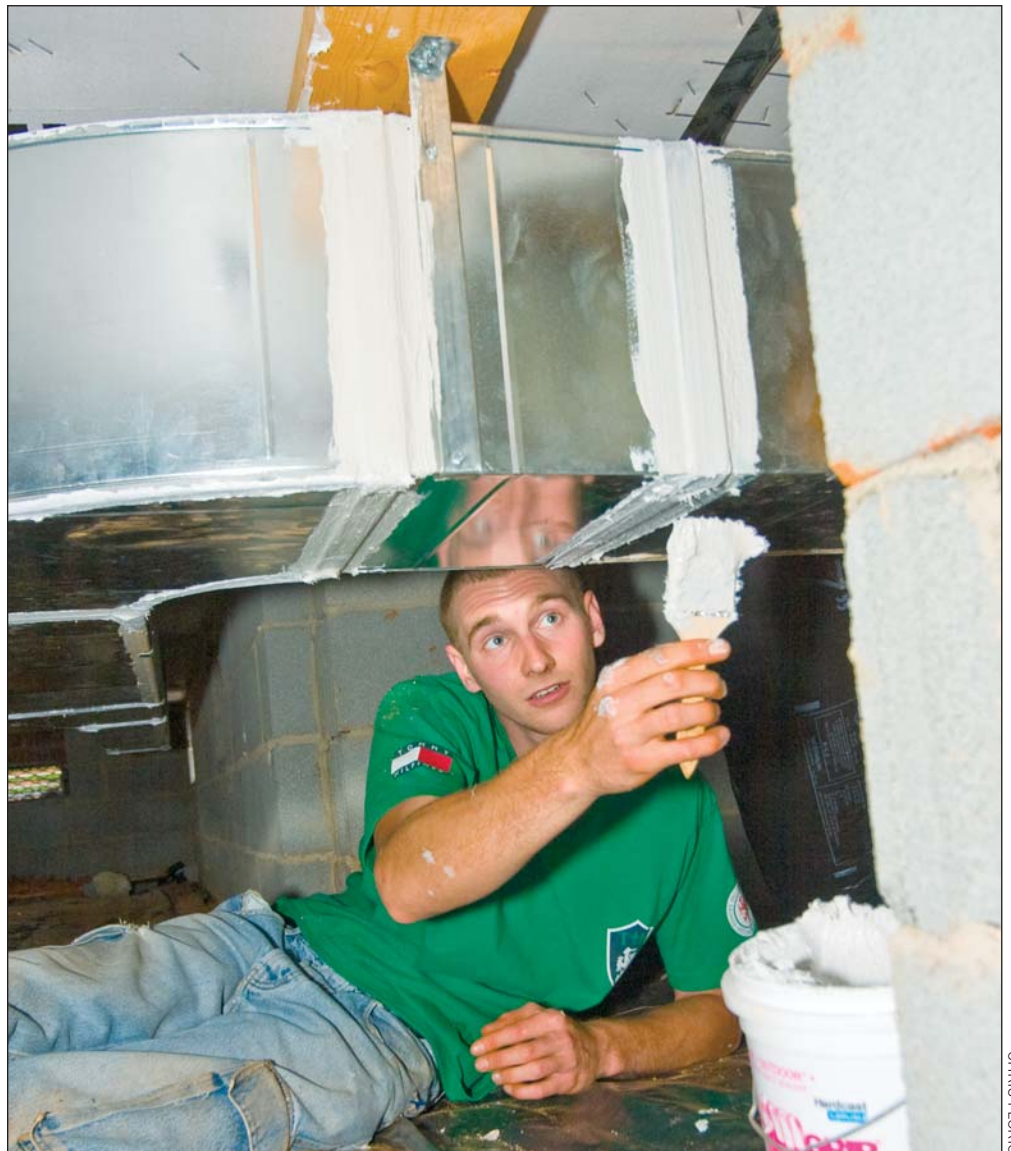


Ductwork That Works

Air distribution is the weak link in many heating and cooling systems. Here's how the industry's top pros detail their ductwork — for results you can take to the bank.

Experts agree that sealing ducts is vital to good HVAC performance, especially in a vented crawlspace or attic, where leaky return ducts will continually draw moist unconditioned air directly into the air handler. At around \$6 a bucket, high-performance duct mastic is cheap, but the labor to seal the ductwork properly is tedious and painstaking.



CHRIS FLORIO

by Ted Cushman

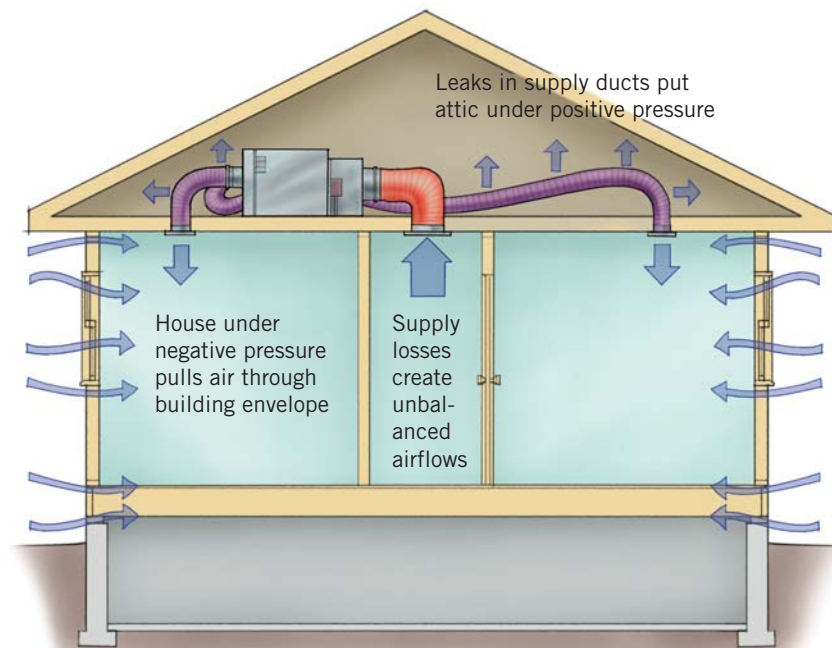
Good ductwork is key to HVAC performance. Yet hidden away in the dank crawlspace or the hot, humid attic, a home's ductwork goes unappreciated and underexamined. And too often, sad to say, this vital part of the HVAC system brings the energy performance of the home to surprising lows.

In one study, for example, researchers with the Florida Solar Energy Center (FSEC) replaced several oversized air conditioning units with "correctly" sized machines that matched the house cooling loads, as calculated according to the Air Conditioning Contractors of America (ACCA) design standard, *Manual J*. In theory, performance should have improved — but instead, the new systems saved little if any energy, while the homes' indoor humidity actually went up.

Why the disappointing results? Ductwork. When the researchers installed the new equipment, they left the old ductwork in place in the homes' roasting-hot attics. In operation, the new smaller units tended to move a lower volume of air through the ducts, more slowly, for longer run times. So the cold air was exposed to hot attic conditions for longer — essen-

tially wasting the equipment's cooling power on what amounts to outdoor space (only hotter). And leaks in the ductwork had more time to do their damage: longer run times meant more cold air was sent into the attic from supply duct leaks, while a greater volume of hot, humid attic air got sucked into the home from return air leaks. Ultimately, the new, supposedly "right-sized" air conditioners couldn't provide comfort while fighting the unfavorable attic conditions. (For the full report, see www.fsec.ucf.edu/en/publications/pdf/FSEC-CR-1641-06.pdf.)

The Florida results came as no surprise to Texas-based building performance consultant Doug Garrett (www.bldgperformance.com). "What happens to lots of people," says Garrett, "is they take out their old SEER 7 or 8 system and put in a new SEER 14 or 16 machine, and they think that their bills are going to go down 50%. But their bills only change, like, 5% — because there's a mismatch between their duct system and the equipment's required airflow. You can take a darn good piece of equipment and just absolutely skewer it by putting it on an existing, crappy duct system."



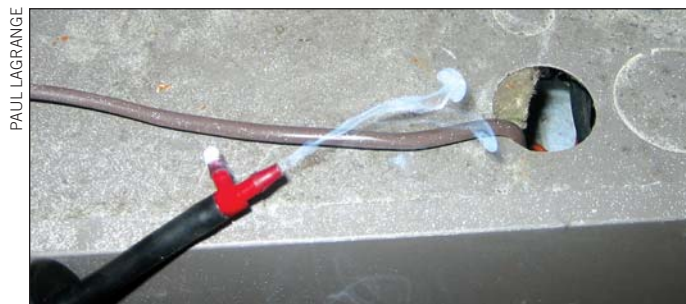
SUPPLY LEAKS

Leaks through supply ducts into unconditioned space may result in negative pressure in the living space, causing unconditioned air to be drawn into building cavities.

Ductwork That Works



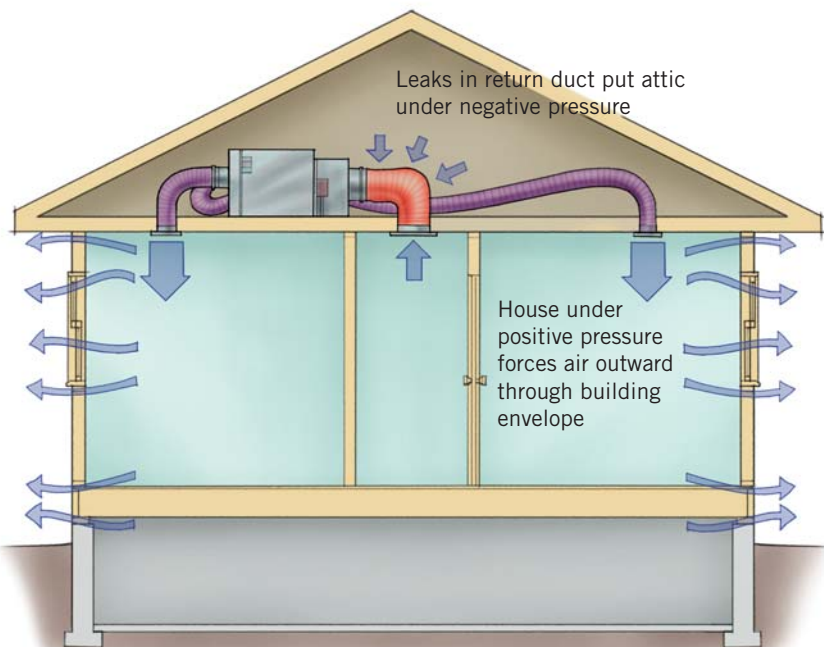
Ordinary “duct tape” does not provide an effective seal because heat, cold, and moisture will break the adhesive bond (left). Note, too, the holes in the metal collar. This whole joint should get mastic, then the liner and insulation should be secured by a plastic compression tie. Ducts aren’t the only source of leaks, however. Below, a smoke gun shows where an air handler cabinet is allowing air to enter the system from the unconditioned attic.



TERRIBLE IS TYPICAL

As it turns out, undersized duct systems with high-friction fittings, major air leaks, excessive run lengths, and crippling twists, kinks, and bends are the norm in the U.S., not the exception. A 1994 Department of Energy study estimated that nationwide, heating and cooling systems were operating at 60% of the design airflow because of undersized ductwork. “I thought that was an amazing result,” notes Garrett. “But when I bought my own flow hood and started measuring airflows, I found the same thing. In my market, systems that are supposed to be 2,000 cfm — say 400 cfm per ton times five tons, for a five-ton system — I’m measuring about 1,150 or 1,200 cfm in the return duct. That is right at 60% of what it should be.” Return ducts especially are usually undersized, says Garrett: “When I go into a house, even before I test the system, I’m already looking to see where I can put the additional return capacity that I already know I’m going to need.”

Don Swift, the Technical and Quality Control



RETURN LEAKS

Leaks in an HVAC return can suck unconditioned air into the HVAC system, increasing the cooling and humidity load, particularly if the unconditioned air drawn in is excessively damp. The unintentional airflows put the living space under a positive pressure that can drive cool, conditioned air into the building cavities. The same effect occurs when the return duct has been undersized — an all-too-typical design flaw.

CHUCK LOCKHART

Ductwork That Works

Director for New Jersey's Home Performance with Energy Star program, sees the same pattern in his state. "Even in some fairly new homes, we see that the duct systems are undersized and leaky. A typical duct system here in New Jersey will lose 20% to 30% of the airflow to the outside." And many New Jersey contractors still use wall cavities as makeshift returns, says Swift. When system fans put the unsealed cavities under negative pressure, the air conditioner sucks in outdoor air via floor system voids that communicate with the building's band-joint area. This leaves retrofit technicians with no choice but to break open walls to install real ducts, or else abandon the existing duct chases entirely and install new ducts (if they can find space for doing that). Those repairs cost a lot more than it would have cost to do the job correctly in the first place, notes Swift. "That's why Energy Star's new homes program tries to educate builders to do it right from the beginning — so we don't keep creating these problems."

In Louisiana's hot, humid coastal climate, ductwork in the attic can also cause moisture problems. Home-building consultant Paul LaGrange says most HVAC contractors in his south Louisiana market use flexible duct for their attic duct runs. Careless installation practices often result in ducts being intertwined and tangled around each other. "If the ducts touch each

other, or touch insulation, that contact surface becomes cool enough for moisture in the attic air to condense on the duct," explains LaGrange. "From July through October, my phone rings off the hook — people saying that it's raining in their house. And you go there and you realize that their ductwork is reaching the dew point. You stick your hand in between two flex ducts, or between rigid duct and blown insulation, and it comes out sopping wet. Water is dripping over the insulation and through the gypsum board ceiling, because the air conditioner is running all day and night and it is constantly condensing and dripping."

It's another case where bad ductwork can work against advanced equipment, says Doug Garrett. "The advanced variable-speed systems, the ones that have a dehumidification function — they slow the fan speed down, and they do extra-good dehumidification. That means that they put out extra-cold air, and so the ducts get extra cold. On really high dew-point days, especially down there along the coasts, I have seen all of the ducts in people's attics — and I mean *all* of them, from the unit to the boot, every duct in the attic — covered in water. You could not touch any part of any ducts without water running down to your elbow." In one luxury home, says Garrett, the executive owner "had little plastic buckets under every supply grille in the 12,000-square-foot house, because water was dripping out of the grilles. They thought the grilles were condensing, but they weren't — every duct in the attic was condensing, and the moisture was just running down to the grilles."

In that case, the repair was to insulate the attic ducts to higher levels and to keep them isolated from each other and from any attic insulation. And the hotter and more humid the climate, the more insulation exposed air conditioning ductwork needs. In coastal Louisiana's climate, notes Paul LaGrange, the International Energy Conservation Code (IECC) calls for R-8 insulation liners on attic flex duct — but the state legislature has stepped in to back the requirement down to R-6. It's a marginal cost savings, says LaGrange, but a surefire recipe for moisture problems.

DOING DUCTS RIGHT

In new construction, builders have the opportunity to start fresh, with right-sized heating and cooling equipment and properly designed, carefully installed ductwork. Good results do require skill and atten-



Twisted, tangled flex duct not only slows airflow, but the contact between the ducts cools the contact surface and promotes harmful condensation on the duct surface.

PAUL LAGRANGE

Ductwork That Works

tion. But with a systematic approach, success is within reach.

Start with the house plans. Most house plans make no allowance for ductwork, says Doug Garrett. “Architects evidently are not aware that houses are heated and cooled with forced-air systems. I sometimes think it would be front page news in an architecture magazine if you ever informed them of this. I have seen rooms 28 by 32 feet that have no way that you can get a duct to them — like, with red iron

in the way.” Says Brad Townsend, a building science manager with Masco Corporation’s Environments for Living program (www.effbuilder.com): “People design these buildings, and now the poor HVAC contractor has to make his ducts fit around all this structural stuff. And sometimes, there’s just no way to get air from point A to point B.” It can be as basic as right-sizing a duct chase, explains Townsend. “Give the contractor enough room in the chase to install the duct you need. A lot of times, they’ll restrict that flow with a 12-inch chase when the guy needs to use a 16-inch duct. You’re just setting yourself up to fail.”

One solution employed in the LSU LaHouse demonstration home uses a dropped chase in the central hallway, so that all the ductwork has a place to run below the insulated attic floor, within the conditioned space. This makes sealing and insulation less critical (although sizing and airflow balancing remain as important as ever).

For her “Not So Big” show house at the 2005 International Builders Show in Orlando, Fla., nationally known residential architect Sarah Susanka brought the ductwork inside the building envelope. She placed the ducts within chases created by ceiling soffits running around the room perimeters. In this case, the lowered ceiling provides a distinctive design element that does double duty serving a practical HVAC purpose.

Get the loads right. To make AC and forced-air

Duct sealing and insulation are less critical when ductwork is brought within the home’s insulated envelope. Here, we see ducts in a dropped hallway chase at the LaHouse project.



LSU AG EXTENSION



DAVID HOAK, FLORIDA SOLAR ENERGY CENTER

Sarah Susanka’s “Not So Big” show house in Orlando, Fla., features a soffit at the perimeter of most rooms. This provides ample room for running ductwork and keeps those ducts inside the building envelope. These chases also provide a key design element, providing ceiling height variety that makes each room feel larger.



DAVID HOAK, FLORIDA SOLAR ENERGY CENTER

Ductwork That Works



Flex duct needs proper support every 4 to 5 feet. A narrow strap like this (top) chokes off the duct and reduces the airflow. Good support should be provided by broad saddles or wide straps (above), which allow air to flow through the ducts at their full design capacity. For best results, contractors should test and verify actual airflows after installing, then correct any discrepancies.

heat work, you need to calculate the heating and cooling loads for the whole house, room by room. The right way to do this is with ACCA *Manual J*. The latest version, Edition 8, accounts for things like window area, dual low-E glazing, shading, and orientation — not just insulation levels and room volume — and the figuring gets too complicated to do by hand. A pro HVAC contractor should have an ACCA-recognized computer program to size systems — and he should know how to use it, without any fudging or guesstimating.

Size the ducts accurately. *Manual J* supplies room-by-room heating and cooling loads, and also specifies the required airflows to handle the loads. Software packages also let the user run a “Manual D” calculation with the click of a mouse (*Manual D* is ACCA’s duct design standard, a spinoff of *Manual J*). But once you know the design airflow requirements, you don’t have to use *Manual D* — simple duct calculators, or “ductulators,” can also provide good answers. However, you do need the right ductulator for the material you’re using — sheet metal ducts, fiberglass duct board, and flex duct all allow different airflows for a given diameter of duct. Relying on a ductulator calibrated for sheet metal — the most common kind — for a job that uses flex duct will give you ducts with only 70% of the needed capacity, or less.

Use short, straight, well-supported runs. Bends create friction that slows the air down. Every 90-degree bend in a duct adds the equivalent of 70 feet of duct length, reducing airflow to the room the duct serves. If you have to turn a corner, try to do it with two 45-degree bends instead of one right angle — gentler angles or slow curves are less damaging. In any case, every bend should be noted in the duct design program, so the program can compensate by increasing duct diameter if need be.

Just as a tight bend can inhibit airflow, poor support can cause the duct to collapse and the few straps provided can choke off the duct. Codes typically require support for flex duct at least every 4 to 5 feet.

Use low-friction fittings. Different fittings have different air resistance characteristics. “All people have to do is look on the back of their ductulators,” says Doug Garrett. A tee fitting, for instance, creates more drag than a wye. And again, fitting choice should be fed back into the ductulator or program to allow for adjustments.

Ductwork That Works



LSU AG EXTENSION (LAHOUSE)



TOM BRICK



LSU AG EXTENSION (LAHOUSE)

While a UL-181 duct tape is allowed by code, best practice calls for sealing ducts and fittings with mastic. Joints in metal ducts should be reinforced with a fiberglass mesh tape (top). Fittings should also be enshrouded in mastic. Duct tape has obvious limitations for sealing the multiple penetrations in a metal duct boot (middle), whereas mastic provides a lasting seal (above).

Seal thoroughly. Leakage losses are the biggest threat to duct performance — and the more friction in the duct, the more air will escape through leaks instead of reaching its intended destination. Codes allow either duct-sealing mastic, or specialty tapes that meet the UL-181 standard from United Laboratories. But some programs insist on the mastic, arguing that mastic is more flexible, resilient, and durable than tape.

Test and correct. Whatever design program, duct material, and duct-sealing method you use, you can't be sure what you have accomplished if you don't test. Only the top professional contractors tend to be equipped with flow hoods and duct blasters for measuring airflow and leakage, but those are the contractors who can guarantee that they've done what they set out to do. Says Brad Townsend, "There are ways to test these systems in the rough, before I drywall, when I can still access everything. Most furnaces run on 110 power. So I can plug into a generator, install the grill, and attach my flow hood so I can capture and measure that air in the rough." Top contractors, says Townsend, leave themselves a little margin for error with their ductwork sizing, and install adjustable dampers at the register so they can make fine adjustments. That way, they can nail the design airflows in the field, every time.

And in the production setting, Townsend points out, you only have to figure things out once. "I'm going to build this model for the next five years," he says, "and probably build several hundred of them. Once I get this design, that structure's not going to change. And I can get consistent and repeat that performance, over and over." ~

Contributing editor Ted Cushman has been covering construction business and technology since 1993.