Of Mastic and Mistakes

by Bruce Manclark

DAVID ANDREWS

My company has been in the HVAC business for eight years. Last year, our crews passed the 100-mile mark—they sealed their 100th mile of ductwork. They have applied somewhere around 16,000 gallons of duct mastic, conducted 8,000 Duct Blaster tests, increased comfort for scores of homeowners, saved loads of Btus, and well … profoundly messed up a few heating and cooling systems. Following are a few of the most interesting examples of our messing up—perhaps by reading these, you'll avoid making the mistakes that we made!

Case One: The Iceberg

Mrs. Jones (not her real name for obvious reasons) was an older woman with a 3-ton heat pump in her home, a newer home that had extremely leaky ducts. Our crew was able to decrease her duct leakage from more than 600 CFM at 50 Pascals (Pa) down to 75 CFM at 50 Pa. That's 525 CFM of leakage. The crew was pumped. They had just done a great job and they knew it. It was a Friday afternoon, ending the week on a high note.

The next day we received a call from Mrs. Jones, who was wondering if it was normal to have the inside coil of her A/C freeze up after duct sealing, because if it was, she would like her holes back. At least with the holes she could cool the house.

I promptly went out to Mrs. Jones's house, and sure enough, her inside coil was a solid block of ice that was now melting. I was a little mystified. What was the connection between our crews having sealed holes and the freezing up of her indoor air coil? It was very perplexing.

I knew that coils can freeze up due to insufficient air across the inside coil. I checked the filter. It was clean; the crew had given her a new throwaway fiberglass type. I checked to make sure all the registers were open and unblocked. They were fine. As the ice continued to melt, I checked to see if the coil was clean. It was very clean. Had the crew somehow lowered the fan speed? No, it was on the high-speed tap. So what had happened? How was the ice related to our crew fixing the holes in the duct system? I asked if this had ever happened before. Unfortunately for me, the answer was "No." So much for blaming someone else.

I kept going over and over possible causes for the low air flow, making up a few more possible causes in the process. As I stared at the 10-inch main return, the link between the sealing of the duct leakage and the frozen coil finally hit me: The ducts were undersized. This particular system should have had a 16-inch return (see "The Energy Penalty of Poor Duct Design," *HE* Mar/Apr '01, p. 36).

Undersized ducts increase the amount of pressure that an HVAC fan operates against. As the static pressure in a duct system increases, the amount of air that the fan can move decreases. HVAC fans act just like water pumps. A pump may be rated at 10 gallons per minute, but if enough resistance is added in the form of small pipes, too many elbows, or clogged filters, that pump will not deliver 10 gallons per minute.

This resistance for air handler fans is usually measured in water column (WC) inches of pressure. Every air handler has a set fan curve for each fan speed. The fan curve shows that, against a given number of WC inches of pressure, the fan will move a certain amount of air.

To measure this resistance, I conducted an external static pressure (ESP) test. This test measures the static pressure external to the air handler the fan operates against. Fortunately for me, the installer's booklet containing the fan curve was still attached to the furnace. The fan curve stated that at .5 WC inches, this fan, on high speed, moves 1,200 CFM of air. Which is the amount of air this 3-ton heat pump needed to achieve its rated capacity and efficiency.

My reading, however, was 1.4 inches of static pressure! The pressure was so high that the fan could move very little air. The fan was insufficient, as evidenced by the iceberg on the coil.

BRUCE MANCLARK

This is one well-sealed elbow.

DAVID BAUMGARTNER

Bruce Andrews holds a trophy duct; fixing holes this big can cause unintended problems.

What our crew had accomplished by sealing the holes was to make the undersized duct system work like an undersized duct system. With the holes in it, there was pressure relief that kept the ESP low; this in turn allowed sufficient air across the coil.

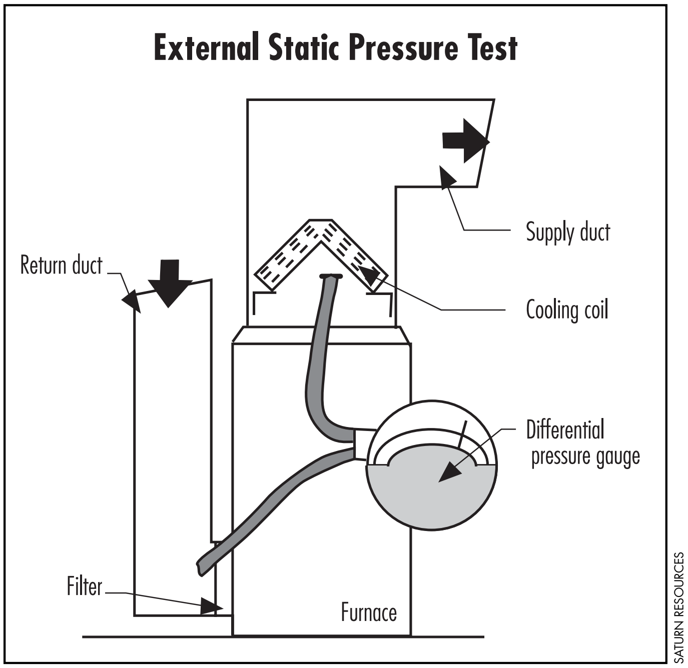
After I explained to Mrs. Jones what had happened, she asked how it could be fixed—short of putting back the holes. I explained that we needed to install larger, less restrictive ductwork. We gave her a bid that she accepted (luckily for us). We installed the larger return, and took a few kinks out of the supply ducts, decreasing the ESP to just over .5 WC inches. At this point, we checked the refrigerant charge of the system, found it to be overcharged, and adjusted it accordingly. Mrs. Jones was now happy, and even called back to comment on how much better her heat pump cooled the house. I suppose she also could have gotten a smaller A/C unit, but it would have cost at least $2,500.

Reflecting back on this house, it is my guess that before we started, Mrs. Jones had insufficient air flow across the inside coil. Our duct sealing made a bad situation worse by taking away the pressure relief. This prompted me to ask myself, "On how many heat pumps has our duct sealing decreased the air flow to the point of also decreasing the efficiency and capacity of the system? In how many electric and gas furnaces have we decreased air flow to the point of causing the safety controls to kick in?"

Field tests performed by Proctor Engineering Group have consistently found a high percentage of air conditioners with low air flow. In five different studies, airflow in 24%–67% of units was low by at least 50 CFM per ton. The average A/C requires around 400 CFM per ton.

Measuring a system's ESP is a useful way to tell if its air flow is on or off the chart. If you do enough of these tests, you will soon realize that moving the static pressure probe just a few inches in any given direction can make a difference in the results. The trick is to try to get a reading that is representative of the average pressure—not just an isolated reading. Keep in mind that ESP is just a measurement we use to get the real information we need, which is the amount of air flow across the inside coil.

The True Flow, a new tool on the market from the Energy Conservatory, allows a user to dial in the air flow with a high degree of accuracy. It consists of a Plexiglas plate with a series of holes drilled through it at regular intervals. This plate fits into the filter slot of the furnace. The user measures the pressure drop across the plate and looks up the flow in CFM on a table provided by the Energy Conservatory. Adjustments to the flow are made based on static pressure measurements downstream from the fan.



This gas furnace with air conditioner unit is tested with the external static pressure test. This is done to estimate CFM through the fan, so that the system can be sized correctly. Hoses run from the supply and return ducts to a manometer.

Since we hit the iceberg at Mrs. Jones's house, we routinely test for air flow across the coil before and after duct repair. By testing the static pressure before we sealed Mrs. Jones's duct system, we could have avoided the callback. Achieving the correct air flow across the indoor coil is critical to achieving the capacity and efficiency of air conditioners and heat pumps. A little testing can save you callbacks and allow you to sell a more comprehensive duct repair job.

Case Two: Hello! Hello! Speak Up!

Once again, the crew had done an outstanding job of duct sealing, taking nearly 1,000 CFM at 50 Pa from a large house with a 25 kW electric furnace. This time the homeowner did not wait until the next day to call. She noticed the problem as soon as the system came on. It was loud. *Really* loud. I was convinced she was holding the telephone receiver against the return grille. Unfortunately for us, she wasn't.

Upon arriving at the house, I could not do anything but agree in a loud voice that, yes indeed, the system seemed to be running loud.

The duct leakage reduction the crew had achieved was primarily on the return side. They had taken a building cavity return and made it tight. They had removed a collapsed duct board return plenum that was leading to this building cavity and had installed a sealed sheetmetal transition piece.

The noise was most apparent at the two return grilles in the house. At one of the grilles, it was actually a whistling noise. This problem wasn't quite so hard to figure out. The work we did had obviously created a continuous-return air path that forced the return air through the grilles and back to the furnace down a building cavity that was now airtight. The velocity of the air crossing the vanes on the return grilles was creating this noise. The Air Conditioning Contractors of America (ACCA) in their duct design guidebook, *Manual D,* recommend a face velocity of no more than 400 ft per minute (FPM). We were almost double that.

The fix was to greatly enlarge the grille sizes, which got us to around 600 FPM. Enlarging the entire building cavity that was being used as a return would have been very expensive and was not an option we seriously considered. That left us with trying to reduce the amount of air the fan was moving. The fan was set on the highest of four possible settings. We moved it to the second lowest setting. That solved the noise problem, but it raised the delivered air temperature beyond acceptable levels. In fact, it probably would have tripped the temperature limit switches.

After more discussion, the homeowner suggested that maybe she did not need all 25 kW worth of electric heat now that the heating system was sealed. A quick calculation on the back of an envelope suggested that she was probably right. We flipped the breaker on 10kW worth of heat and left the fan setting on the second lowest setting. The noise went away, and the furnace was operating within specifications.

When a homeowner describes comfort, noise levels are included. Noise levels that increase as a result of duct sealing get noticed right away. Conversely, if you can lower noise levels by doing a comprehensive duct rehabilitation, you're a hero.

Case Three: Black Soot

One of our crews had just sealed a duct system on an older house. The house had a five-year-old gas furnace. We could tell that it had had an oil heating system prior to that.

Again, the system was very leaky, with most of the leaks being near the air handler. The crew did another great job of duct sealing, bringing the system to below 100 CFM to the outside at 50 Pa. This result was outstanding, considering that the air handler was located in the garage.

What we did not know was that the old oil furnace had been replaced due to a breached heat exchanger. Like most oil furnaces with

Checklist for HVAC Work

Now we know that for each house we work on, we must always check the following, or we can expect to see problems similar to the cases outlined here:

- duct leakage;
- worst-case depressurization;
- velocity of air at grilles and registers;
- air flow through fan; and
- room-by-room heat loss.

breached heat exchangers, this one had operated long enough to coat the inside of the ducts with a layer of soot. Yep, you guessed it: That layer of soot was lifted off the duct system by the increased velocity of the air and was deposited evenly throughout the house (for more about how black stains are caused and cured, see “Black Stains in Houses: Soot, Dust, or Ghosts?” *HE* Jan/Feb ’98, p. 15).

Before the professional housecleaning service arrived, we had the ducts cleaned by someone we trusted. After the house and the ducts were cleaned, we had a happy homeowner. But after this incident, we keep in mind that sealing large holes in a duct system can increase the velocity of the air in the system. Now, if we work in a home where the ducts are extremely dirty, we recommend having them cleaned before we seal them. If we suspect that the house has ever had a failed heat exchanger in an oil furnace, we require that the homeowner have the ducts cleaned by a duct-cleaning service that we choose.

Your Ducts Are Tight, Why Aren’t You Happy?

You can see by the three cases presented here that simply sealing the ductwork does not solve every problem in every home. But it took us a while to learn that. As the old saying goes, “When the only tool in your tool belt is a hammer, everything looks like a nail.” When we started sealing ducts, we were committed and self-righteous duct sealers. Have a problem with your ductwork? Just seal it! We were a bit like the old snake oil peddlers who sold magical medical elixirs to cure everything from hangnails to hangovers. The only difference being that we actually believed that enough mastic could solve all ductwork problems.

We believed so much in the elixir of mesh and mastic in those early years that we didn’t listen to the real complaints the customers had. No matter what they said, we heard, “My ducts leak.” If they said, “My energy bills are too high,” we heard, “My ducts leak.” If they were uncomfortable, we heard, “My ducts leak.” Sometimes we were right. But even a broken watch is right twice a day.

BRUCE MANCLARK

You never know what you may find in a client’s home—even commercial package units such as this one can turn up in residential buildings.

In cases like these, we were very surprised, after doing a great job of duct sealing, to find that homeowners still complained they were uncomfortable. How could they be uncomfortable? Their ducts were tight. We managed to placate most of these customers but a few actually refused to pay their full bill because we had not delivered what we promised. They thought they were buying comfort, but we thought we were selling tight duct systems.

Not paying your contractors is a good way to get their attention, and when our customers got our attention this way, we decided we needed a better plan to address comfort complaints.

Creating thermal comfort with forced-air heating and cooling systems is a matter of supplying the required amount of air at the right temperature to meet the heat loss or heat gain of a particular zone. This means that it is possible to create thermal comfort with leaky ducts, as long as the volume of air and the air temperature are sufficient to offset the heating and cooling load. It also means that an efficient duct system is no guarantee of comfortable occupants.

We eventually realized that in order to create comfort (and get paid), we needed to be able to increase or decrease the air flow to individual rooms. In most cases, problems were due to a lack of air flow to a particular zone. In some cases, we would do a room-by-room heat loss and heat gain calculation to determine the target CFM of air for that zone. Adding more duct runs to rooms, increasing the size of the ductwork to certain zones, and installing dampers at plenum takeoffs gives us this ability. Of course we still seal the duct system.

In all aspects of life, it is possible to do harm by trying to do good. Sealing ducts is no different. In homes where crews may make a large reduction in leakage, it is critical to know what problems you may create—before you get started. Lowering the efficiency and the capacity of an air conditioner or causing a gas furnace to cycle on the high-limit switch is not the result we want from our efforts.

The experiences described here, plus a few instances when gas furnaces operated on their high-limit switches, forced us to be more than duct sealers. We now routinely look at ESPs before we start sealing. If the client needs larger ducts or a different air filter, we prepare the bid that way. Yes, it increases the cost, but the average homeowner responds to the fact that we are looking at the entire HVAC system, not just at the tightness of the ducts. We have moved from the world of duct sealing to the world of duct retrofitting, and that means we are able to address not just the tightness of the duct system but also the capacity, efficiency, and safety requirements of the heating and cooling equipment, along with the comfort needs of the homeowner.

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