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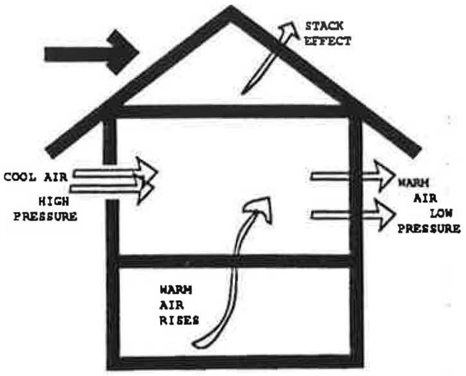
TECH TALK

"MAD AIR" Is A Major Infiltration Source

By Gary Anderson, The Energy Conservatory

Every book written about weatherizing and retrofitting homes talks about the two driving forces for infiltration/exfiltration - the wind, and the stack effect caused by the temperature difference between inside and outside.



Only recently have we begun to recognize a third force driving air in or out of houses; the furnace fan or air handler. Several studies done in the last two years by researchers in the Pacific Northwest have found that houses with forced air heating systems have natural infiltration rates that are 30-70% higher than similar houses with non-forced air systems. Studies done at Natural Florida Retrofit, Inc. are showing even more dramatic problems in southern housing due in part to the fact that their air handlers for air conditioning are much more powerful. They have come up with the acronym "MAD AIR" - Mechanical Air Distribution And Interacting Relationships - to describe the problem.

The furnace fan can increase ventilation in two ways. First, some air is forced directly out or in through leaks in the ducts going through walls or attics. Second, imbalances in the forced air distribution system (resulting from excessive supply or return duct leakage) cause parts of the house to be either pressurized or depressurized. This forces air in or out through unconditioned space.

About a year ago our company began to check for these pressure differences and duct leaks in every forced air heated house we evaluate. We are finding that these fan induced pressure differences not only exist in many houses but they are large enough to overpower other infiltration driving forces, causing condensation in walls or attics, excessive spillage, or even backdrafting of combustion exhaust flues and contributing to high radon levels.

Before I try to explain how to diagnose and solve "MAD AIR" problems, let's take a close look at how a forced air distribution system works and how it can act as an infiltration driving force.

In order to have airflow we need a pressure difference (driving force) and a hole for the air to go through. When a fan is running in an open space, the fan blades create the pressure difference between one side of the fan and the other. There is a positive pressure (+P) on one side of the blades, and a negative pressure (-P) on the other. If the fan is in an open space the hole is essentially infinite. (Figure 1)

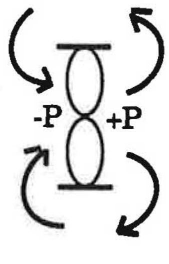


Figure 1

A fan works a lot like a bank loan. If the amount given out (exhausted) doesn't come back fast enough, pressure is applied as required to get it back. (You can even think of the energy required to run the fan as the interest charge.) So what happens if we build an airtight box around one side of the fan? (Figure 2) The fan will create as strong a negative pressure as it can in an effort to suck in air to equal the amount of air it is trying to exhaust. Since there is no hole allowing air to get back to the fan, flow stops.

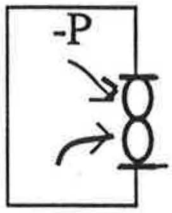


Figure 2

If we allow some air to return to the fan through leaks in the box, we relieve some of the pressure and we get some flow. (Figure 3). The pressure and flow at which this equilibrium occurs is a function of both how hard the fan is trying and how restricted the air flow (the size of the leaks in the box).

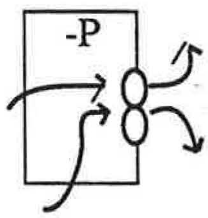


Figure 3

This equilibrium pressure and flow, incidentally, is what we measure when we do a blower door test on the house. A tight house requires a higher pressure difference between inside and outside the house to provide a given volume of make-up air to the blower door fan. Conversely, less flow is required to maintain a given pressure difference.

Now let's put this leaky box inside a larger, airtight box and think of it as a room in a house. If the room is very open to the house so the airflow in and out of the fan is unrestricted, the pressure between the room and the house is zero. But if we restrict the air flow back to the fan (e.g. by losing the door) there will be a egative pressure in the room and at he same time there will be a ositive pressure in the rest of the house. (Figure 4)

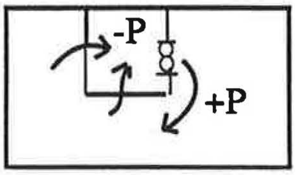


Figure 4

f we allow more air to get back to he fan through a hole between the oom and outside, some of the egative pressure would be relieved nd air flow through the fan would ncrease. (Figure 5)

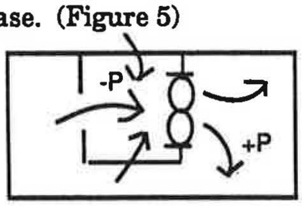


Figure 5

But since flow to the rest of the iouse increases, so does the positive ressure between the house and utside. The house/outside pressure ould be relieved by letting some of he air go outside through a hole in he house or back to the fan through larger hole between the room and he house (open the door to the oom). In either case flow through he fan will increase. But if we ncrease flow by opening the house o the outside, the negative pressure n the room will increase because we aven't made it any easier for air to et back to the fan. (Figure 6) This reatly increases the ventilation rate f the house because there will be nore infiltration to the room and xfiltration from the rest of the ouse.

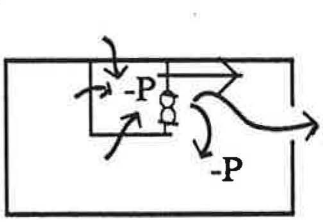


Figure 6

The picture looks more complicated if we consider the ductwork through which air moves to or from the fan. But you can think of the ducts as long, skinny "rooms" that connect the fan to different parts of the house. The leaks in the ducts are another set of holes that contribute to the equilibrium pressures and flows in the same way discussed above. An important difference is that ducts are under much greater pressure than the house ever sees, so that a small duct leak will allow much more flow than the same size room or house leak. As you would expect, those problems tend to be much worse when the air handler and/or ducts are in unconditioned space such as the attic or garage.

The main points are that pressure imbalances can exist because of duct leaks and/or unbalanced return or supply flows, and, these imbalances can be unwittingly created when we change the size of the holes in a house or its ductwork through normal weatherization (caulking or insulating with densely blown cellulose, for instance. Problems can also be created when a larger air handler is installed, as could happen if you add central air conditioning, or replace an old furnace with a new, high efficiency system.

This all sounds complicated - and in a way it is - but the good news is that these problems are relatively easy to diagnose and solve. To diagnose the problem all you need is a sensitive differential pressure gauge costing less than $50 and a few feet of small plastic hose. We just use one of the pressure gauges from our blower door system. With the furnace fan running, check the pressure difference between each room and the house by running the hose from the gauge under the closed door to the room. In general, a pressure of 2 or 3 pascals (.01" w.c.) is significant in terms of increasing ventilation or moisture problems. Spillage and backdrafting usually won't be a problem if the negative pressure in the furnace room is less than 5 or 6 pascals.

We found several minor pressure differentials in the houses we looked at as part of the blower door training last fall in the Anchorage area. In one house we found the baby's bedroom had a positive pressure of 8 pascals with the door closed. Air was being pumped into the room through the hot air vent, but since there was no return air vent, it was being pressurized. Only after finding this did we notice the water stains on the ceiling around the leaky attic hatch. This was no doubt due to the condensation of moisture in the large volume of air that was being forced into the attic.

The solution to this problem could be as simple as leaving the door open or installing a vent in the door or interior wall. Of course the attic hatch should be sealed even if the pressure difference is eliminated.

The most important room to check is the furnace room. If there are leaks in the return air plenum or main return duct the furnace fan will suck air from the furnace room, crating a negative pressure. If the room (basement, crawl space, or garage) is very tight and the return air duct is very leaky, the negative pressure can be large enough to cause flue gas spillage or backdrafting. Even a small increased negative pressure in the basement can greatly increase the amount of radon gas that gets sucked in if it is present in the soil.

The best way to eliminate the pressure in this case is to seal the return air duct leaks. A good way to find the leaks is to use a smoke pencil with the furnace fan running. If you can't seal enough of these leaks to equalize the pressure, the room should be made leakier to the rest of the house by cutting off the bottom of the door or by installing a vent. Of course if a house is being built the solution is to provide adequate return duct capacity to each room and make sure the duct work is very tight, both to the outside and to the house.

Another thing to check is the pressure different between the house and the outside with the furnace fan on and all room doors closed. If a significant amount of air is being forced outside through supply duct leaks or leaks in rooms that are being pressurized, the pressure between the rest of the house and outside will be negative. The pressure will be even greater if exhaust appliances (e.g. kitchen or bathroom fans clothes dryer) are running so your measurement should be made with these on. If there are large return duct leaks (e.g. a wall cavity, used as a return duct, that is open to the attic) the air handler will suck air into the house and create a positive pressure.

A blower door is useful to assess the total amount of duct leakage to the outside. With the blower door depressurizing the house, all the air you feel coming in through supply or return vents is coming from outside. Even if this test shows large outside duct leaks, the air handler won't cause a pressure difference if the supply and return ducts are leaking equally. Further investigation (including checking pressures as described above) is necessary to pinpoint the leaks.

Mobile homes are especially susceptible to "MAD AIR" problems for several reasons. They often have no return duct system so that every room gets pressurized when the door is closed. The supply ducts running under the home tend to be very leaky so the fan pumps a large volume of hot air outside. Also, mobile homes are often relatively tight, making it easier for the furnace fan to create significant pressure differentials. The solution again is to seal the duct leaks and somehow open each room to the main living space.

It seems incredible that this common and serious problem has been almost totally overlooked until recently. Part of the explanation lies in the fact that it is a bigger problem now because houses are being made tighter. At the same time, newer heating and air conditioning systems often have larger fans. In any case, research is really just beginning and I am sure we will soon have a much better understanding of the problems and solutions. At that point the whole building community will need to consider the problem in their design, construction and inspection decisions. It already appears to be a prime example of the importance of thinking of the house as a system of interactive components. This concept eventually needs to be reflected in building codes and construction and remodeling practices.

Gary Anderson is a partner in The Energy Conservatory, a Minnesota-based energy consulting company that also manufactures the Minneapolis Blower Door.

House Depressurization Limits For Induced Draft Furnaces

While mid-efficiency, induced draft gas furnaces have become a popular solution to avoiding chimney backdrafting and spillage problems, especially in tighter houses, a new Canadian study suggests that the current design of these furnaces is not appropriate in airtight housing where frequent or continuous house depressurization is a possibility.

Sebastian and Peter Moffatt, of Vancouver, B.C., tested 5 such furnaces, of different brands, to establish their susceptibility to pressure-induced spillage. They were all furnaces that had been previously installed in homes, and the test did not attempt to separate the efficiency of the furnace from that of the entire system, including chimney and house.

The maximum safe level of house depressurization for a furnace or chimney design is called the House Depressurization Limit (HDL). When a house exceeds the HDL, the potential exists for spillage or backdrafting whenever the furnace operates.

In a house with a natural-draft gas furnace, the HDL is approximately 5 Pascals. If the house is depressurized more than this, the chimney may backdraft under stand-by conditions. Upon firing, the furnace is unable to reverse the backdraft and establish proper venting, and the combustion gases spill indoors for as long as the furnace is operating.

It has been assumed that the HDL for induced-draft fans is about 20-30 Pascals - about the same as the minimum draft that exists in a hot chimney. This testing found 4 of the 5 had some degree of spillage **with no depressurization,** and only one model performed well during depressurization. The authors recommend sealed combustion furnaces. ACHP requires sealed combustion appliances for home certification.

For more information on this study contact:

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