Backdrafting Causes And Cures

Sebastian Moffatt

Steps can be taken to prevent hazardous furnace gasses from re-entering tightly built or weatherized homes.

If there were universal laws to describe ventilation, the first might be: *Air out equals air in.* This means that all of the air exhausted from fans and chimneys in a house is immediately replaced—somehow. Either it is forced into the house by a fan, or the indoor air pressures drop until outdoor pressures are strong enough to push replacement air through leaks and holes in the structure.

This works fine up to a point. But when indoor negative pressures overcome the natural buoyancy of warm gas in a chimney flue, they can reverse the upward flow of combustion gases and draw them back down into the house. When this happens, you have *backdrafting:* the pressure-induced spillage of exhaust gases into the house living space (see Figure 1).

Backdrafting is a health, safety, and comfort concern. To prevent it you must either build a house without a chimney, or balance all the ventilation systems to prevent indoor-outdoor pressure differentials. In short, houses need to inhale as easily as they exhale.

New Trends Beget New Problems

Backdrafting has always been a problem. But several recent trends in construction have narrowed the margin of safety for houses with unbalanced ventilation systems.

Tight houses

We're building tighter houses than ever. In Canada, new housing has become 30% tighter on average in the last eight years, and a similar pattern is occurring in the northern U.S. Tight houses are more prone to backdrafting problems because you can't rely on air leaks to balance sudden surges in "exhalation" from a powerful stovetop, bathroom, or dryer fan. As the shift to tight housing continues, builders will have to counter the backdrafting potential created by airtight construction.

More Powerful Exhaust Fans

Today's more numerous and powerful local exhaust fans also contribute to backdrafting. Downdraft cooktops pose the biggest problem because their make-up air requirements (the amount of air they draw) are extraordinary, sometimes as much as 1,000 cubic feet per minute (cfm). I've visited many houses where the chimney backdrafts virtually every time the cooktop fan is operated.

I'm also seeing more powerful overhead range hoods. And some new clothes dryers exhaust at 250 cfm. That's about twice the previous norm! Unless a house is built like a sieve, the make-up air demands of such fans can be met only by a forced make-up air supply or an adequate opening to the outside.

Exhaust-Only Ventilation Systems

Finally, the increasing reliance upon exhaust-only whole-house ventilation systems poses a backdrafting threat. Until recently, the few whole-house exhaust fans in use were unlikely to exhaust more than half their specified capacity. However, the recent introduction of highly effective, continuous-use central exhaust ventilators (CEVs) changed that. In combination with more powerful local exhaust fans and tighter building envelopes, the backdrafting effect of these whole-house exhaust fans could be deadly.

* * * *

A 1984 survey of hundreds of houses suggested that 10% to 15% of them experienced furnace spillage at least once per year. Oil-fired systems spilled most frequently, but only for 15 seconds or so at the start-up of each operating cycle. Gas-fired systems spilled less frequently, but often for the entire five or six minutes of the cycle. And over the past five years, the incidence of backdrafting in new houses has certainly grown, with spillage-prone houses now comprising 20% or more of the total stock.

Gas Furnace Spillage

Fortunately, spillage from gas-fired furnaces or water heaters rarely poses a serious health hazard. In tighter houses, spillage raises humidity and carbon dioxide (CO_2)

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levels above the norms recommended for indoor air, but seldom above what might be considered a health limit.

Natural gas combustion exhaust contains nitrogen dioxide gas (NO_2) which can damage lungs. Fortunately NO_2 is unstable and is usually neutralized or diluted before it pollutes the living areas. A gas range actually poses a much greater NO_2 pollution risk than a gas furnace since people will be close to the source and exhaust hoods seldom capture more than 50% of stove-top exhaust.

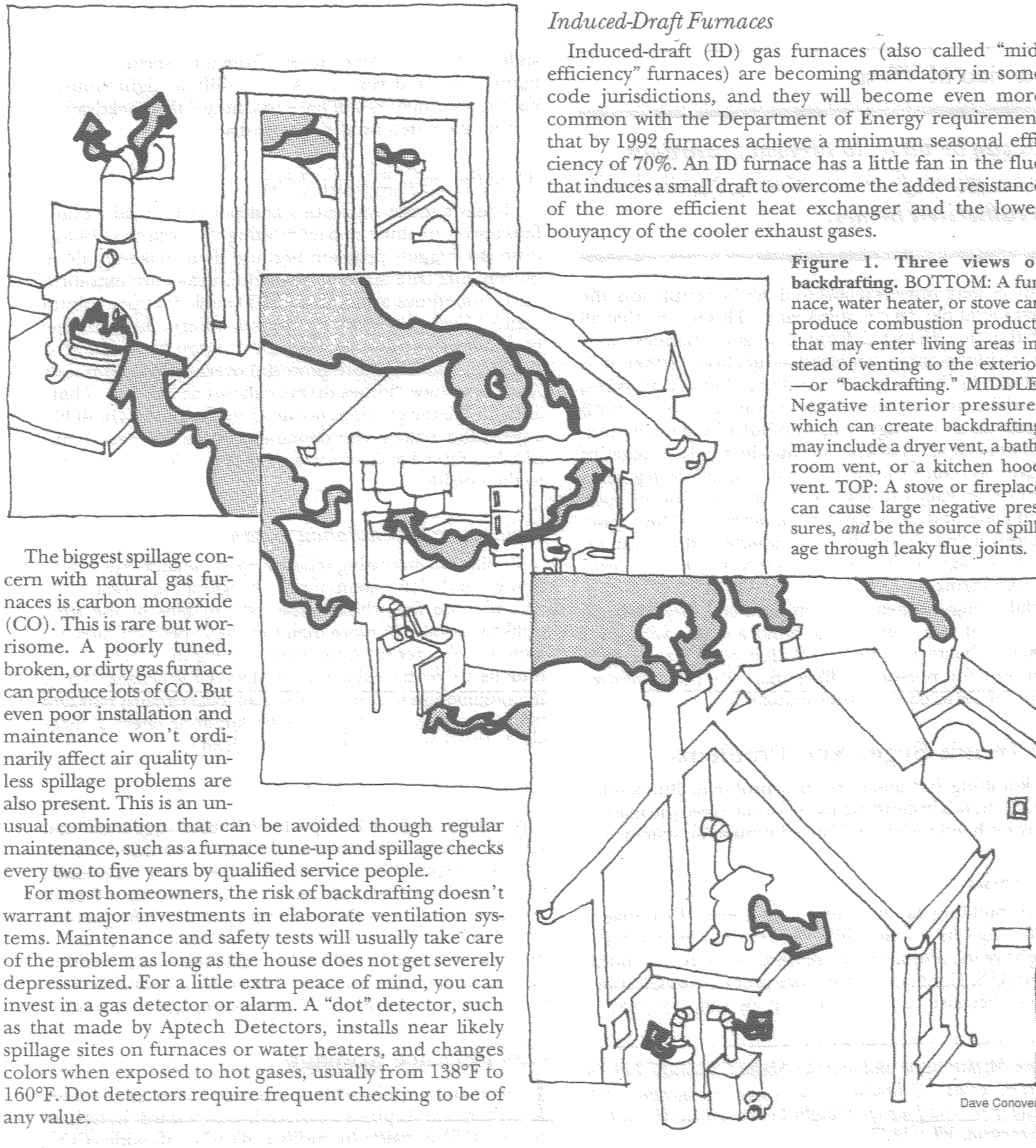


Figure 1. Three views of backdrafting. BOTTOM: A furnace, water heater, or stove can produce combustion products that may enter living areas instead of venting to the exterior —or "backdrafting." MIDDLE: Negative interior pressures which can create backdrafting may include a dryer vent, a bathroom vent, or a kitchen hood vent. TOP: A stove or fireplace can cause large negative pressures, *and* be the source of spillage through leaky flue joints.

The biggest spillage concern with natural gas furnaces is carbon monoxide (CO). This is rare but worrisome. A poorly tuned, broken, or dirty gas furnace can produce lots of CO. But even poor installation and maintenance won't ordinarily affect air quality unless spillage problems are also present. This is an unusual combination that can be avoided though regular maintenance, such as a furnace tune-up and spillage checks every two to five years by qualified service people.

For most homeowners, the risk of backdrafting doesn't warrant major investments in elaborate ventilation systems. Maintenance and safety tests will usually take care of the problem as long as the house does not get severely depressurized. For a little extra peace of mind, you can invest in a gas detector or alarm. A "dot" detector, such as that made by Aptech Detectors, installs near likely spillage sites on furnaces or water heaters, and changes colors when exposed to hot gases, usually from 138°F to 160°F. Dot detectors require frequent checking to be of any value.

At least two companies make CO alarms that blare like smoke alarms. Asahi Electronics makes both battery-powered and hard-wired models for $89.95. Another manufacturer, Quantum, makes a model called the Canary.

Gas Furnace Solutions—Good and Bad

Eventually, changes to gas furnace design will probably solve the problem of spillage. So far, however, the more expensive alternatives have been disappointing.

Induced-Draft Furnaces

Induced-draft (ID) gas furnaces (also called "mid-efficiency" furnaces) are becoming mandatory in some code jurisdictions, and they will become even more common with the Department of Energy requirement that by 1992 furnaces achieve a minimum seasonal efficiency of 70%. An ID furnace has a little fan in the flue that induces a small draft to overcome the added resistance of the more efficient heat exchanger and the lower bouyancy of the cooler exhaust gases.

Theoretically, these furnaces should be able to withstand a normal range of house depressurization—up to about 20 Pa. (A Pascal is a unit of pressure equal to 1/250 of the pressure exerted by an inch-deep column of water. As an example, the average pressure on the side of a house exerted by a 20-knot wind is 10 Pa. On a very cold day, the warm air in your attic pushes through the cracks at about 3 Pa. Hot chimneys usually have a draft of 20 to 30 Pa.)

Unfortunately, ID furnaces were designed solely for energy efficiency. They were never intended to meet the depressurization demands found in air-tight housing. The draft fan merely regulates the burner pressure and "primes" the flue. It doesn't guarantee a chimney draft.

Spillage can occur even if the furnace housing is airtight, since the flue above is often so leaky that the entire gas flow can escape into the house. Manufacturers specify that flues be tightened during installation, and codes require installers to follow these instructions, but I've yet to see any installer do a proper job of flue sealing. In addition, the fan units themselves in these furnaces are often of leaky design and *can't* be tightened. Four of every five ID furnaces I tested showed continuous spillage around the induced-draft fan housing and axle, even without house depressurization (see Figure 2).

Induced-draft water heaters have the same shortcomings. Resist the temptation to install a conventional, natural-draft water heater next to an ID furnace and "Y" the two units into the same flue. This makes both appliances more susceptible to backdrafting problems. Some minor design modifications, already underway, will probably fix these problems. Eventually, we may see a test for ID furnaces to certify that they can perform without spillage within a normal range of house depressurizations. Until then, let the buyer beware!

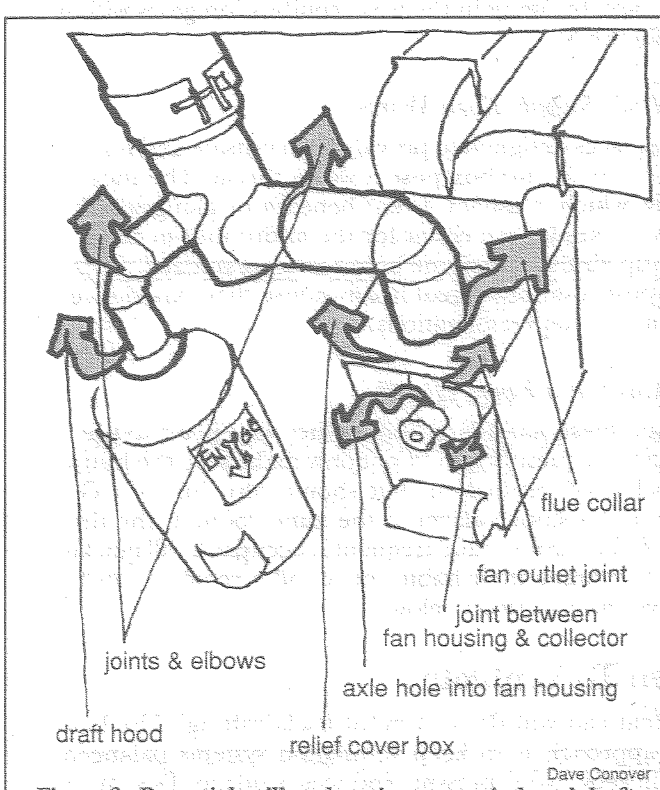


Figure 2. Potential spillage locations on an induced-draft furnace and water heater.

Sealed Combustion And Condensing Units

Many installers lately opt for expensive sealed-combustion and condensing furnaces. Based on a few tests, I think most of these designs are virtually immune to spillage problems if properly installed, even with house depressurization as high as 50 Pa. They are much more reliable than even a few years ago. But the cost is hard to justify, especially in energy-efficient houses where heat loads are low and the extra efficiency won't save many heating dollars.

Power Venters

An attractive alternative to installing an expensive induced-draft or sealed-combustion furnace unit is to install a conventional unit and vent it with a "power venter kit." Such a kit lets you vent the furnace through any convenient external wall rather than a vertical chimney flue. For instance, it can be a horizontal "flue" of ductwork that exits a basement wall. The key is the fan at the flue's end which maintains a negative pressure inside the flue. This will reliably pull exhaust out. The water heater can be vented through the same power venter. (Code acceptance of these kits varies tremendously, so check with your local jurisdiction.) A power venter helps to eliminate stand-by losses and, used this way, should only slightly increase fuel consumption rates over mid-efficiency appliances.

Power venters offer many advantages. You have a single fan and a short flue, all easily accessible for monitoring and maintenance. (This greatly decreases the chance of leakage.) You can buy a cheaper, more durable and reliable water heater or furnace, and you can save the cost of a vertical chimney.

The units cost between $200 and $400 and come as a kit with controls and color-coded wiring included. The average gas fitter can install one without previous training. Two companies make them—Field Controls Co. and Tjernlund Products Inc. Field makes a unit that mounts outside the house which ensures that any leakage from around the fan housing can't spill indoors.

Oil Furnace Spillage—and Solutions

The most toxic by-product of oil combustion is sulfur dioxide (SO_2) which, like the NO_2 from gas furnaces, is an acid gas that damages lungs. Fortunately SO_2, unlike NO_2, carries a strong odor that makes even small quantities easily detected.

Delayed Action Solenoid Valves

To protect against spillage from a conventional oil burner, the burner should be fitted with a *delayed action solenoid valve.* This delays the flow of oil to the combustion chamber for about three to six seconds after the burner blower starts, giving the air-flow within the burner time to set up a draft. This ensures that the oil is burned more completely, which reduces sooting and backdrafting, and also increases efficiency.

Delayed action solenoid valves cost under $100, and the increase in efficiency will pay back their cost within a couple of years. The flue pipe should have a high-quality barometric damper that is balanced and lubricated every year. Since even the best dampers leak, you should mount a smoke alarm on the ceiling directly over the damper to give warning if gases do spill for more than a few seconds at start-up.

High-Pressure Oil Burners

A better approach is to forsake the conventional oil burner for a *high-pressure* oil burner. A high-pressure oil burner forces combustion air into the combustion chamber under pressure, so that the furnace burns with less excess air. This allows you to have a smaller chimney with less heat loss and higher efficiency. These units also withstand pressure changes up to 10 Pa, preventing backdrafting and blow-outs within a normal range of chimney pressure fluctuations. They don't cost much more than conventional systems, and they eliminate the need for a barometric damper altogether. They also burn very cleanly. I've checked chimneys on these furnaces four years after installation and found them perfectly clean. Make sure to seal both the furnace or boiler and the flue pipe airtight at all joints.

Fireplaces—Serious Hazards

Fireplaces number fewer than furnaces, but their backdrafting record is worse. My 1986 field monitoring of fireplaces indicated that virtually every fireplace backdrafts or spills at least once per year, and that the typical unit spills for 1% to 2% of its operating time. This will happen most commonly at start-up and during stoking, and less often as the fire burns down. (This is less true for wood stoves, because their smaller, better-insulated flues are more resistant to pressure-induced spillage.)

Since fireplace spillage contains poisonous gases such as CO and cancer-causing substances such as benzene, backdrafting *always* poses a serious health hazard. CO concentrations in fireplace combustion gases run far above health limits, and they get worse at the end of burn, when backdrafting is most likely. From a rational point of view, the conventional fireplace doesn't belong in a modern home.

Of course, decisions about fireplaces are seldom rational. Since you can't know whether occupants will use a fireplace every day or only on Christmas, you must account for the worst case scenario, which is constant use.

Fireplace Solutions

Airtight Fireplaces Not The Answer

"Airtight" fireplaces—with airtight doors to the indoors and make-up air supplied directly from outdoors to the firebox—sound promising. Unfortunately, these designs depend heavily on the tightness of the fireplace doors, which fireplace manufacturers have yet to make airtight. As a result, when a house is depressurized by an exhaust fan or other force, these fireplaces—with pressurized outside air behind them and imperfect seals in front—act essentially as big make-up air ducts. Air comes from the outdoor fireplace supply, through the fireplace, and into the house, bringing in the toxic combustion gases with it (see Figure 3).

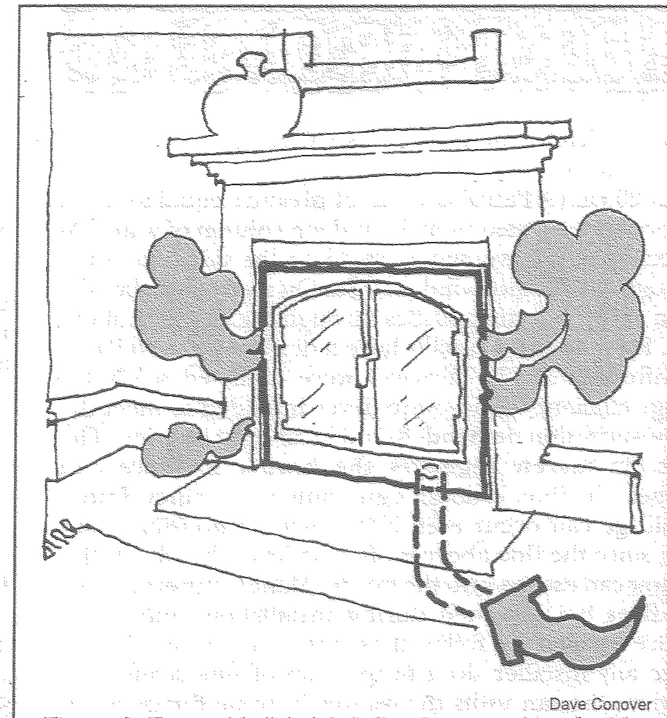


Figure 3. Even with "airtight" fireplaces equipped with outside air feeds, outside air can be pulled into the house through unsealed doors.

Dual Air Supply Even Worse

Fireplaces designed to provide both outside and household air to the firebox pose a worse threat. The indoor supply, which is usually a vent beneath or alongside the doors, makes it even easier for the entire unit to act as a make-up air duct when the house is depressurized. These units pose a serious threat in any house that experiences even minor depressurizations.

An Alarm For Every Hearth

Given these hazards, a homeowner who plans to use a fireplace frequently should not only make sure the house has balanced ventilation, but should also install a CO alarm and a smoke alarm in the same room as the fireplace. If the alarms sound frequently, occupants will quickly learn to change their habits, or install a reliable ventilation system, described below.

When To Ventilate

What can you do to prevent backdrafting? The best approach is to keep ventilation systems balanced and thereby avoid pressure-induced spillage. Design or retrofit a house to let fresh air intake match peak forced exhaust, and you'll avoid backdrafting.

As a rule of thumb, you should provide additional fresh air intake to balance any single exhaust fan that blows more than ½ air change per hour (ACH). For example, in a 12,000 ft² house (a 1,500 ft² house with 8-foot ceilings), a 100 cfm exhaust fan would be the maximum unbalanced exhaust permitted, because such a fan blows 6,000 ft³ per hour (100 cfm x 60 minutes). You can roughly figure a house's volume by multiplying its floor area by 8, assuming the ceilings are about 8 feet high.

The main problem with this method is that predicting the actual airflow from exhaust fans is almost as tricky as guessing how tight a house will be. Manufacturers provide air delivery ratings, but actual flows vary depending on how much restriction is created by ducts, grills, screens, and louvers, and how tight the house is. We recently tested all the ventilation devices in 200 houses. The measured airflows generally ran at about half the ratings. So you can usually safely figure than an exhaust fan actually moves about half its advertised rate.

Combined use of two or more smaller exhaust fans can cause problems. For example, a range hood, bathroom fan, and clothes dryer operating at the same time can produce up to 285 cfm in exhaust and a depressurization of 5 Pa or more. Because these events are infrequent and of short duration, however, they can usually be tolerated.

After construction or retrofit, you can run a test to provide more precise data that will indicate whether balanced ventilation is required. It takes only a few minutes and gives you hard information on which to base your ventilation decisions. (See "A Simple Chimney Backdrafting Test.")

Supplying More Air

How do you meet the need for increased air supply? You can get into heat recovery ventilators, air-to-air heat exchangers, and the like, but there are at least two ways that are effective and much simpler.

Interlocking Supply With Exhaust

One way is to install an "interlocked" air supply fan tied electrically to any exhaust fan(s) likely to depressurize the house. You simply wire the intake fan so that it comes on whenever the exhaust fan is turned on. Some of the fans used for sub-slab radon control work well.

Because even tight houses leak internally, such a supply fan can go virtually anywhere and still deliver the needed make-up air. It's usually best placed where the cool air will cause the least discomfort, so basements and utility rooms are obvious candidates (see Figure 4). Or you can run ductwork through the basement and deliver the make-up air to more than one room. The ducts will warm the air slightly and distribute its impact evenly. Builders in the coldest parts of Canada use Sonotubes instead of ductwork.

A Simple Chimney Backdrafting Test

Detecting Depressurization

In general, houses with chimneys or furnace flues should avoid depressurization in excess of 5 Pa. To measure the amount of depressurization that will occur under "worst case" situations in a given house, follow the checklist below. You will need a Magnahelic-type pressure guage, accurate within a low range and with a resolution of 1 Pa or less. Several companies make such pressure gauges, including Dwyer Instruments (which makes the Magnahelic) whose models of this type start at $43.

1. Prepare and calibrate the equipment.
- Turn off all fans.
- Turn off furnace and water heater.
- Close windows and exterior doors.
- Close interior doors leading to perimeter and basement rooms.
- Close fireplaces and wood stoves.
- Set up pressure gauge close to the chimney or flue you are concerned about.
- As per the gauge manufacturer's instructions, extend a hose to a sheltered position outdoors to get a pressure sampling there.
- "Zero" the pressure gauge.
- Observe normal fluctuations in pressure due to wind. If they are greater than 2 Pa, wait for a calmer period to do the test.

2. Conduct the test and record the pressure drop.
- Operate all exhaust fans (as well as any interlocked supply air systems) one at a time.
- Record level of house depressurization measured by the gauge.
- Operate any other fans that may be imbalanced, such as heat recovery ventilators, furnace blowers, etc.
- Record those levels of house depressurizations.

This will give you the basic depressurization levels you need. If a depressurization exists, you can try to locate the site of any leakage using the following test.

Locating Leakage

Operate all the vented combustion appliances one at a time. While you have this depressurization in effect, check for flue gas spillage near the furnace, using either a smoke tube that creates "cool" colored smoke or a CO_2 gas analyzer.

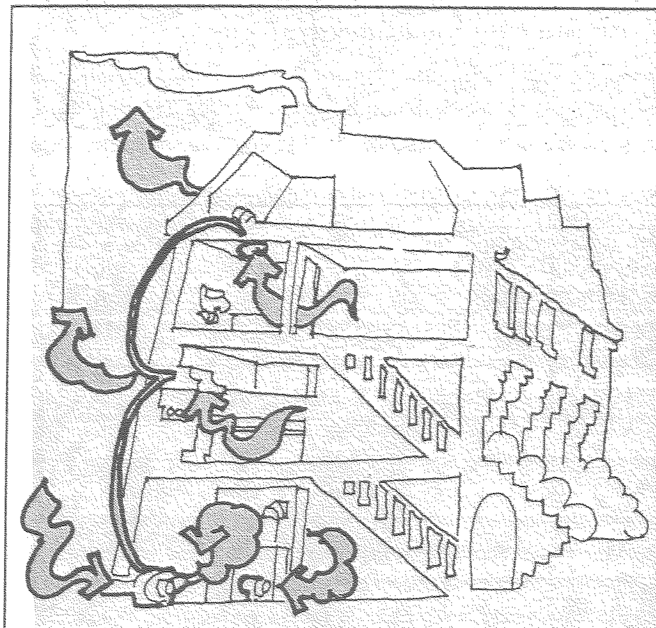
Clean-up

Return house to condition in which it was found—reset thermostats, turn off hot water taps if running, switch off furnace blowers and exhaust fans, etc.

For a more complete description of this test, contact the Canadian General Standards Board, 9C1 Place Portage, Phase 3, 11 Laurier St., Ottawa, ON, K1A 1G6, Canada. Tel: (613) 965-0400. Ask for Standard 51.71.

Interlocking Exhaust With The Thermostat

An alternative approach—seldom used but effective—is to interlock the exhaust fan(s) with the house thermostat, so that turning *on* the kitchen fan, for example, switches *off* the thermostat, preventing the furnace from operating. This is even cheaper than using a supply fan. It



Dave Conover

Figure 4. Interlocking supply with exhaust: electric wiring links the operation of the intake and exhaust fans. Cool air supplied through the basement causes less discomfort to the occupants.

doesn't supply fresh air, but it does make sure the make-up air won't be taken out of the furnace or flue. Its main drawback is that it doesn't provide a total solution if the house also has a spillage-prone water heater or fireplace chimney.

The Folly Of More Passive Supply

One seemingly obvious solution to increasing air supply is to install a larger make-up air opening or another "combustion-air" duct. Unfortunately, passive air supply rarely does the job. Or rather, it does it too crudely. For the typical house with an exhaust flow of 235 cfm, you would need an opening of 93 in^2 to avoid excess home depressurization—that is, a hole 9 x 10 inches. Double that size if, as is almost certain, you'll be using a screened and louvered inlet. Such massive openings inevitably get covered up by the house's chilly, incredulous occupants.

Connecting the make-up air supply to a return air plenum leading directly to the furnace may avoid such tampering, but this leads to a slew of other problems: high heating costs, cool drafts, condensation on furnace heat exchangers, and even frosty door hardware in freezing weather. (Using an automatic damper on make-up air openings can avoid some of these problems, assuming you can find a damper large enough.)

Despite these drawbacks, codes often require some type of passive air opening to supply combustion air. But in limiting their attention to combustion air rather than total make-up air requirements, the codes miss the point. Almost any furnace will be able to draw sufficient combustion air through leaks, even in tight houses. The issue that should be addressed is not whether appliances have sufficient combustion air, but whether a house has sufficient make-up air to prevent backdrafting. ■