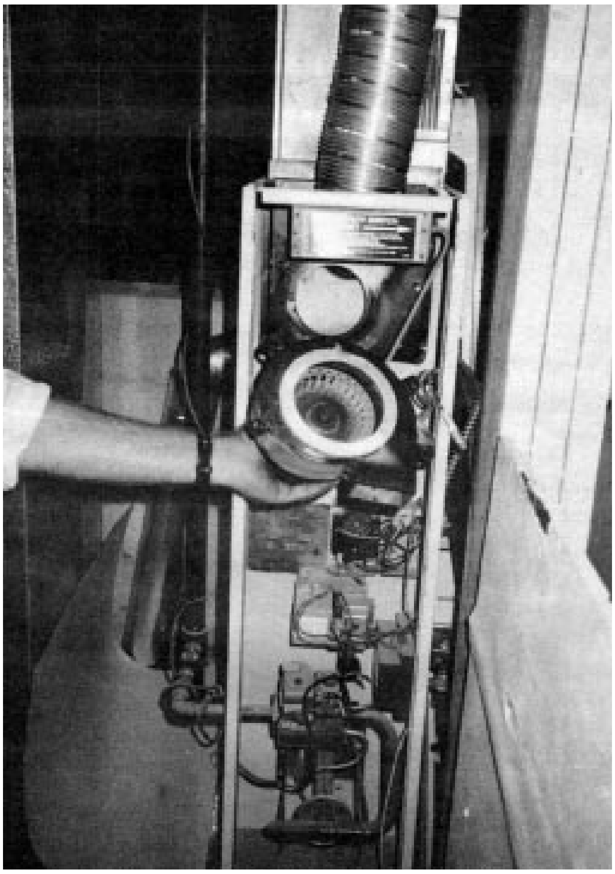
Backdrafting Causes & Cures

To keep exhaust gases going up the chimney, make sure the house can inhale as fast as it exhales

by Sebastian Moffatt



Induced-draft furnaces, such as the one above, are not safe from backdrafting as is commonly thought. In this case, because of a misaligned blower gasket (center) and unsealed flue collar, gases high in carbon monoxide were spilling into the house.

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 chimney flues, 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's living space.

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.

Tighter Housing Part of the Problem

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 the northern U.S. is following suit. 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 it is 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.

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 can be deadly.

Gas Furnace Problems

A 1984 survey of hundreds of houses suggested that 10% to 15% 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) levels above the norms recommended for indoor air, but seldom above what might be considered a health limit.

Natural gas combustion exhaust can contain nitrogen oxides, such as nitrogen dioxide gas (NO_2), which can damage lungs. Fortunately, NO_2 is unstable and is usually neutralized or diluted before it pollutes 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 stovetop exhaust.

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 through regular maintenance, such as a furnace tune-up and spillage check every two to five years by qualified service people.

For most homeowners, then, 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.

To give a little extra piece of mind, you can invest in a gas detector or alarm. A "dot" detector, such as that made by Aptech Detectors (547 Courtenay Ave., Ottawa, ON K2A 3B4, Canada: 613/837-4470), installs near likely spillage sites on furnaces or water heaters and changes colors when exposed to hot gases — usually from 138° to 160°F. These require frequent checking to be of any value.

At least two companies make CO alarms that blare like smoke alarms. Asahi Electronics (30 Alden Road, Unit 4, Markham, ON L3R 2S1, Canada; 416/477-3320) makes both battery-powered and hard-wired models for $89.95. Another manufacturer is Quantum (11211 Sorrento Valley Road, Suite D, San Diego, CA 92121; 619/457-3048), which 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 or *I.D.* 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 I.D. furnace has a little fan

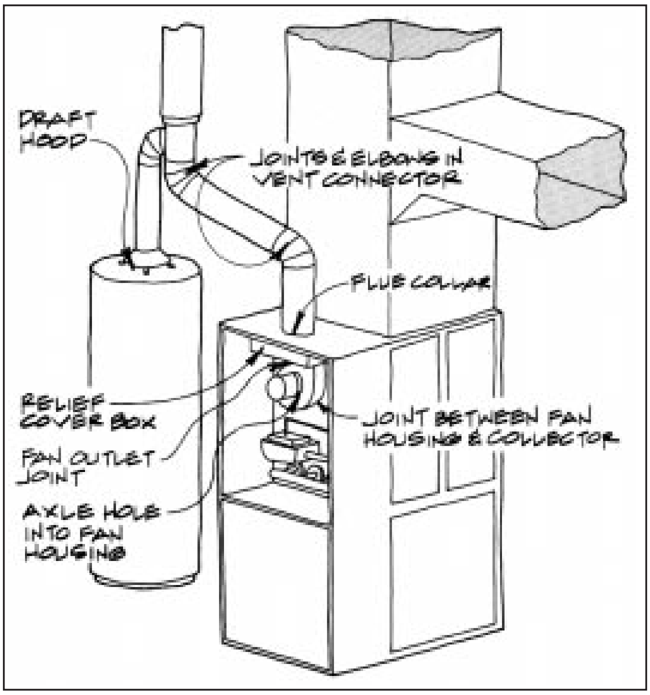


Figure 1. *Potential spillage locations on an induced-draft furnace.* *Even induced-draft furnaces have a surprising number of potential spillage sites. The so-called "spillage switches" on these units will shut off the furnace if the chimney is completely plugged, but they generally fail to detect the backdrafting or spillage common in normal use.*

in the flue that induces a small draft to overcome the added resistance of the more efficient heat exchanger.

Theoretically, these furnaces should be able to withstand a normal range of house depressurization — up to about 20 pascals. (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 pascals; on a very cold day, the warm air in your attic pushes through the cracks at about 3 pascals; hot chimneys usually have a draft of 20 to 30 pascals.)

Unfortunately, I.D. furnaces were designed solely for energy efficiency. They were never intended to meet the depressurization demands found in airtight 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. The 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 (see lead photo). Four of every five I.D. furnaces I tested showed continuous spillage around the induced-draft fan housing and axle, even without house depressurization (see Figure 1).

Induced-draft water heaters have the same shortcomings. Resist the temptation to install a conventional, natural-draft water heater next to an I.D. furnace and "Y" the two units into the same flue, as this makes both appliances more susceptible to backdrafting problems.

Some minor design modifications, already underway, will probably fix these problems. Eventually, I think we'll see a test for I.D. furnaces to certify that they can perform without spillage within a normal range of house depressurizations. But until then, let the buyer beware.

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 pascals. 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 can be a better option. 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 (see Figure 2). For instance, it can be a horizontal "flue" of ductwork that exits a basement wall.

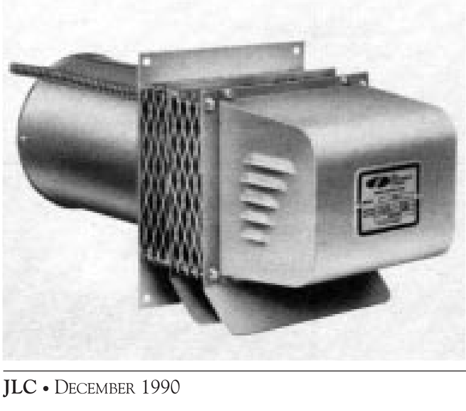


Figure 2. *Add-on power venters can help prevent backdrafting by pulling furnace or water heater exhausts out of the house. The Field Controls model, shown at left,, typically vents out a side wall.*

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; check with your local jurisdiction.) A power venter helps to eliminate stand-by losses and 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 Company (2308 Airport Road, Kinston, NC 28501; 919/522-3031) and Tjernlund Products Inc. (1601 9th St., White Bear Lake, MN 55110; 612/426-2993). Field makes a unit that mounts outside the house; the external location ensures that any leakage from around the fan housing can't spill indoors.

Backdrafting in Oil Furnaces

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.

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 ignition, giving the airflow 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 values cost under $100, and the increase in efficiency will pay for them 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.

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 ten pascals, and this prevents backdrafting and blowouts 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.

A Simple Chimney Backdrafting Test

In general, houses with chimneys or furnace flues should avoid depressurization in excess of five pascals. 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" pressure gauge accurate within a low range and with a resolution of one pascal or less. Several companies make such pressure gauges, including Dwyer Instruments (P.O. Box 373, Michigan City, IN 46360; 219/872-9141), which has models of this type starting at $43.

For a more complete description of this test, obtain a draft copy of the Canadian General Standards Board Standard 51.71, available from Canadian General Standards Board (9C1 Place Portage, Phase 3, 11 Laurier St., Ottawa, ON K1A 1G6, Canada; 613/956-0400).

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 two pascals, wait for a calmer period to do the test.

2. Conduct the test and record pressure drop.

- Operate all exhaust fans (as well as any interlocked supply air systems), one at a time.
- Record level of house depressurization as measured on 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 spillage using the following test:

Leakage Test

- 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.

—S.M.

Fireplaces

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 one to two percent 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.

Airtights 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 the toxic combustion gases with it.

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 such as that described later in this article.

Testing for and Preventing Backdrafting

With airtight furnaces and fireplaces so elusive, what can you do to prevent backdrafting?

The best approach is to keep ventilation systems balanced and thereby avoid pressure-induced spillage: Design a house that lets fresh air intake match peak forced exhaust, and you'll avoid backdrafting.

When to ventilate. As a rule of thumb, you should provide additional fresh air intake to balance any single exhaust fan that blows more than 1/2 air change per hour. For example, in a 12,000-cubic-foot house (a 1,500-square-foot house with 8-foot ceilings), a 100 cfm exhaust fan would be the maximum unbalanced exhaust permitted, because such a fan blows 6,000 cubic feet per hour (100 cfm x 60 minutes). You can roughly figure a house's area by multiplying its square footage by 8, assuming the ceilings are about 8 feet high.

The main problem with this method is that predicting the actual air-flow 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. We recently tested all the ventilation devices in 200 houses; the measured air-flows generally ran at about half the ratings. So you can usually safely figure that 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 pascals or more. But these events are infrequent and of short duration, so they can usually be tolerated.

The "Chimney Backdraft Test." After construction you can run a more exact test to see if balanced ventilation is required. This test is described in "A Simple Chimney Backdrafting Test," (previous page). It takes only a few minutes and gives you hard information on which to base your ventilation decisions.

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. 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.

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 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 square inches to avoid excess home depressurization.

From a rational point of view, the conventional fireplace doesn't belong in a modern home. But decisions about fireplaces are seldom rational.

Ninety-three square inches is a hole 9x10 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. ■

Sebastian Moffatt is the owner and manager of Sheltair Scientific Ltd., a Vancouver-based company that specializes in developing technology and testing buildings for health, safety, comfort, and energy efficiency.