Putting Pressure on Building Codes

by David Brook

House depressurization is a ubiquitous, dangerous problem. As regional mechanical codes move toward consolidation into one International Mechanical Code, now is the time to add a performance testing requirement for house depressurization.

"Sure, privacy can be an issue—but the pressure balance is perfect!"

Last winter, in Oregon's Willamette Valley, a family was spending their first season in a new custom colonial-style house. After enjoying a fire one evening in their living room fireplace with its handsome exterior chimney, they closed the glass fireplace doors and went upstairs to bed, closing their bedroom doors for the night. They awoke several hours later to a house full of wood smoke. No one was hurt, but the homeowner was shaken. The builder tried to fix the problem but couldn't find the cause. Others were called in, until finally Bryan Boe of the Oregon State University Extension Energy Program identified the source of the problem using standard house diagnostic procedures (see "User-Friendly Pressure Diagnostics," *HE,* Sept/Oct '94, p.19).

The house was built to current Oregon building code, but it still had problems. During the night the forced-air heating system cycled on. Because the bedroom doors were closed, air flow to the central return registers was reduced. This depressurized the main area of the house, where the fireplace was located. As the fire died down, the exterior chimney cooled down and the draft weakened, until the depressurization was stronger than the chimney draft.

Such interaction between mechanical systems (including exhaust devices and forced air systems) and naturally vented appliances such as furnaces, water heaters, wood stoves, and fireplaces, occur all over the country. The occupants don't always get off with just a scare and a bad smell.

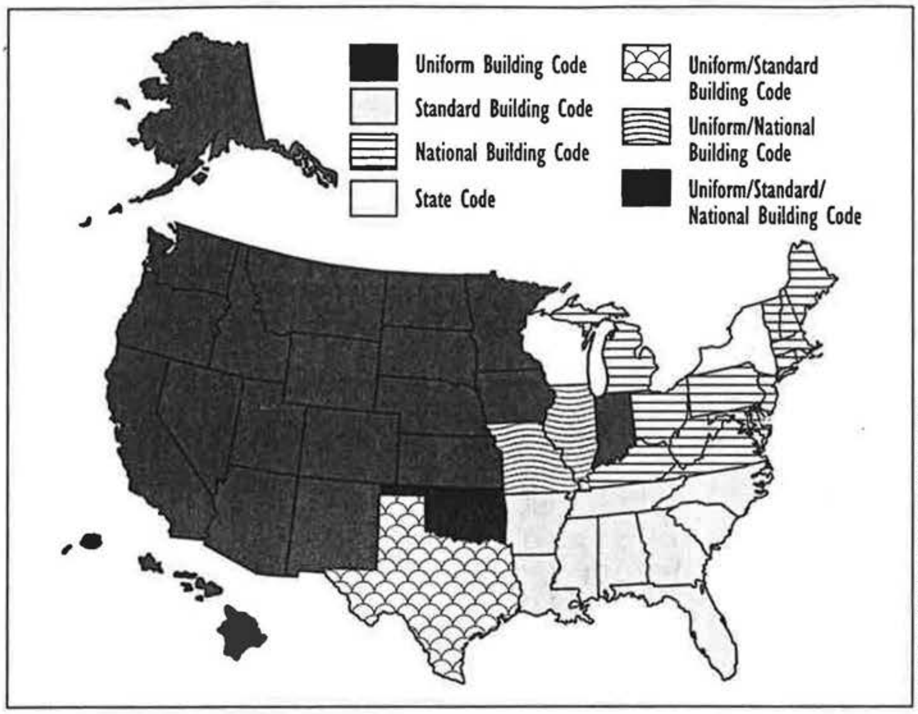


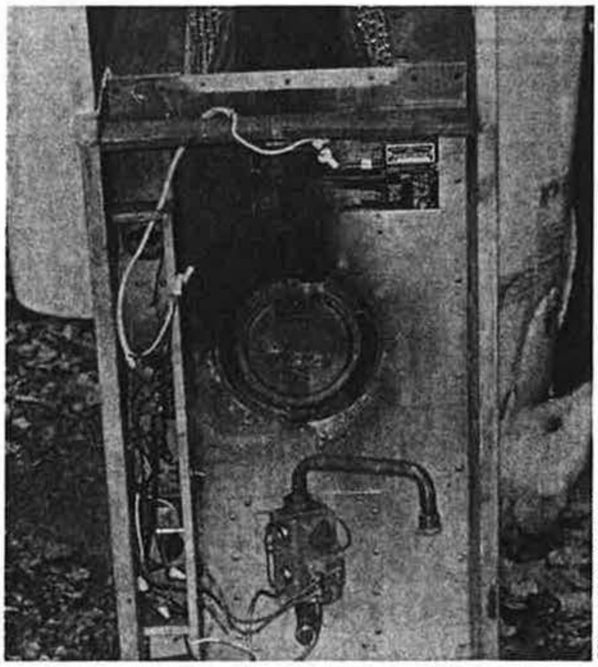
Figure 1. Areas of code usage. The United States is governed by a variety of major regional codes, local amendments, and in some areas, no codes at all. None of the major U. S. codes requires any house pressure testing. Mechanical codes are currently being combined into one International Mechanical Code, providing an opportunity for a national pressure testing requirement.

Depressurization can have less dramatic, but equally important, health and comfort effects. Depressurization can speed the entrance of radon and other soil gases into the house, and can increase air infiltration through the building shell.

How Common Is Depressurization?

With the increasingly widespread use of sensitive manometers (pressure gauges), we are learning more about the effects of house depressurization on venting systems of combustion appliances. Yet most home builders, HVAC contractors, building code officials, and even some wood stove installers, remain blissfully unaware of the these effects.

It is generally accepted that depressurization of –5 Pascals (Pa) or more can cause problems for natural draft appliances (see "How Do House Air Pressures Affect Chimney Draft?"). Continuous depressurization may be caused by forced air systems or whole-house ventilation systems. Less harmful intermittent depressurization may be caused by exhaust fans, clothes dryers, and other exhaust devices rated greater than about 160 cubic feet per minute (CFM).



Negative house pressures can cause a variety of dangerous situations including flame roll-out. Worst-case pressure testing can help assess whether a house has depressurization problems, thus allowing contractors to correct pressure imbalances.

There are no national data on the extent of depressurization problems. But various studies are suggestive. The Bonneville Power Administration's 1994 Residential Construction Demonstration Project in Oregon, Washington, Idaho, and Montana found that 14 of 25 new houses (56%) had combustion appliance zone pressures worse than –5 Pa. None of the houses were specially built to be airtight; they were all of construction similar to that of standard "code" houses.

Depressurization problems are not limited to new houses. Oregon's Springfield Utility Board studied 16 houses built between 1948 and 1993, and found that 6 of the houses (37%) had depressurization of over 5 Pa in the area of a fireplace or a wood or pellet stove. An industrial hygiene firm inspected houses for carbon monoxide (CO) problems in Chicago, Illinois, during the winter of 1994–95. Four of 28 houses tested (14%) had depressurization at or worse than –5 Pa.

Depressurization without Representation

While Canada and many other countries have national building codes, the United States is governed by a mishmash of major codes, local amendments, and in some areas, no codes at all. None of the major U.S. codes requires testing for building depressurization.

The Uniform Building Code (UBC) and its companion Uniform Mechanical Code (UMC), are issued by the International Conference of Building Officials (ICBO); UMC covers HVAC and plumbing. The Southern Building Code Congress International (SBCCI) issues the widely used Standard Building Code (SBC). Yet another code, established by the Council of American Building Officials (CABO) for one- and two-family homes is an attempt to incorporate the common aspects of the ICBO's and SBCCI's codes. Efforts are well underway to consolidate the HVAC and plumbing aspects of all three codes into the International Mechanical Code. Manufactured housing is covered by a national code issued by the

U.S. Department of Housing and Urban Development.

Frequently these codes make reference to, and often quote from, standards set by other nationally recognized groups, such as the American National Standards Institute (ANSI) or the National Fire Protection Association (NFPA), which has issued the National Fuel Gas Code. Most states adopt one of these codes and then add state amendments to cover what they feel is missing in the national codes.

Combustion Air

Building codes have long been concerned with providing sufficient fresh air to support combustion. One of the earliest standards for combustion air was issued in 1927 by the predecessor of the NFPA: "No appliance designed to burn gas at a rate greater than an ordinary lighting burner shall be installed in a room that is not adequately ventilated." Specific requirements for cutting holes to connect confined spaces to areas with "adequate infiltration" did not appear until 1950 in the National Fuel Gas Code.[1]

Today, all U.S. codes detail procedures for determining whether appliances require additional combustion air if located in "confined spaces" or in buildings with "unusually tight construction," and they specify how large the holes need to be. However, they are short on ensuring that things will happen as intended. None of the codes give house air pressures any more than a passing reference.

For example, CABO advises that chimneys and vents "shall be constructed and installed to develop a positive flow to convey combustion products to the outside atmosphere"[2] and that "air requirements for the operation of exhaust fans, kitchen ventilation systems, clothes dryers and fireplaces shall be considered in determining the adequacy of a space to provide combustion air."[3] No guidance is provided to help determine whether a space is "adequate." Ducts shall be made "substantially air tight," using sealing techniques that include foil tape and mastic, but there is no requirement to verify that ducts meet any specified level of tightness or that air flows are balanced. Allowing building cavities to be used as ducts, meanwhile, virtually guarantees duct leakage in basements, where combustion equipment is likely to be located. CABO does not address the central issue in the Oregon mystery—unbalanced air flows when interior doors are closed, obstructing air flow from supply registers to return grilles. CABO does recommend supplying additional combustion air for "unusually tight construction." However, by CABO's definition, virtually every house constructed today is unusually tight!

The Standard Building Code specifies that "return air may travel through the living space to the return air intake if there are no restrictions, such as solid doors, to the air movement."[4] Perhaps builders will offer a house without interior doors to meet code? The code even "helpfully" provides specific CFM capacities for panned floor joists used as ducts, making life easier for HVAC installers who still use this flawed type of distribution.

The Uniform Mechanical Code also fails to deal with pressure. It requires exhaust fans larger than 350 CFM to receive make-up air from an opening a minimum of 6 inches in diameter.[5] (According to Canadian specialist John Gulland, author of the Hearth Products Association's *Reliable Chimney Venting Training Manual*, a 6-inch passive vent would be appropriate to supply about 50 CFM.)

The heart of the problem is that these codes address the problem of effective venting prescriptively, rather than with a performance test. As a result, they do not address the way the

How Do House Air Pressures Affect Chimney Draft?

Most gas or oil furnaces, boilers, and water heaters, as well as fireplaces and wood stoves, have *natural draft* venting, which depends on warmer temperatures in the chimney to create a draft that carries combustion by-products from the house. These systems have a draft diverter, barometric damper, or dilution port at the base of the chimney, which is open to the house at all times (see "Fireplaces: Studies in Contrasts," *HE* Sept/Oct '94, p.27).

The strength of the draft depends on the temperature difference between the chimney and outside, on air flow around the top of the chimney, and on air pressures created inside the house. Many people are familiar with fireplaces that have difficulty getting draft established until the chimney is warmed up, or with wood stoves or fireplaces that back-puff when the wind blows from certain directions. What has only recently been recognized is the powerful interaction of fans and other mechanical systems with chimney venting. (See "Backdrafting Causes and Cures," *HE* May/June '91, p. 30.)

House air pressures are affected by natural forces such as convection, or hot air rising inside the house (sometimes called the stack effect—the same driving force the chimney utilizes). They can also be influenced by mechanical systems, including exhaust fans for bathrooms, kitchens, or clothes dryers, and ducted heating systems, such as heat pumps or furnaces when the air handler operates. Air leaks in ducts cause unbalanced air flows between the return side and the supply side. Leaks on the supply side may cause depressurization where the return registers are located. Leaks in return ducts located near a gas or oil furnace (in a basement, for instance) will depressurize that area. In many forced air systems, the only return registers are located in a central part of the house with supply registers in each room. When interior doors are closed, air flows in these duct systems can become significantly unbalanced.

If a naturally vented combustion appliance is located in an area of depressurization, the equipment may have difficulty establishing or maintaining draft, and combustion by-products will enter the house rather than going up the chimney. This effect depends on the severity of the depressurization and strength of the draft. Failure of a chimney to establish draft within 30 seconds to one minute is called *spillage;* failure that lasts longer than 1 to 5 minutes is called *backdrafting*. Such problems can occur with wood, gas, propane, and oil systems.

Each venting system has its own threshold of depressurization that causes backdrafting. Extensive research in Canada has established -5 Pa as a reasonable limit for most equipment.

air flows through the holes once they are cut. Anyone familiar with house diagnostics could describe a situation where adding holes to meet combustion air requirements could make the problem worse rather than better.

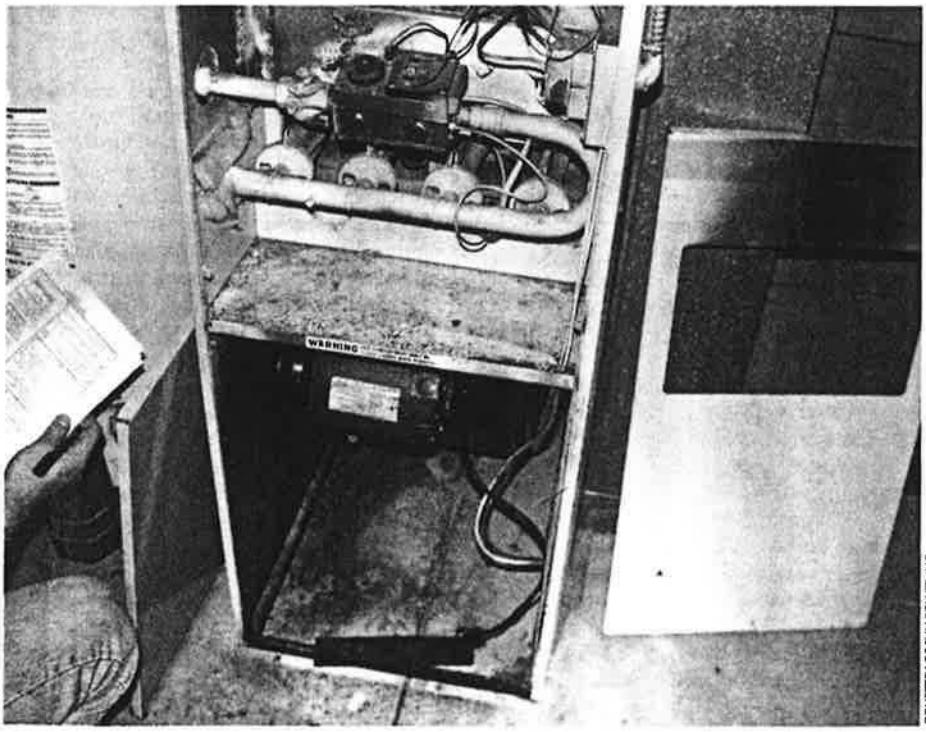
Although most HVAC installers, code officials, and builders don't know about it, one section of the 1995 CABO actually refers to a sort of worst-case depressurization test. In Appendix H of the National Fuel Gas Code, Step 7 of the "Recommended Procedure for Safety Inspection" involves turning on exhaust fans and firing the appliance for five minutes and then holding a "match, candle or smoke from a cigarette, cigar or pipe" close to the draft hood. While the test does check sources of intermittent depressurization, potential continuous depressurization from the forced-air system is not tested.

Canada's Standard

As a result of extensive research on depressurization in the 1980s, the Canadian General Standards Board (CGSB) has a useful standard to refer to—"The Spillage Test: a method to determine the potential for pressure-induced spillage from vented, fuel-fired space heating appliances, water heaters, and fireplaces." The standard was adopted in 1995 and resulted from extensive research on venting by the Canada Mortgage and Housing Corporation. Most of the procedures described in the standard are familiar to any blower door operator who has done a worst-case depressurization test. The standard sets different limits for continuous and intermittent depressurization.

Unlike most worst-case tests used in the United States, the standard requires the use of a "fireplace simulator," a two-burner camp stove, for open fireplaces (those without glass doors). The standard limits depressurization to a range between -5 Pa and -20 Pa, depending on the category of equipment and associated venting system. The continuous and intermittent limits for most naturally vented equipment are -5 Pa.

In addition to referring to the performance test, Canada's 1995 National Building Code has two relevant prescriptive sections about depressurization. "Protection against Depressurization" requires that in dwellings with fuel-fired appliances vented through a chimney, "any mechanical air exhausting device, or group of devices, operated by a single control, with a net exhaust capacity greater than 75 liters/second (L/s) [160 CFM] shall be provided with make-up air ... by a supply fan rated to deliver not less than the amount by which the net exhaust rate of the device exceeds 75 L/s ... wired so that it is activated whenever the device is activated." The Canadian code also requires that "The return-air system shall be designed so that negative pressure from the circulating fan cannot: a) affect the furnace combustion air supply; nor b) draw combustion products from joints or openings in the furnace or flue pipe."[6]



COURTESY OF SUN POWER INC.

The dark soot visible on the door of this furnace is a sign of flame roll-out—a grave symptom of severe depressurization

Types of Venting for Combustion Appliances

vent. A passage used to carry the products of combustion from the appliance to the outdoors.

flue. A vent that uses *natural draft* to carry combustion products out of the living space.

natural draft or *gravity vent.* A vent system in which the flow, or draft, is caused by the natural buoyancy of the hot products of combustion.

forced, fan-assisted, or *mechanical draft.* A vent system in which the flow of combustion products is caused by the action of a motor-driven fan. Typically used on higher efficiency appliances where the products of combustion are not hot enough to provide adequate natural draft.

direct vent. An air supply and appliance venting system in which all air for combustion is obtained from outdoors and all gases are discharged outdoors.

vent-free or *unvented.* An appliance that releases its combustion products indoors (see "Unvented Gas Space Heaters: Drainless Sinks?" p.9).

induced draft. A furnace combustion system designed to maintain a negative pressure where the vent connects to the chimney, in order to control the amount of air in the combustion chamber for greater efficiency. Sometimes confused with *mechanical draft*, but *induced draft* does not force exhaust gases up the chimney nor overcome depressurization.

Source: *GATC Focus*, May, 1996. Published by the Gas Appliance Technology Center, a project of the Gas Research Institute.

Toward a U.S. Standard

The U.S. codes could require depressurization testing. (Most building codes already contain several performance tests; plumbing systems and gas piping must be pressure-tested before going into service.) A few jurisdictions have considered adopting the Canadian standard, including Fort Collins, Colorado. It was not included in the adopted code in Fort Collins for two reasons. First, there was little reliable data available to assess the frequency and severity of problems. Second, there were questions whether the Canadian "House Depressurization Limits" should be a universal standard. Instead, Fort Collins required combustion air ducts to be labeled as to their function, vowed to raise awareness of the issues among builders and subcontractors through training, and began comprehensive diagnostic testing of a sample of new homes to get local data.

There is concern that the Canadian standards may not be applicable in the warm climates of the southern U.S. To address this problem, the Gas Research Institute (GRI) has a multiyear research project to develop field test procedures. David Grimsrud of the University of Minnesota, who has been leading the GRI effort, says that such a procedure could eventually become a standard. He has carefully monitored venting systems to identify the factors that may cause problems. The current version of his test procedure examines the pressure of the vent or flue with reference to the room; worst-case depressurization tests typically measure room pressure with reference to the outdoors.

A single consolidated International Mechanical Code could eventually replace CABO, SBC, and UMC. Unless efforts to require a performance test begin soon, it is unlikely that future codes will be any smarter about depressurization than current ones. With such major changes taking place, this is an excellent opportunity to incorporate a depressurization testing requirement and protocol.

In the meantime, HVAC contractors, builders, code officials, health departments, and manufacturers and installers of large exhaust fans all need to be more aware of the hazards of depressurization.

David Brook is an extension agent with the Oregon State University Extension Service. He recently introduced an amendment to the Oregon State Code to require a worst-case depressurization test.

Notes

1. Theodore Lemhof, ed. *National Fuel Gas Code Handbook*, 2nd Edition. (National Fire Protection Association: Quincy, MA, 1992), p. 123.

2. Council of American Building Officials. *CABO One and Two Family Dwelling Code*. 1986 ed., Authorized ed. (Falls Church, VA: Council of American Building Officials, 1987), section 2101.2.

3. CABO section 2001.1

4. Southern Building Code Congress International. *Standard Building Code*. 1994 ed. (Birmingham, AL : SBCCI, 1994), section 517.2

5. International Conference of Building Officials. *Uniform Mechanical Code*. 1994 ed. (Whittier, CA: International Conference of Building Officials, 1994), section 706.

6. Canadian General Standards Board, *National Building Code* (Ottawa: CGSB 1995), Section 9.33.6.14.