Industrial Revolution

Every home makes compromises among different and often competing goals: comfort, convenience, durability, energy consumption, maintenance, construction costs, appearance, strength, community acceptance, and resale value. Often consumers and developers making the tradeoffs among these goals do so with incomplete information, increasing the risks and slowing the adoption of innovative products and processes. This slow diffusion negatively affects productivity, quality, performance, and value. This department of Cityscape *presents, in graphic form, a few promising technological improvements to the U.S. housing stock. If you have an idea for a future department feature, please send your diagram or photograph, along with a few, well-chosen words, to dana.b.bres@hud.gov.*

Reducing Appliance Backdrafting Risks With HVAC-Integrated Makeup Air Systems

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Abstract

Kitchens are often a significant source of indoor air pollution, and cooking byproducts should be vented to the outside, but range hoods should not be installed without taking certain precautions. Exhaust equipment, such as range hoods, may create negative pressure inside a house, resulting in backdrafting of combustion appliances. This scenario is particularly true because of modern construction practices that yield tight building enclosures and because of consumer demand for large range hoods. A properly sized and installed heating-, ventilation-, and air-conditioning-integrated makeup air system will alleviate building pressures and reduce the risk of backdrafting appliances.

With Americans spending roughly 90 percent of their time indoors, the quality of the indoor environment can have a profound effect on occupants' health. Cooking, particularly with unvented gas ranges, is the source of a variety of indoor air pollutants. Products of natural gas combustion include carbon monoxide, nitrogen dioxide, formaldehyde, and particulates. Nitrogen dioxide may cause eye, nose, and throat irritation and impaired lung function (EPA, 2012), and carbon monoxide may produce symptoms associated with oxygen deprivation. The food itself may also be a significant source of indoor air pollution, particularly in the form of cooking oil fumes (Wallace, Emmerich, and Howard-Reed, 2004).

In addition to the release of these pollutants, moisture released into the air from burning gas and boiling water may indirectly affect human health, because high indoor humidity levels facilitate mold growth. The Environmental Protection Agency recommends that homeowners maintain their dwellings at between 30 and 60 percent relative humidity to reduce the risk of mold growth. If moist conditions exist, mold growth may begin to occur within 24 to 48 hours, possibly resulting in health effects and symptoms including allergic reactions, asthma, and respiratory complaints (EPA, 2010).

Yik, Sat, and Niu (2004) reported amounts of moisture released from cooking various dishes, ranging from 0.055 pounds for noodles to more than 2.000 pounds for boiling soup. These numbers do not include the moisture released from the combustion of natural gas, which adds about 1.000 pound per hour for a 10,000 British thermal unit (Btu) burner set on high (TenWolde and Pilon, 2007). Cooking may not be the greatest overall source of moisture in a house, but it may contribute to high indoor humidity levels when combined with human and pet respiration, plant transpiration, showering, and wet foundations. In addition to affecting health, moisture may also affect the building negatively in terms of condensation on windows and the decay of wood-based building materials. Modern construction practices, which feature relatively airtight building enclosures for the purpose of energy conservation, may exacerbate concentrations of these pollutants.

To remove cooking-related air pollutants, builders, remodelers, and mechanical contractors generally install some type of range hood device. These devices frequently consist only of a circulating fan and a filter with no actual exhaust of indoor air to the outdoors. These filters remove some odors, but they have a limited ability to remove pollutants and do not remove heat or moisture from the living space. Other range hoods exhaust air, pollutants, and moisture to the outdoors. The industry-recommended ventilation rate is 250 cubic feet per minute (cfm) for a standard 30-inch range (HVI, 2013), but the installation of range hoods with exhaust rates in the range of 400 to 1,500 cfm is common.

Although a high-rate exhaust system might seem like an excellent solution for removing cooking-related indoor air pollutants, the system may create unhealthy or hazardous conditions by *backdrafting* appliances. In some instances, the negative house pressure induced by the exhaust system may be great enough to reverse the draft of combustion appliances, causing dangerous combustion products to spill into the living space. This spillage may result in unhealthy or dangerous levels of nitrogen dioxide and carbon monoxide and result in large amounts of moisture entering the house (about 1 pound per 10,000 Btu/hour).

The risk of backdrafting appliances is a function of the total building exhaust rate and house tightness. The total building exhaust rate is the exhaust rate of the kitchen exhaust system combined with the exhaust rates of other appliances that might be running simultaneously; for example, dryers, bath fans, and heating, ventilating, and air-conditioning (HVAC) duct leakage. These exhaust appliances will combine to induce a negative pressure in the house with respect to the outdoors. The degree to which the house will experience negative pressure also depends on the level of air tightness of the building enclosure. The tighter the house, the greater the resulting negative pressure from an equivalent rate of exhaust.

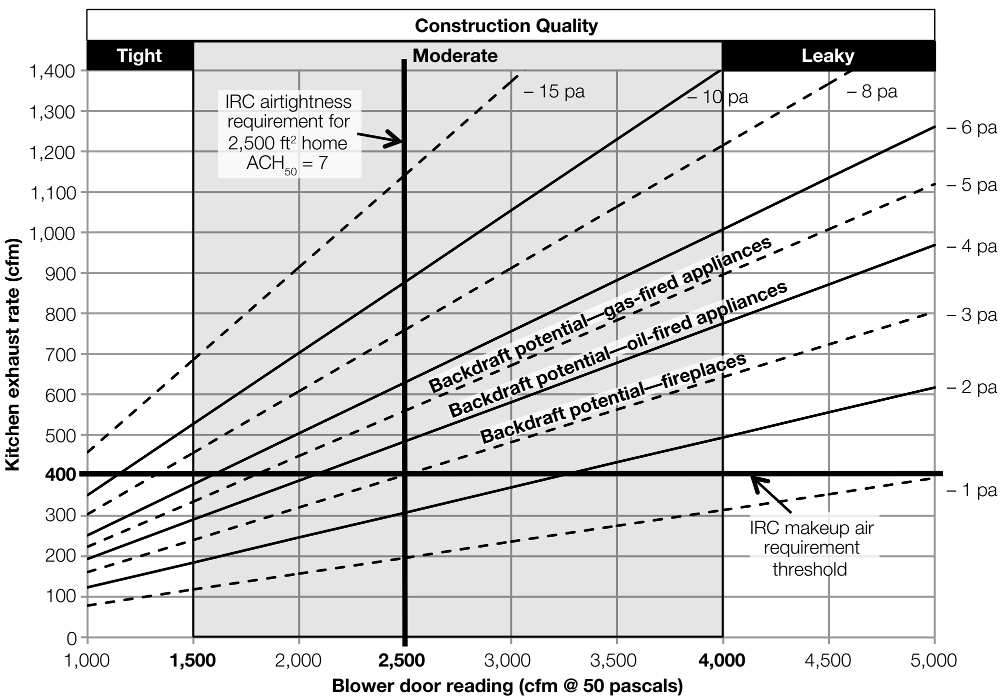
Exhibit 1 provides a reference for assessing the risk of backdrafting various combustion appliances under varying levels of house tightness and exhaust rates. The 2009 International Residential Code requires makeup air for range hoods with exhaust rates in excess of 400 cfm. At this exhaust rate, there is a risk of backdrafting a masonry fireplace in a house built to current construction standards. Even modest levels of exhaust can create risks in tight houses that contain combustion appliances. Similarly, very high exhaust rates may create risks even in relatively leaky houses.

If an installer determines that the operation of a kitchen exhaust system creates a backdrafting risk, the next step is to determine an appropriate means of providing makeup air. *Makeup air* refers to outside air that is brought into the house at a rate roughly equal to the exhaust rate. Properly installed makeup air systems will equalize the pressure inside the house and thereby alleviate the risk of backdrafting.

Makeup air systems fall into two main categories: engineered openings and HVAC-integrated systems. Engineered openings are simply glorified holes in the wall—when a damper in the opening

Exhibit 1

Induced House Pressures Under Various Exhaust Rates and House Tightness



ACH = air changes per hour. cfm= cubic feet per minute. ft² = square feet. IRC = International Residential Code. pa = pascals.
Source: Jellen, Wolfgang, and Turns (2012a)

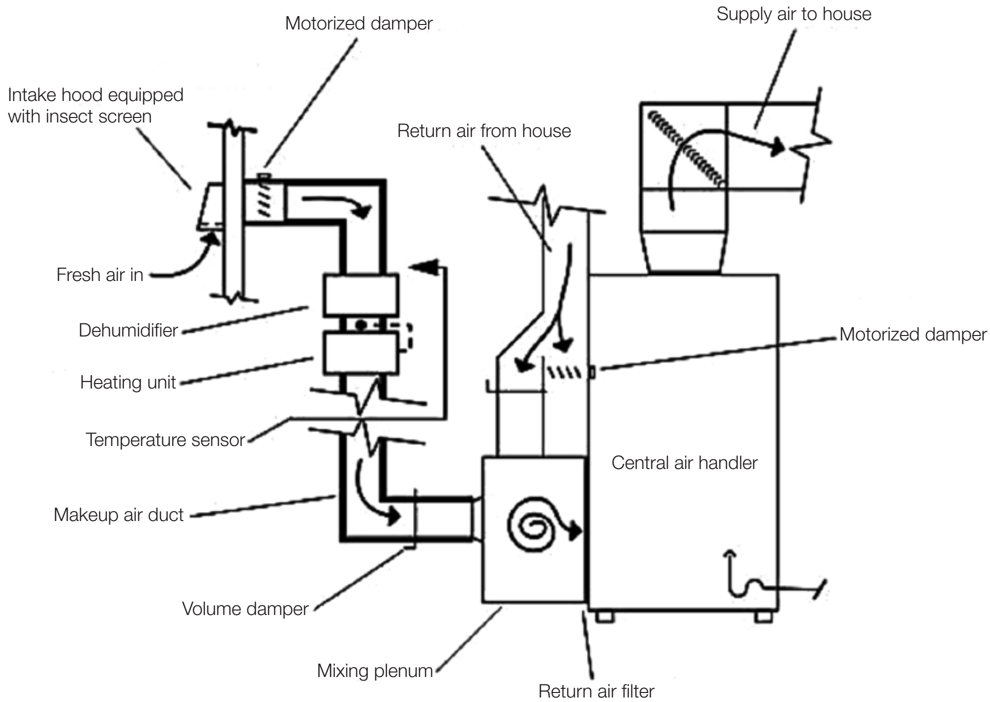
is put under pressure, it opens passively to let air in. Although appealing in their simplicity, engineered openings are effective only at relatively low pressures, and thus relatively low kitchen exhaust rates. With exhaust rates of about 150 cfm or greater and a 10-square-inch opening, the pressure required to let in a roughly equivalent amount of air is already greater than the pressure that could backdraft a masonry fireplace. In addition, there is no opportunity to heat or cool the incoming air, which can lead to occupant discomfort.

HVAC-integrated systems (exhibit 2) solve this problem by locating the air intake remotely from the kitchen and near the air handler. In this configuration, the air-intake damper is in a duct that connects an opening to the outside with the return air plenum of the HVAC system. The damper is electronically linked to the on/off switch for the kitchen exhaust system, thus opening automatically when the range hood is operating. HVAC-integrated makeup air systems allow for much higher rates of air intake and provide the ability to temper incoming air via the HVAC unit (when it is operating) or via a standalone duct heater or dehumidifier.

Another solution is to remove or not install any combustion equipment other than direct-vent equipment and ensure the living space is well-sealed from the garage or other potential sources of pollution. *Direct-vent*, or sealed combustion, equipment brings air into the system, burns the fuel,

Exhibit 2

Typical HVAC-Integrated Makeup Air System With Optional Heating Unit and Dehumidifier



HVAC = heating, ventilating, and air-conditioning.

Source: Jellen, Wolfgang, and Turns (2012b) and exhausts air back out with no communication with the indoor air. This equipment is not new, but most houses that use gas or propane as a fuel source have at least one piece of open combustion equipment.

This article highlights one of the challenges of designing a structure to achieve multiple goals. Achieving the goal of a more energy-efficient housing stock means building tighter homes, and building tighter homes means greater risks of indoor air-quality problems. Furthermore, the measures used to remove pollutants may create new risks such as backdrafting combustion appliances. This problem requires an integrated solution that considers a variety of factors, including house tightness, exhaust rates, building pressures, energy consumption, and occupant comfort, health, and safety.

Author

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Yik, F.W.H., P.S.K. Sat, and J.L. Niu. 2004. "Moisture Generation Through Chinese Household Activities," *Indoor and Built Environment* 13 (2): 115–131.

Additional Resources

Air Conditioning Contractors of America (http://www.acca.org).

Building Performance Institute, Inc. (http://www.bpi.org).

Green Building Advisor (http://www.greenbuildingadvisor.com).

Home Ventilating Institute (http://www.hvi.org).

Lawrence Berkeley National Laboratory (http://www.lbl.gov).

The Pennsylvania Housing Research Center (http://www.engr.psu.edu/phrc).