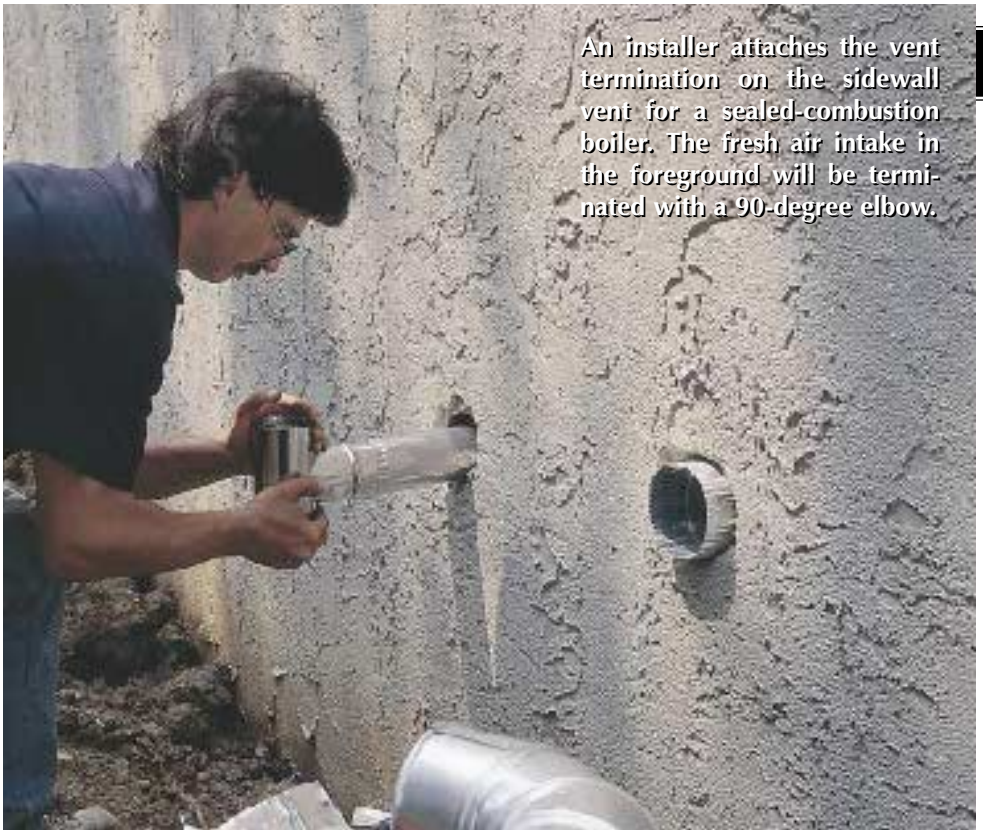
MAKEUP AIR FOR Combustion Equipment



An installer attaches the vent termination on the sidewall vent for a sealed-combustion boiler. The fresh air intake in the foreground will be terminated with a 90-degree elbow.

by Carl Saunders

Boilers, furnaces, and water heaters need adequate fresh air to function properly. Here's how to prevent problems.

Try breathing through a soda straw. It takes effort, and you'll probably get dizzy soon.

A fuel-burning boiler, furnace, or water heater can also end up gasping for air when installed in a very tight house or a confined space. The appliance won't get dizzy, but it can't burn its fuel properly — resulting in reduced efficiency, and possibly exposing occupants to harmful gases such as carbon monoxide.

A fuel-burning appliance needs a lot of air to burn properly. For example, a 100,000 Btu/h boiler or furnace needs 1,250 cubic feet of air per hour for proper combustion. With the exception of vent-free gas fireplaces and kitchen ranges, all gas- and oil-fired appliances are vented, using either fan-assisted venting or traditional atmospheric venting via a chimney.

Thanks to the natural buoyancy of hot flue gas — which rises rapidly up the vent pipe, just as a hot air balloon rises in the open air — vent pipes and chimneys suck flue gas out of appliances and suck in additional air to replace it. Here's the rub:

You must replace the same amount of air that rises up the vent, and the makeup air must flow to the burner as easily as the flue gas was vented.

Causes of Poor Draft

If a vent pipe has poor draft, the burner may perform poorly. There are several possible causes of poor draft:

An undersized, restricted, or blocked vent. Try to locate the appliances as close to the chimney as you can. Long horizontal vent runs, called "lateral piping," decrease the capacity of the vent (see Figure 1). The maximum length of lateral piping is listed on the vent capacity tables in the *National Fuel Gas Code*, as well as the tables provided by the vent pipe manufacturers.

A cold chimney. A cold chimney or vent will cool the flue gas and reduce its buoyancy. In some cases, this "cold stacking" is enough to allow the moisture in the flue gas to condense. Outside chimneys (chimneys exposed to the weather on three sides) are vulnerable to cold stacking, especially when a setback thermostat shuts down a heating appliance for several hours at night. To address the problems of cold stacking, the 1996 *National Fuel Gas Code* included new regulations covering the use of outside chimneys. In most cases, the new regulations require that an outside chimney have a metal liner with a surrounding air space, which allows a cold flue to come up to operating temperature as quickly as possible.

House depressurization. Under certain conditions, the indoor air pressure in a house may fall so low that it interferes with normal venting of flue gas (see "Warning: Building Depressurization May Be Hazardous to Your Health").

Downdrafts of wind. Wind can interfere with normal chimney venting, especially if the chimney is lower than the roof ridge.

Lack of makeup air. If the house is extremely tight, the heating appliance may be unable to suck in enough makeup air to allow complete combustion.

MAC/CEE

Figure 1. Avoid long horizontal runs of vent pipe, which can cool the flue gas and reduce the draft. This gas-fired water heater should have been located closer to the chimney.

Figure 2. A galvanized pipe (foreground) provides combustion air directly from the exterior to the burner of this sealed-combustion boiler. A separate galvanized vent pipe conducts the flue gas through the sidewall.

Spillage and Carbon Monoxide

The most dangerous effect of poor or negative draft is spillage, which is the entry of flue gas into the home. Flue gas can contain dangerous levels of carbon monoxide, which is odorless and poisonous. Carbon monoxide detectors are now required in many locations. It is a good practice to install one, whether or not it is required by your local code.

Methods of Venting

A boiler, furnace, or water heater can be vented either by atmospheric venting (also called natural draft or natural aspiration) or fan-assisted venting. In atmospheric venting, flue gases flow to the chimney — and ultimately to the outdoors — under

Warning: Building Depressurization May Be Hazardous to Your Health

Although atmospherically vented appliances work well in many applications, some contractors and energy experts are so concerned about the dangers of spillage and the potential for carbon monoxide poisoning that they recommend that only sealed-combustion appliances should be used in today's tighter houses.

When a house is significantly depressurized, flue gas can spill into the living space (see photo). According to Ken Tohinaka, senior energy specialist at Vermont Energy Investment Corp., the following appliances or conditions can contribute to house depressurization:

- ***Bath exhaust fans.*** Even small bath exhaust fans in the 50 to 75 cfm range can contribute to depressurization problems.
- ***Kitchen exhaust fans.*** Downdraft exhaust fans are especially powerful, with ratings from 325 cfm to 1,200 cfm.
- ***A competing fuel-burning appliance.*** A strong draft from a wood-fired or gas-fired fireplace, or even an oil-fired boiler, can depressurize a house enough to cause spillage in another appliance, such as a gas-fired water heater.
- ***Powered attic ventilators.*** These fans, which turn on automatically whenever attic temperatures rise above a set point, can suck air out of the conditioned space below. This occurs even when the gable-end vents or soffit vents are sized according to code, because leakage paths between the attic and the occupied space are common (see *Notebook*, 9/95).
- ***Unbalanced forced-air heating or air-conditioning systems.*** A house can be depressurized, for example, if a duct boot becomes disconnected from the main supply duct, allowing air from the duct to blow freely into the attic. The tighter the building envelope, the more likely it is that imbalances in the forced-air distribution system will change the house pressure.
- ***Other appliances that exhaust air to the exterior,*** such as clothes dryers or central vacuum cleaners.

A gas will tend to flow to a zone of lower pressure. If the house is so depressurized that the lower pressure in the house overwhelms the chimney draft, then the flue gas from a fuel-burning appliance will flow into the house instead of up the vent. Even when ducted exterior makeup air has been provided to the room with the fuel-burning appliance, strong exhaust fans can still depressurize the house enough to cause dangerous spillage. Since flue gas can contain carbon monoxide, spillage of flue gas can cause illness or death.

"When there is spillage, it's not a lack of combustion air that is the problem, it's house depressurization," says Don Fugler, senior researcher with Canada Mortgage and Housing Corporation in Ottawa. "Anyone considering installing a kitchen downdraft fan or an open masonry fireplace in a new house should avoid appliances with atmospheric venting."

MAC/CEE

Poor draft or house depressurization can lead to spillage of flue gas into the house. In this case, there is obvious evidence of spillage, since the backdrafting hot flue gas has melted the nearby pipe insulation.

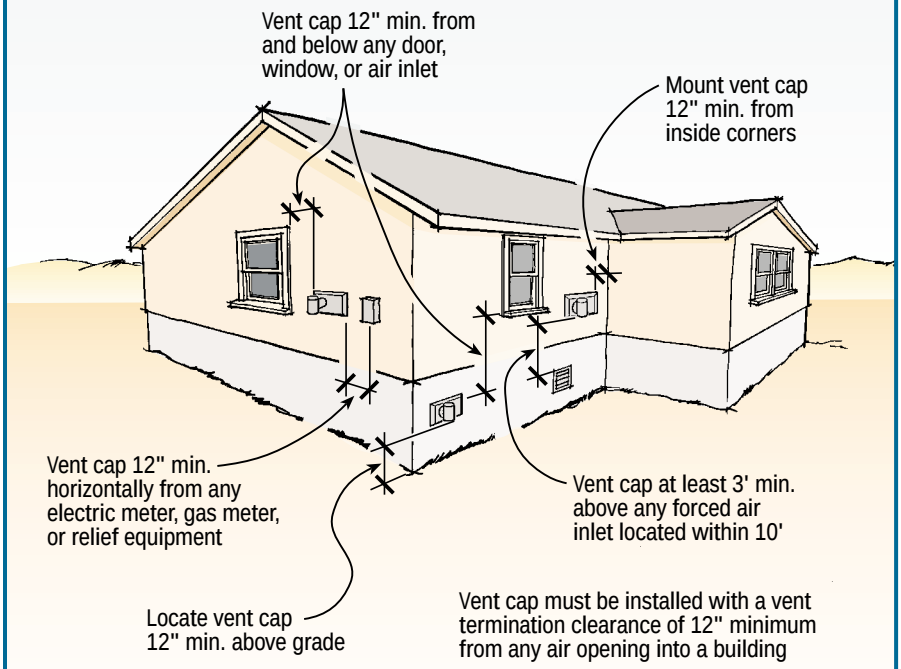
Gary Proskiw is a mechanical engineer in Winnipeg, Manitoba, specializing in residential energy issues. "All of the designs for combustion makeup air are formulated on the assumption that there is no wind," says Proskiw. "If the wind is blowing, and if the combustion air inlet is on the leeward side of the house, then the air inlet could be exhausting air rather than providing makeup air."

Proskiw is also concerned about the long-term reliability of ducted makeup air systems. "The biggest problem with combustion makeup air systems is, will the homeowner defeat them by plugging the duct or disconnecting the makeup air fan? How many people will leave a 6-inch, 8-inch, or 10-inch hole open in the side of their house once winter sets in and they can feel the wind howling through their basement?"

—Martin Holladay

Clearances for Wall Vents

Sealed-Combustion Appliance



Power-Vented Appliance That Is Not Sealed-Combustion

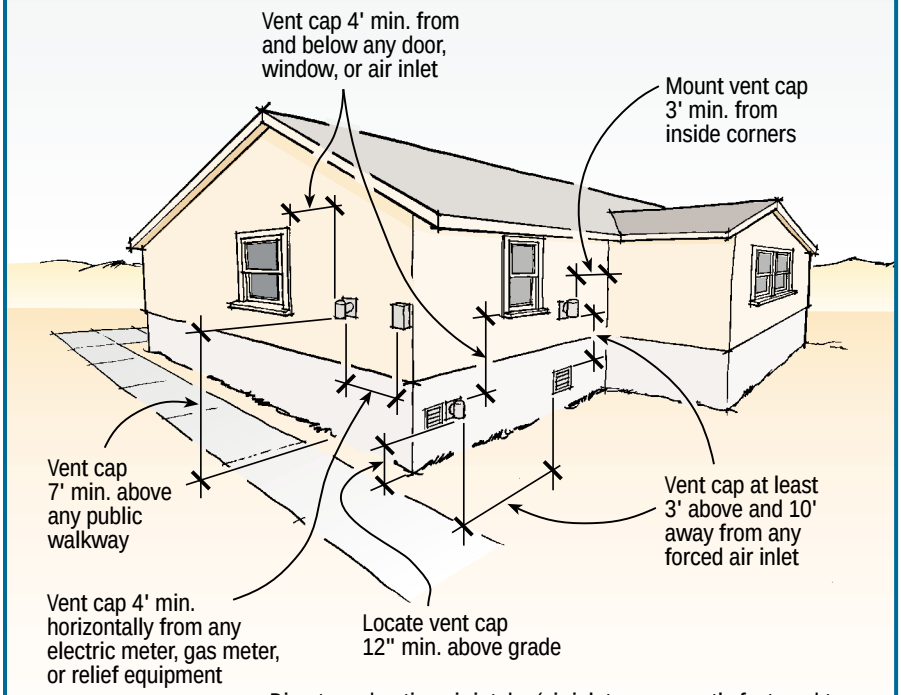


Figure 3. The required clearances between a sidewall vent and various other openings in a wall depend on whether or not the appliance is a sealed-combustion appliance. With a power-vented appliance that is not sealed-combustion, there is a risk that flue gas can be pulled back into the building through an open window if adequate clearances are not observed.

their own power. Until the 1980s, almost all residential fuel-burning appliances used atmospheric venting.

Fan-assisted venting, also called induced draft or forced draft, can use either a sidewall vent or a chimney. A boiler or furnace that has been designed with narrow flueways (to increase efficiency) often requires fan-assisted venting to help suck the flue gas out of the appliance.

Sealed combustion. Sealed-combustion appliances draw combustion air from the exterior directly to the burner (Figure 2, page 3).

Because the fuel is burned in an environment that is entirely separated from the interior air of the living space, sealed-combustion appliances are unaffected by pressure differences inside the building envelope, and are therefore the best choice for tight houses. Some sealed-combustion appliances draw air in by means of concentric pipes, with the smaller diameter vent pipe located within the larger diameter air supply pipe. Sealed-combustion appliances can discharge flue gas either to a side wall, or up through the roof. Most sealed-combustion appliances use fan-assisted venting, except for some direct-vent space heaters.

Condensing vs. Non-Condensing Appliances

Fuel-burning appliances are categorized as either condensing or non-condensing. Non-condensing appliances are limited to about 87% efficiency. Condensing appliances are more efficient, because they extract more heat from the flue gas by cooling the gas to the point where moisture is condensed out. This condensation provides a latent heat exchange, boosting the efficiency of the appliance into the mid-90% range.

Because of the corrosive nature of the condensate, however, condensing appliances have different venting requirements from non-condensing appliances. The condensate can contain acid (sulfuric, nitric, or hydrochloric) that can corrode masonry chimneys, as well as some types of stainless steel vent pipe.

The type of vent material that can be used depends upon whether the appliance is condensing or non-condensing, and whether the venting is natural draft or fan-assisted (see table, next page).

Location of sidewall vents. When installing a sidewall vent, you must maintain certain minimum clearances from grade, as well as from openings, gas meters, and electric meters. These clearances differ, depending upon whether or not the appliance is a sealed-combustion appliance (Figure 3).

Code Requirements

In many parts of the country, the *National Fuel Gas Code* (NFPA 54) applies. Other applicable codes may include NFPA 31, *Standard for the Installation of Oil-Burning Equipment*; NFPA 211, *Standard for Chimneys, Fireplaces, Vents, and Solid Fuel-Burning Appliances*; and Section 607 of the *Uniform Mechanical Code*. In addition, be sure to consult your local code and to adhere to the appliance manufacturer's instructions. If there is a conflict between your local code and the manufacturer's instructions, get the conflict resolved before installing any equipment.

The *National Fuel Gas Code Handbook* can be ordered from NFPA by calling 800/344-3555.

Special Problems With Tight Houses

Thanks to the use of vapor barriers, housewrap, sill seal, weatherstripping, and caulk, we can now routinely build the kind of warm, draft-free homes our grandparents could only dream of. But if you build a very tight house without providing adequate ventilation, it can come back to bite you.

Customers are increasingly concerned with indoor air quality. A while ago, a homeowner showed me his new superinsulated house, which included magnetic weatherstripping on the doors. I mentioned that with a house that tight, perhaps he should stop eating chili. Several months later, he called me for advice concerning the mildew and lingering odor problems in his house. He eventually decided to install a heat-recovery ventilator to improve the indoor air quality. A heat-recovery ventilator will improve ventilation levels, but it is not designed to provide makeup air for the heating appliances.

Figure 4. Combustion makeup air can be provided to a confined space through an opening in the utility room wall. Air enters the confined space from the adjacent basement area, which must meet the definition of an unconfined space.

Makeup Air

All fuel-burning appliances require combustion air. Strictly speaking, combustion air has three components:

Selecting The Right Vent

Appliance type			Vent pipe required
Category I appliances	Natural draft vent	Non-condensing	Lined masonry chimney or Type "B" or "BW" vent for gas or Type "L" all-fuel vent for oil
Category II appliances	Natural draft vent	Condensing	Type AL29-4C stainless steel
Category III appliances	Fan-assisted vent	Non-condensing	Type AL29-4C stainless steel or Type "B" vent (for vertical venting only)
Category IV appliances	Fan-assisted vent	Condensing	PVC or ABS vent pipe
Direct-vent appliances	Fan-assisted vent	Condensing	PVC or ABS vent pipe
Direct-vent appliances	Fan-assisted vent	Non-condensing	Type AL29-4C stainless steel

- Stoichiometric air, which is the air required for the chemical combustion process.
- Excess air, which is the "little bit of extra air" that appliance manufacturers require to ensure that the amount of air available for combustion is adequate.
- Dilution air, which is the air required to dilute the flue gases enough to allow their passage through the vent.

The term "makeup air" is used to describe these three components of combustion air, along with cooling air, which is the air required to cool the room in which the appliance is located.

Appliances in an Unconfined Space

In an unconfined space, the makeup air for heating appliances is provided by the large volume of air present in the space where the appliances are located — usually, a basement or crawlspace.

According to the *National Fuel Gas Code*, a space is defined as unconfined if it has a volume greater than 50 cubic feet per 1,000 Btu/h of the combined input of the fuel-burning appliances. For example, if a house is equipped with a gas furnace with an input rating of 70,000 Btu/h, plus a gas water heater with an input rating of 40,000 Btu/h, the total input of the appliances would be 110,000 Btu/h. The space where these appliances are located would need to measure at least 5,500 cubic feet to be considered unconfined — equivalent to a space about 25x28 feet by 8 feet high.

Makeup air enters an unconfined space through uncontrolled infiltration from the exterior — for example, by finding its way between the top of the concrete foundation and the sill plate. With the advent of tight construction practices, however, some basements that meet the code definition of an unconfined space may not provide enough makeup air for fuel-burning appliances.

Figure 5. In this basement, which is too small to be considered an unconfined space, two ducts provide combustion makeup air from the exterior. One duct terminates near the ceiling, and the other terminates near the floor. The air intakes are protected at the exterior with rain hoods and screening.

How Tight is Too Tight?

How can a builder know when a house becomes too tight for uncontrolled infiltration to provide adequate makeup air to appliances in an unconfined space? Unfortunately, existing codes do not provide clear answers. NFPA 31 refers to the possibility that a building can have "insufficient air because of tight construction," (NFPA 31-1-9.3.2) without defining when that point is reached. The *National Fuel Gas Code* standards for makeup air assume that a building has at least 1/2 air change per hour.

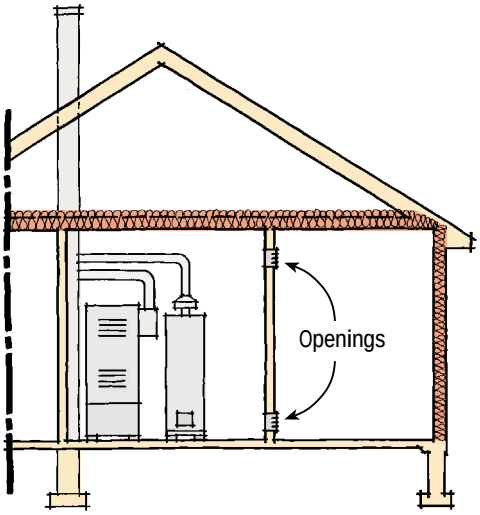
If you are building houses with housewrap, sill seal, weatherstripped doors, and caulked windows, it is probably unwise to depend on uncontrolled infiltration to provide makeup air.

Appliances Installed in a Confined Space

Any space smaller than an "unconfined" space as defined in the *National Fuel Gas Code* is considered to be a confined space and must be provided with openings to admit makeup air. Usually, this requires the installation of a register or grille in the utility room wall (Figure 4, previous page), or the installation of one or more ducts lead-

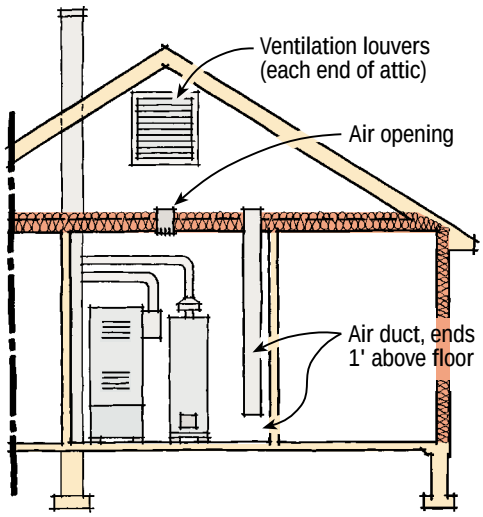
Makeup Air Options in a Confined Space

A. Makeup Air From Inside the Building



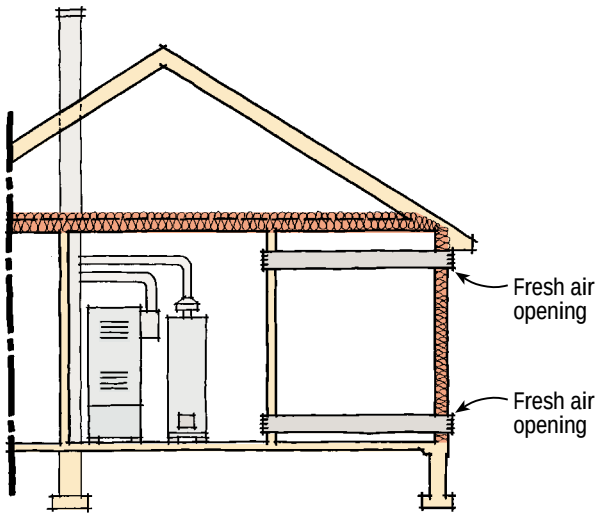
The space where the appliances are located must include two permanent openings communicating with an unconfined space, each of which must have a minimum free area of 1 square inch per 1,000 Btu/h of the total Btu/h input. One opening must be located within 12 inches of the ceiling, and one must be located within 12 inches of the floor. Neither opening can be smaller than 3 inches of free area.

B. Makeup Air From a Ventilated Attic



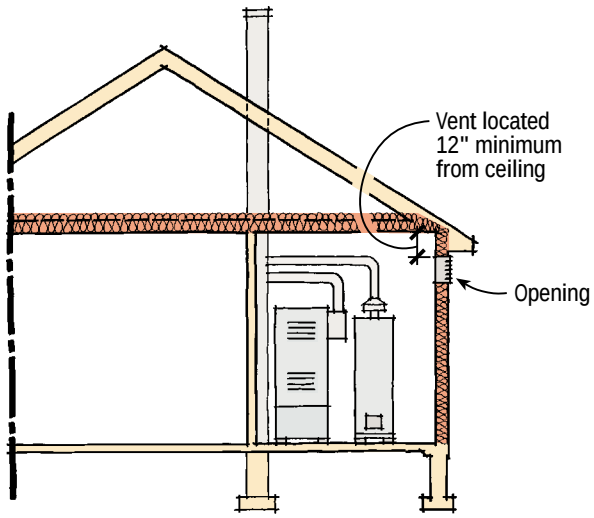
The space where the appliances are located must include two permanent openings communicating with the attic, each with a free area of 1 square inch per 4,000 Btu/h of total Btu/h input. As with option A, one opening must be located within 12 inches of the ceiling, and one must be located within 12 inches of the floor, and neither opening can be smaller than 3 inches of free area.

C. Makeup Air From Outside Using Ducts



The space where the appliances are located must include two permanent openings communicating with the outdoors, each with a free area of 1 square inch per 2,000 Btu/h of total Btu/h input. As with options A and B, one opening must be located within 12 inches of the ceiling, and one must be located within 12 inches of the floor, and neither opening can be smaller than 3 inches of free area.

D. Makeup Air From Outside Using a Single Opening



The space where the appliances are located can include one permanent opening communicating with the outdoors. The opening must have a free area of 1 square inch per 3,000 Btu/h of the total Btu/h input, must measure no less than the total area of the vent connectors, and must be located within 12 inches of the ceiling.

ing to the exterior (Figure 5, page 6). The *National Fuel Gas Code* provides four options for providing these vent openings (see "Makeup Air Options," page 6):

- Provide openings or grilles between the confined space and an adjacent unconfined space.
- Provide two ducts to a ventilated attic.
- Provide two ducts or openings to the exterior.
- Provide a single duct or opening to the exterior.

This last option is a new addition to the 1996 code, and although the allowance of only one opening rather than two may appear to contradict the requirements of the previous three options, it is perfectly acceptable. This option was included to address the concern that two openings to the exterior might cause frozen pipes in colder climates.

Motorized louvers. If you are concerned that makeup air from the exterior could cause pipes to freeze, you might consider installing motorized louvers on the air intake (Figure 6). Any motorized louvers used must be the type that lock out the burner circuit until the louvers are in the full-open position. Contact your heating contractor or supply house for more information on motorized louvers.

Figure 6. Motorized dampers are installed in very cold climates, where exterior makeup air might be cold enough to freeze plumbing pipes in a utility room or basement.

Figure 7. A forced combustion air system uses a fan to introduce makeup air into a utility room. This permits the use of a much smaller duct than when the makeup air enters by gravity.

Forced Combustion Air Systems

Another way to provide makeup air to appliances in a confined space is to install a forced combustion air system, also called a powered air intake system. This approach uses a fan to introduce ducted exterior air to a utility room (Figure 7). The fan is wired to be interlocked with the burner. An airflow switch in the intake air duct prevents operation of the fuel-burning appliance when the air duct is blocked, and a damper prevents off-cycle airflow.

The advantage of a forced combustion air system is the ability to use a small duct (usually, a single 3-inch round duct for a residential system), instead of the two larger ducts that would usually be required when exterior makeup air is provided passively.

Forced combustion air systems are sold by two different manufacturers, Tjernland Products and Field Controls. Although forced combustion air systems are not addressed by existing codes, BOCA is now in the process of developing a proposed standard for their use.

Providing adequate makeup air for a fuel-burning appliance is essential not only for the proper operation of the equipment, but also for safety. Do the job right, and the building's appliances — not to mention its occupants and you, the builder — will be able to breathe easy.

Manufacturers of Combustion Air Fans

Field Controls
2630 Airport Rd.
Kinston, NC 28504
800/742-8368
www.fieldcontrols.com
Circle #15

Tjernland Products Inc.
1601 Ninth St.
White Bear Lake, MN 55110
800/255-4208
Circle #16

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