Vent-Free Gas Heaters – How Safe?

A look at how unvented heaters affect indoor moisture and air quality

by Ted Cushman

Ask a typical hearth retailer what's the hottest product in the showroom these days, and you'll get a two-word answer: "Vent free." Sales are booming for gas-fired appliances that release combustion byproducts directly into the living space instead of to the outdoors through a vent or chimney. Four million unvented appliances are already in homes, and the industry expects to sell half a million more in the coming year.

Vent-free appliances are available in a variety of styles. The most popular products these days are the inexpensive gas logs, which homeowners can buy off the shelf at home centers for a few hundred dollars. The logs are placed in a typical wood-burning fireplace, but with the damper closed.

The vent-free category also includes stoves, wall-mounted heaters, and factory-built fireplaces. Sizes range from 10,000-Btu/hr. space heaters to big units that look like high-end wood stoves and produce up to 40,000 Btu/hr. Price and convenience are key selling points: Because the units vent directly into the living space, homeowners save the cost of a vent or chimney and don't have to put the units near an outside wall.

The main advantage of vent-free heaters, however, is also the chief drawback: With no vent, the byproducts of combustion may degrade indoor air quality and increase moisture problems. Although gas is a relatively clean-burning fuel, it does cause some pollution. Natural gas (methane) and bottled gas (propane) are compounds of hydrogen and carbon, which when burned combine with oxygen to produce water vapor (H_2O), carbon dioxide (CO_2), and, if combustion is incomplete, carbon monoxide (CO). In addition, hot gas flames also convert atmospheric nitrogen and oxygen to nitrogen dioxide (NO_2). In general, cooler gas flames produce more CO_2, while hotter flames produce more NO_2; either is harmful in high concentrations (see "Byproducts of Combustion").

The pollution levels in particular houses will depend on how the appliances are sized and operated. Officially, the vent-free industry recommends that the units be sized very small and operated only for short periods. Reports indicate, however, that some hearth retailers are still applying the "bigger is better" mentality in their sales and marketing efforts.

But the hearth industry itself does not unanimously endorse vent-free appliances, regardless of how they are sized or operated. Fireplace maker Heatilator, Inc., has taken a stand against the devices: In a letter to retail dealers, the company's president said that pollution and safety concerns outweigh the technology's value. (In addition to air quality concerns, Heatilator officials have warned that using gas logs in factory-built fireplaces designed to be operated with the damper open may create dangerous overheating).

However, Heatilator's position puts the company in the minority. With scores of other manufacturers taking the

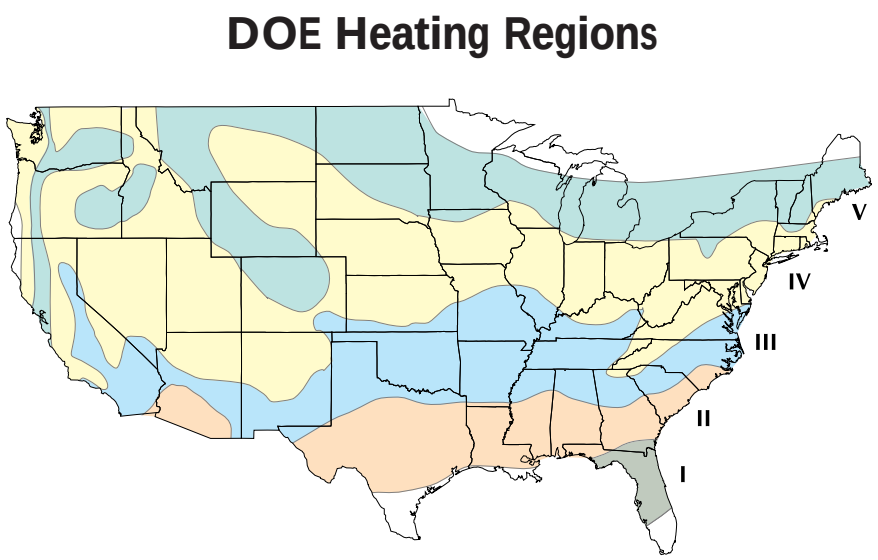

Figure 1. AGARD's report supplies rule-of-thumb sizing guidelines for homes in the five DOE heating regions. AGARD also recommends different installations for "tight," "average," and "loose" houses — the leakier the house, the larger the recommended unit. The bar chart shows the results of using AGARD's formula to size a unit for a 24x30-foot room in a house of "average" tightness in each of the heating zones.

opposite view, it is clear that builders and remodelers will be asked with increasing frequency to recommend or install vent-free heaters in the years to come. When making that decision, it's important to weigh the advantages of low price and design flexibility against the potential risk of adverse health effects caused by higher-than-normal concentrations of CO, CO_2, and NO_2, and the likelihood of moisture damage to building structure and finishes from excessive amounts of water vapor.

At a minimum, builders must follow the industry's latest conservative sizing guidelines, advises John Crouch of the Hearth Products Association: "This technology should not be used just because it's cheap. There are sizing guidelines that show the size of the appliance that is appropriate for the DOE heating zone and the size of the space. In small rooms in some climate zones, you may not be able to find an appliance small enough to be used for more than two hours at a time."

Crouch also says builders must warn homeowners about the risks and limitations of the appliances. "Homeowners have to understand that they cannot mess with that fire, they cannot disturb those logs," he explains. "And the family should understand that the appliance is to be used for four hours, and not in lieu of their primary heating system. If builders tell consumers that they can use this as heat, they are hanging themselves out to dry."

The AGARD Study

The sizing guidelines Crouch is referring to come from a report issued in March 1996 by the American Gas Association Research Division (AGARD), written by researchers Douglas DeWerth, Robert Borgeson, and Michael Aranov; the team's work was funded by the Vent-Free Gas Products Alliance and the Gas Research Institute (GRI). The AGARD study used a computer model to gauge the affect of unvented units on indoor air quality and to develop sizing rules-of-thumb that they claim will keep indoor air pollutants below reasonable limits (see Figure 1).

Marketing spokespeople from the Vent-Free Alliance treat the AGARD study as proof of the technology's safety. Alliance spokesperson Mary Carson told *JLC* the study showed that "vent-free appliances have been tested under all kinds of circumstances, and the air quality has matched all of the recommended standards."

In fact, however, early versions of the AGARD report, which were heavily publicized by the gas industry, gave results only for cases where the outdoor temperatures were above 45°F — conditions where the appliances produce pollution levels that satisfy government recommendations. But later versions of the study predicted higher levels of nitrogen dioxide under conditions found in northern regions — too high, in fact, to meet recommendations by some federal and state agencies. In the most recent versions of the report, AGARD has chosen a less stringent standard for some pollutants.

In any case, the AGARD results are not based on extensive field measurements. They reflect the output of a computer model which has been verified against only two laboratory experi-

Nitrogen Dioxide Concentrations (parts per million), Recommended, Predicted, and Measured

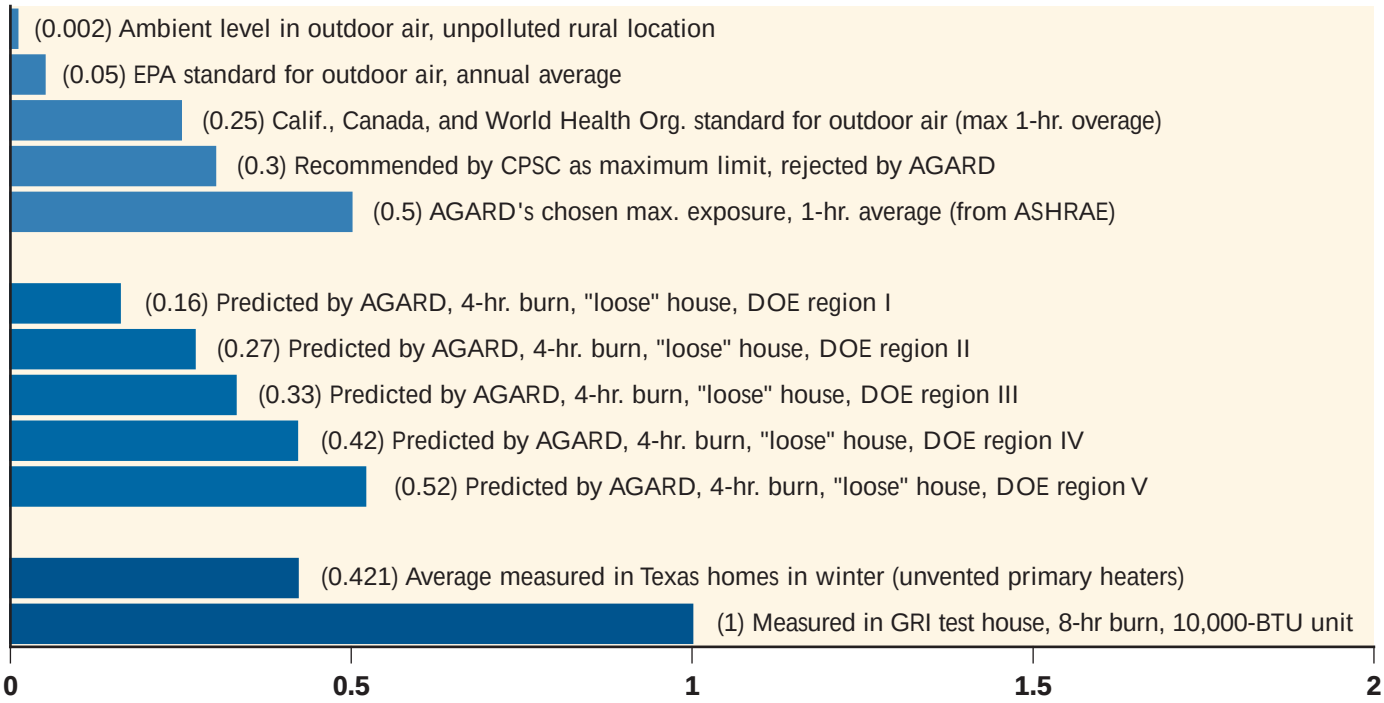

Figure 2. In dealing with the issue of nitrogen dioxide (NO_2) emissions, AGARD has chosen a short-term exposure guideline that is double the standard set by California and Canada. AGARD-sized units would also exceed the Consumer Products Safety Commission recommendation in most climates. In northern climates, AGARD's computer predicts that even the AGARD-preferred standard would be exceeded. Some measurements in test houses and in real homes have shown NO_2 levels created by unvented gas heaters that exceed all recommended guidelines.

ments, and the figures produced by the computer depend heavily on the input assumptions.

While such a computer model can be a useful tool for predicting air quality characteristics, the AGARD study has been widely questioned due to the lack of peer review before publication and the sketchiness of the data reporting. A number of qualified experts and state government officials have criticized the study's assumptions and conclusions, and regard as premature the vent-free industry's use of an early draft of the study to influence code bodies and state legislatures.

A peer review by Brian Leaderer of Yale University's John B. Pierce Laboratory is currently underway by order of New York Governor George Pataki, who in 1996 vetoed a bill that would have allowed unvented heating equipment in New York homes. Leaderer has refused, however, to discuss his work with the press until after his report has itself been reviewed and officially released later this year.

Questionable Assumptions

Critics of the AGARD study focus on key assumptions underlying the sizing guidelines — input parameters, they say, that give vent-free appliances the benefit of considerable doubt. Depending on the characteristics of a particular house, weather conditions, homeowner use patterns, and the pollution levels you consider acceptable, following AGARD's sizing guidelines may not ensure acceptable air quality.

Nitrogen dioxide standard. Since the United States has no official indoor air quality standards, the AGARD study has picked its own "recognized guidelines" from among air-quality recommendations made by a variety of organizations. Of these, the most problematic is the use of ASHRAE's standard for maximum nitrogen dioxide (NO_2) exposure of .50 ppm (parts per million). This is double the .25 ppm standard set for outdoor air by Canada, California, and the World Health Organization, the only governmental bodies that have set short-term NO_2 exposure standards; it is ten times higher than the average annual allowable exposure set by the U.S. Environmental Protection Agency (EPA) for outdoor air (Figure 2). The ASHRAE standard is also higher than a proposed Consumer Product Safety Commission (CPSC) overall limit of .30 ppm.

As the AGARD study points out, the EPA is unsure of a safe level for NO_2, but the agency has described the .50 ppm ASHRAE standard as a "level of signifi-

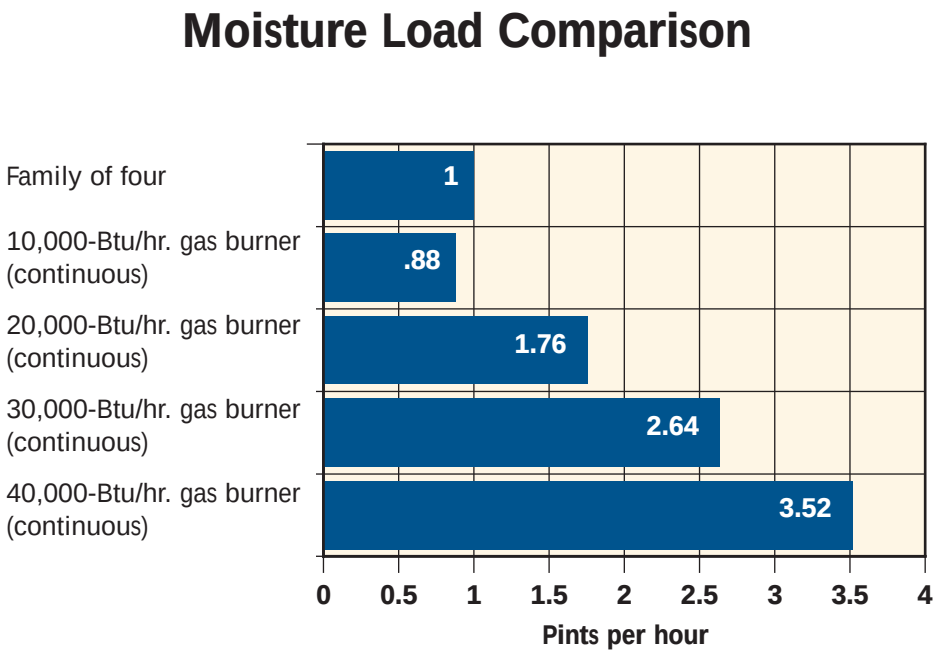

Figure 3. Gas combustion produces water vapor as a byproduct, in known quantities: 100,000 Btu of gas puts out about 1.1 gallons of water. This chart compares the water vapor output, in pints per hour, of various size gas burners with the typical moisture produced by a family of four during normal household activities.

cant harm."

Maximum CO output. Insufficient oxygen supply is one known cause of carbon monoxide (CO) production. Since the early 1980s, every unvented heating product has come equipped with an oxygen depletion sensor, or ODS — a thermocouple in the pilot flame of the burner that sends an electric current to a fuel cutoff switch. If oxygen levels fall below a set point (usually around 18.5%), the flame cools, the thermocouple stops sending its signal, and the switch trips, shutting off the gas.

However, experts I talked to pointed out a number of factors besides insufficient oxygen that can degrade the field performance of the gas burners over time. Burners that become clogged with dust or animal hair can burn inefficiently and produce greater amounts of CO; drafts coming through a damper or air inlet can disturb the flame and increase CO output; even improper arrangement by the consumer of the ceramic logs in a gas log set can obstruct the burner and lead to higher CO levels.

In the AGARD computer model, unvented heaters are assumed to emit pollutants at no more than the maximum rate permitted under ANSI Standard Z21, the test new appliances must pass in the factory. As units age in service, however, they may not perform that well. No comprehensive studies have been done to measure the actual CO output of existing older gas-log units and unvented heaters in real homes, but there are scattered reports of CO concentrations at the 90 ppm to 200 ppm level — less than a lethal dose, but enough to cause headache, fatigue, nausea, and dizziness in people exposed for two to three hours. With millions of vent-free units already in place and sales growing each year, occupants of some homes may experience long-term CO exposure above the 15 ppm to 25 ppm limits accepted by the AGARD study.

Additional pollution sources. The AGARD model assumes that the vent-free heater is the only source of pollutants in the space, but this may not be the case in many homes. If a family cooks with a gas oven and range, for instance, the NO_2 level in the space could start out at the .02 ppm to .04 ppm level. Since gas ovens also produce CO, the background level of this gas may be higher as well.

Heating load. In designing the AGARD model, the researchers relied on each heating region's "1,000-hour temperature" to estimate the heat load unvented units would need to satisfy. This means that for 25% of the heating season, weather would be colder than the calculations assume. They also relied on a single value for heat loss through the skin of the building, when, in fact, heat loss in actual buildings depends on such factors as the area of glass, type of windows, effectiveness of insulation, and conductivity of framing in the wall. Taken together, these heat load assumptions may underpredict heating demand in cold weather, when the unvented burners are likely to consume more fuel and create more indoor pollution than expected.

Homeowner Behavior

While the unvented appliance relies on a large open space for its combustion and dilution air, AGARD assumes that much of the heat for that space is supplied by the home's main heating system. If homeowners chose instead to set back their main thermostat and rely on the unvented heater for a larger share of the house's heat, the pollutant load could exceed AGARD's prediction.

The results produced by the AGARD computer also depend heavily on the assumption that unvented units will be operated for no more than four hours a day. Used by the study to define "proper" operation, the "four-hour burn" is based on a telephone survey conducted by a marketing agency but is contradicted by data from a GRI-funded study of 157 homes in Texas by the research firm Geomet, Inc. In the Texas study, homeowners used their unvented heaters more heavily as weather got colder, running the units for 80% of the day when outdoor temperatures were 25°F colder than indoor temperatures. This use pattern resulted in overpollution of indoor spaces in many of the Texas homes, including about 10% of the homes that used unvented heaters only for supplemental heat. The AGARD model predicts that units in DOE heating zones IV and

V — roughly, the half of the country that is colder than Kentucky — would exceed target levels for NO_2, CO_2, and water vapor between the fourth and eighth hour of use, but would stay below carbon monoxide targets.

Cool start. The AGARD model further assumes that the four-hour period of use starts with the room already at 72°F. If a homeowner lit the burner when the room was cooler by 10°F or more, particularly in cold weather, the fire might need to burn continuously for several hours to reach 72°F, rather than cycle on and off as AGARD assumes. Such cool-start, continuous-run conditions actually existed in one test of a 10,000-Btu unvented heater conducted by the GRI's Roger Hedrick in the GRI Conventional Test House, a 1950s structure located near Chicago, Ill. In that test, NO_2 levels in the building surpassed the .50 ppm limit by the second hour and peaked within eight hours at over 1.0 ppm, double AGARD's own limit and quadruple California's standard.

Ventilation. The AGARD study assumes a minimum ventilation rate in buildings of .35 ACH (air changes per hour), the minimum recommended by ASHRAE. An estimated 25% of new homes, however, are built tighter than that. Also, the natural air change rate in a real building depends mostly on the wind, so the rate in a "leaky" building could be either above or below .35 ACH, causing pollution concentrations to vary from predicted levels.

Sizing guideline: Get small. According to the AGARD model, unvented heaters must have low fuel inputs and must be operated for only brief periods of time to avoid overpolluting the space. The big 30,000- and 40,000-Btu/hr. heaters would exceed the recommended size in many situations. In typical spaces, units would have to be sized in the 10,000- to 20,000-Btu/hr. range; even then, operating them for more than four hours a day could create excessive concentrations of NO_2. For many spaces, AGARD's calculations result in size recommendations so low that the industry does not make appliances small enough to comply.

What About Water?

The problem vent-free devices are most likely to create — a problem that grows worse as weather gets colder — is excessive moisture (Figure 3). The AGARD analysis uses ASHRAE's recommended humidity levels for human comfort as a guideline for water vapor concentrations, allowing a relative humidity from 40% in the northern region to 60% in the southernmost U.S. As most builders realize, however, the problem with indoor moisture is not the humidity in the air, it's condensation. While the AGARD report mentions condensation as a concern, it does not address the problem in realistic terms.

Gallons of water. The AGARD study estimates that a 28,000-Btu/hr. vent-free heater will contribute about 4.6 gallons of water a day to a house if operated all day long for comfort. Building research architect Bill Rose, of the University of Illinois Building Research Council in Champaign-Urbana, put that moisture output in perspective: "The typical moisture contribution from a family of four is 2.9 gallons per day, from all activities — showering, cooking, breathing, and so on. From the AGARD report, a 28,000-Btu/hr. unit will generate 4.6 gallons in a 24-hour period. So you are more than doubling the moisture contribution to the space."

Even if the homeowner runs a 28,000-Btu/hr. unvented unit for only four hours — AGARD's definition of "proper" operation — the building might have to

Byproducts of Combustion

Improvements in combustion technology have significantly reduced the output of nitrogen dioxide and carbon monoxide in the exhaust stream. On the other hand, if you burn gas, you're going to get carbon dioxide and water in predictable amounts.

Depending on their concentrations in the air, any of the following combustion byproducts can cause problems:

Water vapor (H_2O) makes up about 60% of the output of a gas fire. In itself, water vapor is harmless to human health, but too much can damage building components, support rot, and foster the growth of unhealthy mold and mildew.

Carbon dioxide (CO_2) accounts for close to 40% of a gas burner's combustion byproducts. It is a health hazard only at very high concentrations. At moderately high concentrations, however, CO_2 causes discomfort: It raises people's breathing rate and may cause minor eye irritation, particularly in people who wear contact lenses. Ventilation engineers use indoor CO_2 levels to estimate air exchange with the outdoors, but standards set for that purpose mostly reflect comfort issues, not health concerns.

Carbon monoxide (CO), which makes up a tiny fraction (less than .1%) of the exhaust stream from a correctly functioning gas appliance, is a deadly poison. At high concentrations, it can kill people in minutes; at lower concentrations, it can worsen the symptoms of heart disease, or cause headache, dizziness, nausea, and fatigue. Low-level CO poisoning is often mistaken for the flu.

Sensitive groups who are especially vulnerable to low-level CO effects include pregnant women and developing fetuses, and people with cardiovascular or cerebral vascular illnesses.

Nitrogen dioxide (NO_2) is a corrosive oxidant gas that can injure lung tissues at high concentrations. At lower concentrations, there is evidence that NO_2 can hamper the body's immune defenses, creating increased susceptibility to respiratory infections. Researchers also report indications that the gas reduces lung function and increases the allergic response of some asthma sufferers.

cope with an extra gallon of water within the space of four hours.

This problem is likely to increase in cold weather, when the likelihood of increased heater usage combines with cold temperatures on windows and walls and within building structures, magnifying the potential for condensation. As independent hearth consultant Paul Stegmeir explains, the consequences in extreme cases could be dire: "At any building penetrations, you could have moisture in the cracks and soaked insulation. In the attic you'd have condensation and ice under the roof, and when it warmed up you'd have rain in the attic." Stegmeir relates an anecdote of a Minnesota resort owner who winterized some summer cabins to attract snowmobilers, and heated the buildings with vent-free equipment. "There was ice on the floors," says Stegmeir.

This extreme example represents a misuse of the equipment that violates all industry recommendations. But installing vented units in those winter cabins would have avoided the moisture problem, and the example illustrates how heating equipment that adds moisture to a space complicates considerably the builder's moisture control strategy.

What about ventilation? The Vent-Free Alliance's marketing brochure advises homeowners that modern houses may have less than the .35 air changes per hour assumed in the vent-free sizing guidelines, and may therefore have excess humidity. In that case, the brochure recommends that homeowners ask their builder if the house has enough venting.

But in a British Columbia condominium project where residents of units with unvented heaters complained of odors, stuffy air, colds, and headaches, fan-forced venting failed to solve the problem, according to retired B.C. Gas Safety Board official Peter Priebatsch. Outdoor air moved directly from the inlet vents to the exhaust vents, without taking along a significant amount of pollutants. This would not surprise most ventilation experts, who recommend first removing the source of moisture before adding ventilation. In the end, B.C. authorities prohibited unvented units in multifamily construction, and restricted their use in single-family construction.

An Ongoing Discussion

When contacted by fax with questions about the AGARD team's work, researcher Robert Borgeson defended the team's assumptions as reasonable. "The intention of our work was to develop general recommendations on how to use a properly functioning vent-free product," he wrote. "It is not a failure mode analysis, which is properly the domain of a product designer. It is also aimed at the general population, not folks with special health problems."

With regard to NO_2, Borgeson said the team assumed a slower decay rate for the gas than that observed in tests, noting, "The CPSC and other limits you mention are aimed at the 'sensitive' population, such as pregnant women and those with existing respiratory problems. We felt it was more appropriate to use an ambient air quality standard, coupled with our conservative decay rate."

With respect to variations in heating load, Borgeson conceded that "if the conductive heat loss is higher or lower, with the air change rate constant, then the pollutant level will change accordingly." He pointed out, however, that if increased infiltration is the cause of the added heat load, the infiltration will tend to dilute the additional combustion byproducts.

Judging from Borgeson's response to questions about excessive moisture production, the AGARD team is relying on the four-hour operating limit set in their guidelines. "In reality, the homeowner will probably reduce the output of the appliance to maintain the desired set-point temperature, or an automatic thermostat will do it for them," wrote Borgeson. With regard to concerns about how the appliances would be used during cold periods, Borgeson discounted the possibility that homeowners will instead turn down their main heating source, saying, "The product, by code, is meant as a source of supplemental heat. We cannot make useful recommendations based on improper use, and hope that this work will help to reduce this behavior."

From Borgeson's response to questions about how actual pollutant emissions might differ from factory tests, it appears that the AGARD team is comfortable relying on homeowners to follow its guidelines. "It is clear that proper inspection and maintenance is desirable," Borgeson wrote. "We hope that you can see the need to assume proper operation for the purposes of developing reasonable use guidelines."

According to Borgeson, the AGARD guidelines are subject to modification. "As more information regarding product design, health impact, and appropriate sizing criteria become available, we are open to refining the recommendations. The process of developing this information is an ongoing one."

Making the Choice

To date, the AGARD sizing guidelines have not been adopted by any code group — but in areas where the vent-free units are legal, some current codes allow them to be sized as much as six times larger than the report recommends. So for now, it's up to the builder and the customer to decide how strict the design guidelines should be. A builder contemplating a vent-free installation would be well advised to get a copy of AGARD's report and read it closely. (The report is available from the American Gas Association Research Division, 8501 E. Pleasant Valley Rd., Cleveland, OH 44131; 216/524-4995.)

However, if your goal is to provide equipment that can supply plenty of heat in any kind of weather, with much lower concern about indoor pollution or water damage, the solution is obvious, as Bill Rose points out: "If the homeowner wants to know, 'How can I ventilate this house so that I can use this vent-free heater?' here's the answer: The builder should install a vent system that picks up the pollutants directly and takes them to the outdoors. In other words, a chimney."

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