Impacts of Unvented Space Heaters

The May 2022 *ASHRAE Journal* article, "Impacts of Unvented Space Heaters" by Max Sherman, Ph.D., Fellow/Life Member ASHRAE; Philip Fairey, Life Member ASHRAE; Roy Crawford, Ph.D., Life Member ASHRAE, has some problems.

One involves water vapor and relative humidity (RH). The authors correctly identify that RH is dependent on temperature but fail to mention that the relationship between the two is inversely proportional. As temperature increases, relative humidity decreases, and the air will actually become drier. This is especially true during the winter when unvented heaters are typically used.

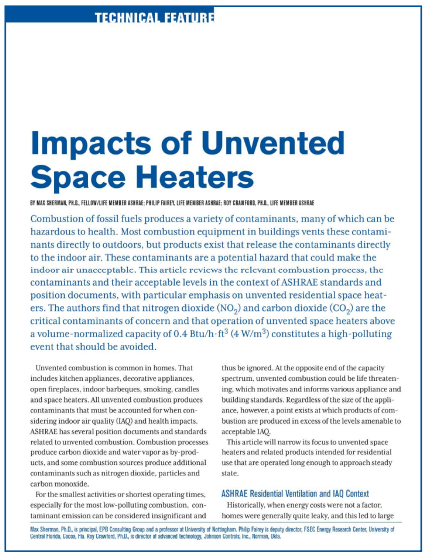
While using stoichiometric combustion calculations may show an increase in the absolute value of water vapor, actual measurements would likely show RH decreasing as air temperature increases. In fact, in winter adding a little humidity may improve conditions, not diminish them.

We have all experienced shocks from static electricity in the winter. That's because the air is dry, which in turn can lead to health problems including increased risk of infection from germs and viruses. So, adding some moisture to cold, dry air is a benefit, not a detriment, an important point overlooked by the authors.

A probabilistic assessment of unvented heaters on indoor RH was conducted in 2002[1] and examined 20,000 simulations over five climate zones. The results showed that even with additional water sources and other variables (considerations beyond what the *Journal* article included), all were below the 70% threshold for mold growth. What's more, the article's mass balance model assumes an ACH of 0.35 and below. That is a very tight building envelope, especially when the 2021 International Energy Conservation Code allows for 5.0 ACH—14 times the value of what the authors used. It would be difficult to find "poorly insulated homes" in such well-constructed residences.

Additionally, a 2008 study[2] measured actual RH and dew-point temperatures of 30 homes in Illinois and showed particularly good results with regard to water vapor generation from unvented heaters. Both dew point and RH measurements were well below the thresholds in the vast majority of measurements taken in various locations in the home. These real-world results contradict the authors' assessment.

Taking a one-dimensional approach to analyze the contribution of water vapor from stoichiometric combustion is flawed. There are too many variables that need to be taken into consideration. This article does not do justice to its topic and instead uses selective facts, excerpts and calculations to condemn unvented space heaters.



TECHNICAL FEATURE

Impacts of Unvented Space Heaters

BY MAX SHERMAN, PH.D., FELLOW/LIFE MEMBER ASHRAE; PHILIP FAIREY, LIFE MEMBER ASHRAE; ROY CRAWFORD, PH.D., LIFE MEMBER ASHRAE

Combustion of fossil fuels produces a variety of contaminants, many of which can be hazardous to health. Most combustion equipment in buildings vents these contaminants directly to outdoors, but products exist that release the contaminants directly to the indoor air. These contaminants are a potential hazard that could make the indoor air unacceptable. This article reviews the relevant combustion process, the contaminants and their acceptable levels in the context of ASHRAE standards and position documents, with particular emphasis on unvented residential space heaters. The authors find that nitrogen dioxide (NO_2) and carbon dioxide (CO_2) are the critical contaminants of concern and that operation of unvented space heaters above a volume-normalized capacity of 0.4 Btu/h·ft^3 (4 W/m^3) constitutes a high-polluting event that should be avoided.

Unvented combustion is common in homes. That includes kitchen appliances, decorative appliances, open fireplaces, indoor barbeques, smoking, candles and space heaters. All unvented combustion produces contaminants that must be accounted for when considering indoor air quality (IAQ) and health impacts. ASHRAE has several position documents and standards related to unvented combustion. Combustion processes produce carbon dioxide and water vapor as by-products, and some combustion sources produce additional contaminants such as nitrogen dioxide, particles and carbon monoxide.

For the smallest activities or shortest operating times, especially for the most low-polluting combustion, contaminant emission can be considered insignificant and thus be ignored. At the opposite end of the capacity spectrum, unvented combustion could be life threatening, which motivates and informs various appliance and building standards. Regardless of the size of the appliance, however, a point exists at which products of combustion are produced in excess of the levels amenable to acceptable IAQ.

This article will narrow its focus to unvented space heaters and related products intended for residential use that are operated long enough to approach steady state.

ASHRAE Residential Ventilation and IAQ Context

Historically, when energy costs were not a factor, homes were generally quite leaky, and this led to large

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References

1. Whitmyre, G.K., et al. 2002. "Assessment of The Potential Impacts of Vent-Free Gas Products on Indoor Relative Humidity."

2. Francisco, P.W., et al., 2008. "Combustion Product Concentrations of Unvented Gas Fireplaces." HUD Grant Number ILLHH0125-04.

Eric Adair, P.E., Arlington, Va.

- The May *ASHRAE Journal* article on unvented space heaters omits one very important detail in the combustion process: the production of heat. We know from basic chemistry that heat is required to produce the reaction that converts methane into carbon dioxide and water vapor. The authors overlook this important aspect of combustion in their analysis.

Why is heat important? Considering the operation of an unvented heater, 100% of the heat is delivered to the space where the heater is located. That heat affects temperature rise, and more importantly, the duration of operation. And that will have a dramatic influence on the contaminant levels delivered during typical heater operation.

The common unit for heat is Btu. It takes only 0.018 Btu to raise one cubic foot of air 1 degree Fahrenheit. So, it should not be surprising that 1,000 Btu will raise 55,556 ft^3 of air 1 degree.

Taking a sample home with a calculated heat load,[1] at an adjusted ventilation rate of 0.35 ACH[2] and installing a properly sized heater[3] we can estimate the temperature rise using an ASHRAE Standard 62.2 Committee endorsed model.[4] This example uses a space volume of 6,400 ft^3, is located in DOE Climate Zone 3 and the unvented heater input rate is 20,000 Btu/h. Setting the infiltration air to the coldest average outdoor air temperature in winter at 33°F, and the starting indoor air temperature at 68°F, we can observe the temperature rise over time.

We find it takes approximately 35 minutes to reach a set temperature of 75°F, and 55 minutes to reach 78°F. Both are reasonable human comfort levels for most people according to ASHRAE Standard 55.

Simply using available sources to model temperature rise in a space clearly reveals a shortened operating cycle time of the heater. This is far shorter than the 4- to 6-plus hours of operation to reach steady-state emission levels assumed by the article. This is just one example of many that demonstrate that the vast majority of installations will likely never reach steady-state condition when operating at full input rate.

In effect, the article incorrectly combines and distorts assumptions that rarely exist in typical installations and then applies the same extreme assumptions to all situations. This is a risky approach to standards development that seek to prohibit the use of targeted products.

References

1. *2021 ASHRAE Handbook—Fundamentals*, Chap. 17, Residential Cooling and Heating Load Calculations.

2. ANSI/ASHRAE Standard 62.2-2019, *Ventilation and Acceptable Indoor Air Quality in Residential Buildings*.

3. DeWerth, D.W., et al. 1996. "Development of Sizing Guidelines for Vent-Free Supplemental Heating Products." American Gas Association Research Division.

4. Francisco, P.W., et al., 2008. "Combustion Product Concentrations of Unvented Gas Fireplaces." HUD Grant Number ILLHH0125-04.

David Delaquila, Member ASHRAE, Warren, Ohio

- The May 2022 *ASHRAE Journal* article, "Impacts of Unvented Space Heaters," requires a reasoned response based upon sound engineering and product experience. Here are some simple facts for your readers to receive a balanced look at this important topic.

• As the most scrutinized product in the gas market, peer-reviewed and published research performed by AGAResearch, Risksciences, Infoscientific, TechTrans, and toXcel, performed by modelers, engineers and toxicologists, produced consistent indoor air quality (IAQ) findings that match the industry's stellar safety record of 25 million units installed over the past four decades in the U.S.

• AGAResearch developed a mathematical model for predicting unvented heater operating performance and IAQ impact. Verification testing in two separate controlled structures confirmed its accuracy by matching theoretical and real-world results. The untested model cited in the article bears no resemblance to the verified AGAR model, thereby arriving at erroneous results.

• Numerous research projects, peer reviewed and published, utilized mass balance mathematical models that included many variables affecting unvented heater IAQ impact, much like those used in numerous ASHRAE research projects. The simplistic algebraic model developed by the article's authors distilled down to hardly anything, and unbelievably, it excluded temperature. The steady-state IAQ levels determined by the authors would occur only at extraordinarily high room temperatures unfit for human occupation.

• Industry product liability information was provided to SSPC 62.2, which included the article's three authors. One would think that if these products are as problematic as the article's authors suggest, lawsuits would be common. However, the litigation proof simply doesn't exist, and both the United States Consumer Product Safety Commission and CSA Group (ANSI Secretariat for many products) have publicly commended the industry for its safety record.

In summary, the simple question is what makes so many credible researchers with IAQ findings backed by exhaustive product use history, proven mass balance models that include many more variables affecting the operation of an unvented heater confirming its minute impact on IAQ, along with a stellar product liability record, wrong and the article's authors right? The simple answer is that it doesn't.

Don Denton

• The May 2022 *ASHRAE Journal* article titled "Impacts of Unvented Space Heaters," though seemingly expounding technical performances of unvented space heaters, is very misleading.

As I read what appeared to be meaningful information on the emissions of unvented gas heaters and the impact on indoor air quality, what jumped out were the disqualifying statements, such as "All of these compounds are known to be harmful to occupants exposed to them, but sufficient research on appliance production of these harmful compounds has not been accomplished to enable quantitative estimates of the risks posed"; "No current consensus exists…"; "No clear consensus exists…"; "There are not, unfortunately, field measurements of homes and equipment that minimally meet both standards, but some measurements of earlier versions exist of each."; "The equipment (heaters) was not known to meet the current ANSI Z21 standard."

As Chairman of the ANSI Z21.11.2 Standard for Gas-Fired Unvented Room Heaters Technical Subcommittee, and an active member of this committee for 35 years, I can confidently say this article does not reflect the unvented heaters complying to the current safety standard. The ANSI safety standard covers the requirements for the products' safety, performance, and construction, including key emission levels. The safety standard constantly develops new performance requirements, such as when the Consumer Product Safety Commission (CPSC) requested to include testing for NO_2 emissions to ensure not to exceed acceptable indoor air quality.

If the article's authors wished to conduct a genuine peer review of their research, they should submit change proposals to the ANSI Z21.11.2 TSC (the nation's experts on the product category) an action they've been encouraged to take for years but have failed to do.

The article's authors provide no shred of evidence to show that any user has ever suffered any personal injury from emissions or that its emissions model matches real-world outcomes. The reason being, there is no evidence, based on the strong safety record of the unvented gas heater.

The article's authors support a ban of the product category in the ASHRAE 62.2 standard. They are long-time, well known opponents, and it's easy to speculate the alleged peer reviewers are of the same mind.

Both ASHRAE Standard 62.2 and ANSI Z21.11.2 are ANSI standards, and there should be harmony among all ANSI standards. ASHRAE should not be in the business of banning well-accepted and safe products.

Ron Smith, Katy, Texas

• The technical feature "Impacts of Unvented Space Heaters" in the May 2022 *ASHRAE Journal* references the "ASHRAE Position Document on Indoor Carbon Dioxide," which ironically was the subject of the article immediately following it in that edition. Yet, this first article ignores the positions of the Indoor Carbon Dioxide position document (PD).

That second article noted the following positions from the Indoor CO_2 PD:

- "Indoor CO_2 concentrations do not provide an overall indication of IAQ, but they can be a useful tool in IAQ assessments if users understand the limitations in these applications." and
- "Existing evidence for impacts of CO_2 on health, well-being, learning outcomes and work performance at commonly observed indoor concentrations is inconsistent, and therefore does not currently justify changes to ventilation and IAQ standards."

These positions contradict and negate the discussion of CO_2 in the "Impacts of Unvented Space Heaters" article.

The unvented space heaters article uses a CO_2 concentration limit of 2,500 ppm as part of the mathematical analysis to justify its recommendation to change an IAQ standard, i.e., ASHRAE Standard 62.2. The article admits this is an arbitrary choice and that there is not ample evidence to determine what the appropriate IAQ acceptability threshold is for CO_2.

It is worth noting that most governmental guidelines and standards specify indoor CO_2 limits as time averaged values, unlike the 2,500 ppm single value used in the analysis. It is also worth noting that in disregard of the positions of the Indoor CO_2 PD noted above, the article makes no attempt to determine what CO_2 concentrations represent concentrations commonly observed indoors.

Using 0.01 ft^3 per minute as the amount of CO_2 exhaled by an average adult and the appropriate

equation, one can calculate how long it takes for CO_2 to reach a certain threshold in a room. With six adults in a 7,200 ft^3 (30 × 30 × 8) openly communicating space, the CO_2 level reaches 1,000 ppm in about 90 minutes. Add four more adults in that space and the CO_2 level reaches 1,600 ppm in 2 hours and 2,500 ppm in under 4.5 hours.

If the article's suggestion were followed, the 10 adults in the space noted would be defined as a high polluting event, and a standard would be needed to restrict how many adults could be in a room and for how long.

This technical article has not assessed the issue of CO_2 properly.

Frank A. Stanonik, Life Member ASHRAE

- I am responding to the "Impacts of Unvented Space Heaters" article published in the May *ASHRAE Journal*. Its #1 conclusion is that "Whenever the normalized capacity of an unvented space heater is greater than 0.4 Btu/h·ft^3 (4 W/m^3), operation of that heater in homes minimally meeting ASHRAE Standard 62.2-2019 ventilation requirements constitutes a high polluting event, even when that appliance complies with ANSI Standard Z21.11.2."

This conclusion contains glaring inconsistencies that need to be explained. They include, but are not limited, to the following:

- How is it that numerous peer-reviewed and published studies on the same subject, which included houses at the ASHRAE Standard 62.2 ventilation rate and even tighter, produced entirely contrary results that actually match industry experience?
- How could a specific heat input limit be determined when the analysis shows that room temperature was not considered?
- How were steady-state indoor air emission levels achieved when a simple heat transfer calculation shows unacceptably high indoor temperatures would be realized long before?
- How is this finding valid when the author's mass balance model has not been verified through actual testing in a controlled house setting to obtain real data?

- How is the finding valid when the products' liability record of 25 million units over 42 years does not reveal emission-related concerns?
- How is this finding valid when the preponderance of evidence indicates otherwise?

These questions are very consequential as the assertions of this article formed the basis for SSPC 62.2 to vote to publish Addendum *j*, which is a ban on unvented gas heating products. For such an extreme action to occur, the evidence should be overwhelming and incontrovertible. Such evidence is nonexistent, not even close.

Sue Walker, Bowling Green, Ky.

The Authors Respond

The letter writers bring up a variety of points that are common issue for the industry. In the writing and reviewing of our paper, we considered all of these points. The authors do not have space to rebut all these issues, but offer a short summary:

Ron Smith implies that the equipment we used does not actually meet the Z21 standard to which it was certified. We did not measure the performance of any equipment to know; rather we assumed that the equipment does minimally meet that safety standard and that the home otherwise minimally met Standard 62.2.

Our purpose was to find out under what conditions (e.g., burn rate) both standards could be met and acceptable IAQ could still be achieved. While the article does not advocate for a product ban, or any other changes to the standard, members of either committee can use this information to improve their standard. The article merely enables solutions to safely achieve acceptable IAQ.

Eric Adair opines that our moisture calculations were incorrect because the ventilation rate we used is 14 times too small. Since moisture (like carbon monoxide) turned out not to be a limiting factor, it would not matter even if true, but we can assure him the psychrometrics were properly done. His confusion may be because the IECC value he cites is for air tightness and not ventilation.

We would also disagree with his assertion that 70% indoor relative humidity would be acceptable. Anything near this could be a disaster (for example, in a cold climate), as many ASHRAE publications have shown.

Frank Stanonik objects to our use of carbon dioxide as a contaminant of concern, citing ASHRAE's position document on carbon dioxide. A careful reading of that document would show that that position is looking "at commonly observed indoor concentrations," which are typically around 1,000 ppm. At some concentrations higher than commonly observed, carbon dioxide becomes a health hazard; and thus, becomes a contaminant of concern to be controlled rather than just a metric. Mr. Stanonik calculates that it is possible to get 2,500 ppm just from people's exhalations. While that is certainly true, it is not true in any space meeting ASHRAE's ventilation standard and thus his concerns do not apply to our article.

Despite the clear and supported assumptions of what the article is doing, several of the letter writers object to the article using steady-state and thus not considering that some of the equipment may cycle because of a thermostat. It is certainly true that in some situations steady-state might not be achieved, but as neither of the two standards have any requirements about thermal load, temperature settings or on-time length, it can easily be true that the equipment could be used for many hours in a row. The rather extensive information the letter writers refer to that uses cycling, or does not use minimally acceptable equipment or does not meet Standard 62.2, is thus not very useful for the article's purpose.

Several of the letter writers take the position that our article is flawed because there has not been enough successful litigation against manufacturers. Admittedly, we did not consider lawsuits to be relevant to calculating contaminant levels. Rather, we set out to enable improvements to IAQ in homes by advancing the arts and sciences of HVAC&R.

Max Sherman, Ph.D., Fellow/Life Member ASHRAE, Moraga, Calif; Philip Fairey, Life Member ASHRAE, Cocoa, Fla; Roy Crawford, Ph.D., Life Member ASHRAE, Norman, Okla.

ASHRAE Journal welcomes letters to the editor. The letters should be no more than 250 words and must relate to an article published in *ASHRAE Journal*.

Please send your letters to rebecca@ashrae.org.