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Proper Design of HVAC Systems for Spray Foam Homes

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INTRODUCTION

Spray polyurethane foam (SPF) insulation is becoming the product of choice in many homes today. Building science practitioners are known to say, "that a house is a system," meaning that all aspects of a house – construction materials, construction techniques, appliances, changes in the house's performance criteria – are interrelated and changes to any one of them can cause the house system to change. The bottom line is that these homes are a different building system than the ones built in the past. As such, they require some different thinking on heating, ventilation, and air conditioning (HVAC) systems than in the past.

This paper will examine the differences between SPF homes and homes built in the "traditional" way, helping to highlight the changes to HVAC systems that are necessary when insulating homes with SPF.

How are Spray Foam Insulated Homes Different?

There are two key differences between SPF homes and homes built in the "traditional way." The first is that SPF homes are significantly tighter than other new homes. The second is that SPF homes almost always include ducts and furnaces within the conditioned space. This isn't new to [some] parts of the country, but when combined with the air tightness of the home, it can have significant impacts on equipment selection.

The range of air tightness in homes is large. Older homes when tested with a blower door (a calibrated fan used to determine the air infiltration rate of a structure) can often exceed 1.0 air change per hour (ACH), meaning all of the air inside the house is replaced by outside air every hour or more often. A home this drafty makes it very hard for the HVAC units to maintain a constant inside temperature and provide comfort.

The average home in America built in the last 20 years will fall in the range of 0.35 to 0.70 ACH under normal wind and temperature conditions, meaning the air inside of the house is replaced by outside air as often as roughly every 90 minutes in leaky homes and up to roughly every three hours in tighter homes. The typical spray foam insulated home falls in the range of 0.10 to 0.20 ACH. These homes experience an exchange of air every five to 10 hours. The reduction in heating and cooling loads is significant, and the increased comfort is substantial.

How Tight is Too Tight?

The question, "How tight is too tight to build a home for both indoor air quality and energy efficiency?" has been the subject of a decade long debate among industry professionals. The building science community knew that determining the right answer was critical, since it had a major impact on both efficiency and the health of the occupants.

At one time, most people believed that one could build a home too tight for good indoor air quality. As more research became available, the truth emerged and a consensus was reached: **A home can't be built too airtight for efficiency and healthy indoor air quality, but a home can be under-ventilated.**

Homes do truly function as systems, not just as a group of stand-alone components that can be mixed and matched `a la carte. In a system, all of the parts are interlinked and when one or more are changed, others must also be changed to keep the system in balance. The transition towards tight building construction and greatly reduced heat flows, such as with SPF, requires builders and HVAC contractors to rethink the way things were done in the past. Utilizing SPF with the correct HVAC considerations will create an energy-efficient, comfortable, healthy home.

THESE CONSIDERATIONS ARE:

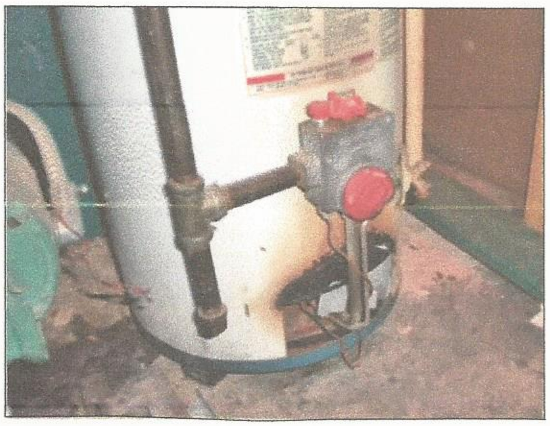
- Combustion Safety
- Ventilation
- Right Sizing the HVAC Equipment
- Humidity and Moisture
- Use of Manual J
- Duct and Register Considerations

COMBUSTION SAFETY ISSUES

Furnaces, Water Heaters, Fireplaces and Other Open Combustion Appliances:

Because all SPF-insulated homes are very tightly constructed, one should not install naturally aspirating or open *combustion* furnaces, water heaters or other combustion appliances in them. The homes are so tight that these units cannot operate safely. **Sealed combustion or power vented equipment must always be selected for these homes.** This is a non-negotiable item, as occupant safety is of the highest priority.

For naturally aspirating combustion appliances to operate [illegible]ly, they must be able to easily draw in outside air to replace the air that they are sending up their flues to carry away the by-products of combustion. SPF homes are so tightly sealed that they fall into the category building codes refer to as "unusually tight construction." Open combustion appliances will back draft with only two or three Pascals (0.012-inch water column) of negative pressure. More extreme negative pressure can even cause flame roll-out. Sealed combustion and power vented equipment will not back draft at less than minus 25 Pascals, making them the safe choice. Selecting sealed combustion or power-vented equipment ensures that they will operate safely in these well-sealed envelopes.



Evidence of flame roll-out.

VENTILATION ISSUES

Build Tight, Ventilate Right

The question of leaving the house leaky often comes up. Isn't it the same thing as tightening the house up, then properly ventilating it?" No, it's not at all the same. A leaky home depends on random holes, in random places, and wind and temperature differences to make the air move into and out of the home. It only works occasionally and when it does it's purely by chance.

Building science testing leads one to believe that relying on uncontrolled chance infiltration results in homes that are over ventilated during the day or in cold, windy times and under ventilated at night or in warm, still weather.

Industry experience from blower door air infiltration testing has shown that the attic, the basement, the crawlspace and the garage are the most likely places from which air will enter a new home.

It's not a very healthy or efficient picture is it? The incoming air tends to be too hot, too cold or too humid, and is almost always too dirty for the occupants' comfort and health.

When professionals take control of this situation, they can ensure the source of the air, and its cleanliness. Temperature and humidity can be altered, thus ensuring that homes get clean, comfortable, fresh air in exactly the right amount all of the time. This is a scenario that promises much improved indoor air quality. It is in fact the way clean, healthy air is ensured in our hospitals and in manufacturing facilities that rely on cleanliness during production.

The American Lung Association and the U.S. EPA Energy Star Program Are On Board

The American Lung Association (ALA) has joined the movement advocating a very tightly sealed and properly ventilated home. In its *Health House* program[1], they advocate for tightly-sealed homes urging home builders and HVAC contractors to employ advanced air sealing and insulation techniques along with whole house ventilation, humidity control and high efficiency air filtration.

ENERGY STAR® Homes with the Indoor Air Package

The U. S. EPA's highly successful ENERGY STAR® for New Homes program has recognized the need for a "systems" approach, and requires all qualifying homes be very tightly air sealed and third- party tested to verify air tightness. The ENERGY STAR Indoor Air Package 4 addresses the need for "careful selection and installation of moisture control systems, heating, cooling, and ventilation (HVAC) equipment, combustion venting systems."

Specifically the ENERGY STAR standard requires that HVAC systems sized and selected according to Air Conditioning Contractors of America (ACCA) Manual J, and that equipment maintain the house at below 60 percent relative humidity (RH) with either stand-alone equipment or via the use of specialized thermidistat controls. The ventilation system must meet ASHRAE Std. 62.2 requirement, with special attention paid to moisture control in hot and humid climates. The standard also requires combustion appliances to be either direct-vented or power-vented for safety.

Like the rest of the building science community, the ALA and EPA recognize that these measures form a package that creates a functioning system, not an `a la carte menu. When properly designed, these measures together create a reliably healthy, comfortable, efficient and clean indoor environment.

ASHRAE Standard 62.2, The Standard Acceptable Indoor Air Quality

The American Society of Heating, Air-conditioning and Refrigeration Engineers (ASHRAE) provides ventilation standards that are cited in the national building codes and used across the United States. These standards are commonly drawn from ASHRAE Standards 62 (commercial buildings) and 62.2 (residential structures). The official title of 62.2 is, "*Ventilation and Acceptable Indoor Air Quality in Low-Rise Residential Buildings.*"

The ASHRAE 62.2 ventilation rate is based on the home's square footage and the number of occupants. The number of bedrooms is used to estimate how many people will be in the home on average, and the assumption is there will be one person in each bedroom and two in the master bedroom. The standard calls for providing 10 cubic feet per minute of outside air for each 1,000 square feet of floor space plus 7.5 cubic feet per minute for each person (number of bedrooms plus one). The equation for ventilation rate in cubic feet per minute (CFM) is then:

$$\text{VENTILATION} = \frac{\text{sqft}}{100} + ((\#\text{BRs} + 1)*7.5)$$

Generally, recommended ventilation rates range from 50 to 90 CFM of outside air, with most homes in the 50 - 65 CFM range. It's a relatively small airflow, but it provides critical benefits.

ASHRAE 62.2 recommends using mechanical ventilation when homes reach 0.35 ACH or lower under natural conditions to ensure adequate indoor air quality. Because SPF-insulated homes generally are in the 0.10 to 0.20 ACH range, **ventilation will always be recommended in newly-built SPF homes to maintain good indoor air quality.**

It's up to the home builder to select a ventilation plan and ensure that it is executed. Most ventilation plans are at least partially the responsibility of the HVAC contractor, but one method simply involves the specification and installation of a special exhaust fan.

EQUIPMENT & TECHNIQUES FOR VENTILATION

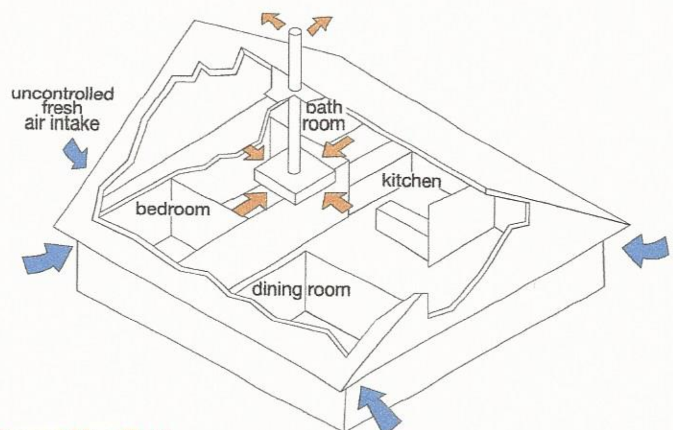
Ventilation for residential homes can be provided naturally or mechanically. Because SPF houses are tightly constructed, mechanical ventilation must be used. A home can be mechanically ventilated by either:

Exhaust Ventilation - Installing an exhaust fan, pulling air from the house and blowing it outside, which in-turn draws in outside air from random holes in an equal amount to replace it

Supply Ventilation - Drawing air into the HVAC return side and then blowing it into the house through the HVAC system, which forces an equal amount of air out of the house

Balanced Ventilation - Providing an equal flow in both directions, exhausting as much air as we bring in, creating no pressure at all. This is accomplished with a heat recovery ventilator (HRV) or an enthalpy recovery ventilator (ERV).

Either way, one cubic foot of air coming in equals one cubic foot of air going out and vice versa.



Exhaust Ventilation

Exhaust ventilation is often the least expensive option and can most easily be done using a new type of ultra quiet, high efficiency bathroom exhaust fan. These fans use continuous duty-rated DC motors and make less than 0.5 sones or 1/10th the noise of traditional bathroom fans. They can operate 24/7 all year for under $30 of electricity for the ENERGY STAR-rated units. The flow rates most homes need to maintain healthy indoor air quality are well within these fans' operating range. This method does not provide a means to control the quality or distribution of fresh air. However, it is an easy and inexpensive way to meet home ventilation needs.