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 safely, 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 2 or 3 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 -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 Environmental Protection Agency's (EPA) 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 be 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 Standard 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 for Acceptable Indoor Air Quality

The American Society of Heating, Air-conditioning and Refrigeration Engineers (ASHRAE) provide 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

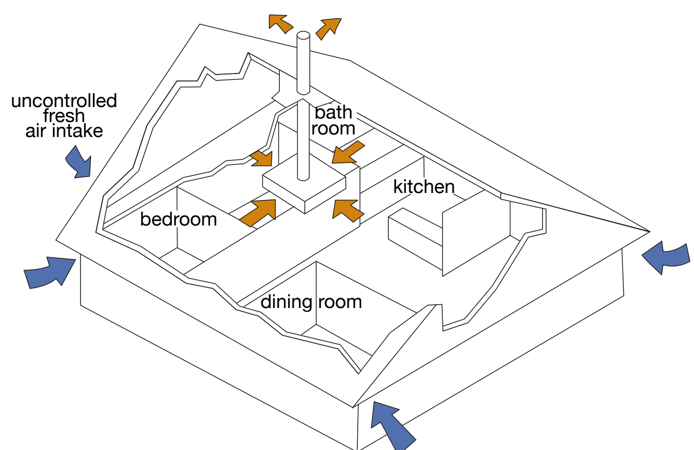
Ventilation for residential homes can be provided naturally or mechanically. Because SPF houses are tightly constructed, mechanical ventilation must be used. A home can be mechanically ventilated by either:

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.

Important Note About Air Handlers

If a ventilation system that uses the HVAC air handler fan to provide the needed fresh air (as is the case in many supply ventilation strategies) is used, it is imperative to ensure that the air handler fan operates often enough to provide sufficient fresh air. During periods of mild weather, or at night in the summer, the air handler fan may not be called on to run for several hours, so the house would get no fresh air during these times. To address this, control units are now available that will ensure the house always gets the needed ventilation. If the air handler does not operate enough for sufficient ventilation, the monitors will call for the fan to operate and provide sufficient fresh air.

Typically, most homes need for the fan to run for between 10 and 20 minutes each hour to meet the home's ventilation needs. An example of this type of fan control unit is the AirCycler[2].

Regardless of technique, this exchange of air with the outside not only affects the temperature in the house, it also impacts the humidity in the house. Therefore, it's critical to include ventilation air in the *ACCA Manual J, Eighth Edition* (J8) HVAC sizing calculations.

House Pressures

When providing mechanical ventilation, it's best to keep the pressure generated by the ventilation very small. Most standards recommend keeping any negative or positive pressures below +/- 3 Pascals or 0.012-inch water column with reference to the outside.

In heating dominated climates, a builder wants to keep the house under less than +3 Pascals to avoid forcing warm indoor air into the wall cavity where it could cause condensation. In all areas of the country, builders want to keep the house pressure with reference to the outside from exceeding -3 Pascals to avoid drawing combustion by-products into the house from open combustion furnace, fireplace and water heater flues or radon in from basements and crawlspaces. This should not be an issue in a tight home. The required ventilation airflow rates are so small and there should not be any open combination appliances.

The exception is when large exhaust fans, like big kitchen exhaust hoods are installed. These units require that one provide make up air. Hard wiring the big exhaust appliance to a fan that brings in sufficient air to offset the exhaust rate of the appliance will accomplish this.

RIGHT SIZING HVAC EQUIPMENT

Old "Rules of Thumb" No Longer Apply

In the beginning, the residential HVAC industry relied on "rules of thumb." The most commonly applied rule of thumb states that one ton of air conditioning equipment was needed for each 400 - 500 square feet of conditioned space. Homes like those in the 1950s and '60s with little or no insulation, leaky single pane windows, no air sealing package, ducts that lost one fourth of the conditioned air and other common attributes of older homes needed a ton of capacity for each 400 - 500 square feet of conditioned space in cooling-dominated climates. Similarly, each region had rules of thumb for heating requirements.

The home building industry has made significant strides in improving energy efficiency with higher R-values, improved windows and improved air tightness in both the envelope and the ducts. As a result, the sensible cooling and heating loads on a home are significantly less than when the rules of thumb were developed. SPF takes energy efficiency to the next level by allowing ducts and equipment in conditioned space and greatly reducing air infiltration. Given that air infiltration and duct leakage often contribute 40 percent or more of the heating and cooling load, SPF homes have greatly reduced sensible heating and cooling loads.

Today, most HVAC units are installed without the contractor performing a Manual J8 calculation. Most contractors just apply one of the rules of thumb. ACCA states that these typical industry practices result in the average system being between 150 - 200 percent oversized! With higher efficiency SPF homes, the old rules result in even greater over sizing.

Over sizing equipment will result in short cycling of the equipment and higher upfront costs for the builder and the homeowner. This reduces the efficiency of the units, leading to higher utility costs for the homeowner. Heating units and air conditioners start each cycle at a much lower efficiency than their stated efficiency rating. That is the efficiency they reach after running long enough to reach what is called "steady state efficiency." It takes at least 10 minutes for them to reach this efficiency level. When they short cycle, they are always operating at a much lower efficiency, so utility costs are higher than necessary. In addition, air conditioners that short cycle do not run long enough to perform dehumidification, which can lead to high indoor relative humidity and poor comfort.

Performing strict Manual J8 loads gives builders credit for the much-improved envelopes they are delivering. Ideal equipment operation is then accomplished by following the ACCA Manual S for equipment selection (now required by IECC 2009); never over sizing by more than 15 percent over the calculated actual BTU load, and being willing to reduce the tonnage of the equipment to closely match the now reduced sensible load.

HUMIDITY AND MOISTURE RELATED ISSUES

This increase in air tightness also changes the moisture dynamics in the home in several ways. First, the moisture generated in the house, stays in the house. Second, the sensible or temperature load on the house goes down significantly, while the latent or humidity load remains the same. Therefore, if adjustments are not made – the air conditioner is oversized, it short cycles and the inside humidity goes up.

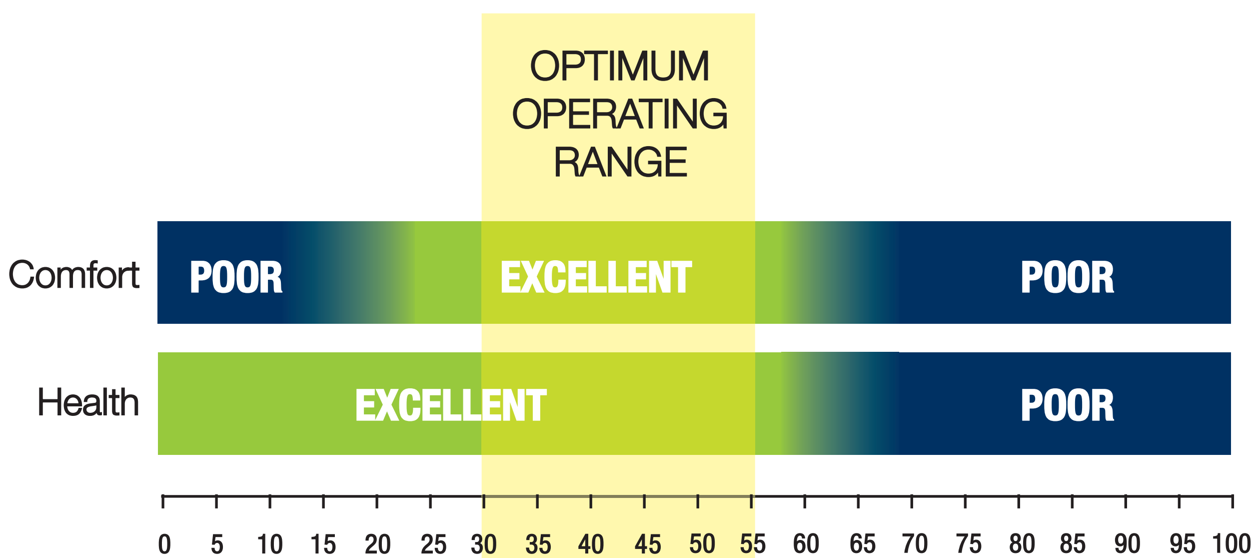
Moisture control is critical to both human comfort and to our health. ASHRAE studies have shown that most people are comfortable when the relative humidity is between 30 - 60 percent. When the indoor humidity exceeds 60 percent, owners will try to address this discomfort by lowering the temperature to find comfort. This just increases the electric bills and can lead to condensation on supply grilles and the growth of mold. When the indoor relative humidity is allowed to exceed 55 percent, dust mites begin to flourish. Dust mites are a primary cause of asthma attacks and one of the most common allergens present in our environment. Similarly, growth and activity of mold and various bacteria increase at higher humidity levels.

The chart below shows the relationship between indoor relative humidity, comfort and the growth and activity of various organisms that contribute to unhealthy indoor air quality.

There is a reference to an “Optimum Operating Range” between 30 - 55 percent indoor relative humidity. In this range, most people are comfortable, and the home experiences low levels of activity by the organisms that are detrimental to healthy indoor air quality.

Higher relative humidity levels also increase the risk of condensation, which can lead to mold and rot. Moisture can condense on relatively warm surfaces in a high relative humidity environment. Keeping humidity levels under control will reduce this risk.

Optimum relative humidity effects on comfort and health



Equipment Sizing and Selection:

There are several methods that contribute to controlling humidity in tight, SPF homes:

- Right-sized air conditioner
- Evaporator coil selection
- Variable speed blower (ECM) units with a humidistat
- Stand-alone dehumidifier (hot humid climates)

Using the traditional rules of thumb for sizing will result in oversized equipment and short cycling in tight, SPF homes. Why is it important to ensure short cycling does not occur? Most evaporator coils today don't begin to remove moisture from the indoor air until 8 or 9 minutes into the cooling cycle. Over sizing the system results in short cycling because the unit can lower the house temperature so quickly that the system never runs long enough to get into the mode where it performs good moisture removal. Right sizing the equipment to ensure efficient and adequate run times will improve the humidity control of the air conditioning system.

Another necessary adjustment is to select evaporator coils (the indoor component of an air conditioner) with a good sensible heat ratio (SHR). SHR is the ratio of air cooling to humidity removal that a coil does. Many contactors select the coil that gives them the highest seasonal energy efficiency ratio (SEER) rating. This is usually a coil that has a lower latent capacity than other coils that could be matched to the selected condenser using AHRI-certified equipment, so it does less dehumidification. This is all right if one lives in an arid or desert climate. For everyone else, a good number to aim at is an SHR of 0.75 or less. This means that at-design conditions, the coil will expend 75 percent of its energy cooling air and 25 percent of its capacity in de-humidification. This is particularly critical in humid climates.

It is also wise to use electronically commutated motors (ECM) or variable speed blowers paired with a thermostat/humidistat combination controller often called a "thermidistat." This combination of a variable speed blower with an advanced control unit can greatly improve indoor humidity control. Thermidistats sense and operate to control indoor relative humidity, as well as temperature. When the indoor relative humidity exceeds the level set by the owner, say 50 percent, the compressor comes on, and the fan operates at a slower speed than it does in normal cooling mode. This moves a smaller amount of air over the coil, so the air gets colder before leaving the coil and this increases the amount of moisture removed. The unit will run in this mode until the humidity level is reduced and then if necessary, it will ramp up to high speed to meet the temperature setting. In many climates these adjustments will be sufficient, but not necessarily in the more extreme climates.

Since the system is also cooling the house as it dehumidifies, it can overcool the home. Most systems have an override that cuts the air conditioner off if the house temperature drops to more than 3 degrees below the thermostat set point. In very humid climates, the dehumidification cycle can be ended by this override before the humidity level is reduced to the desired level, leaving the house uncomfortable.

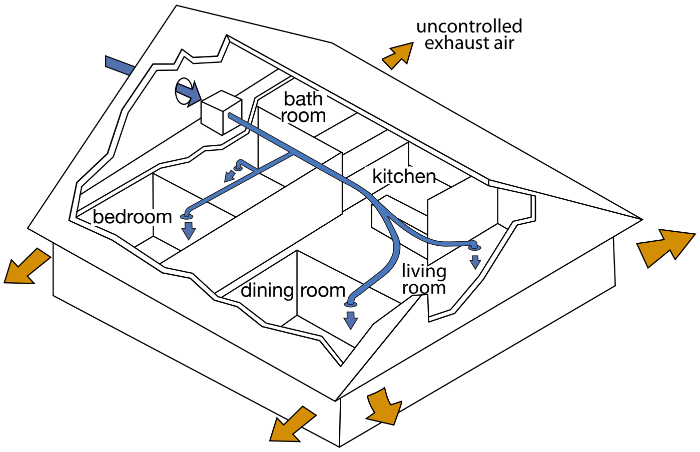
In especially humid climates, it is a good idea to install a separate, stand-alone dehumidifier to address the latent load in the mild "shoulder" months and at night, when the sensible temperature load limits the run time of the air conditioner. A good option in these cases is the installation of a unit that combines the ability to ventilate the house, with high efficiency filtration and very efficient humidity control that is not dependent on air conditioner run time. Since these units are designed to remove moisture, they are optimized for this job. Many units will remove each pint of water for one-third of the energy that an air conditioner would take to remove the same amount of water, thus making them energy efficient options. Several studies have researched the pros and cons of several humidity control options in a hot and humid climate[3].

USE OF MANUAL J

Before desktop computers, it took 3 or 4 hours with a pencil and eraser of doing hundreds of multiplication, addition and subtraction problems by hand and looking up dozens of heat transfer multipliers for many materials in a myriad of tables to do a Manual J calculation. The investment of time for the contractor was too great, so rules of thumb were used. With today's software, one can perform a Manual J calculation in less than an hour.

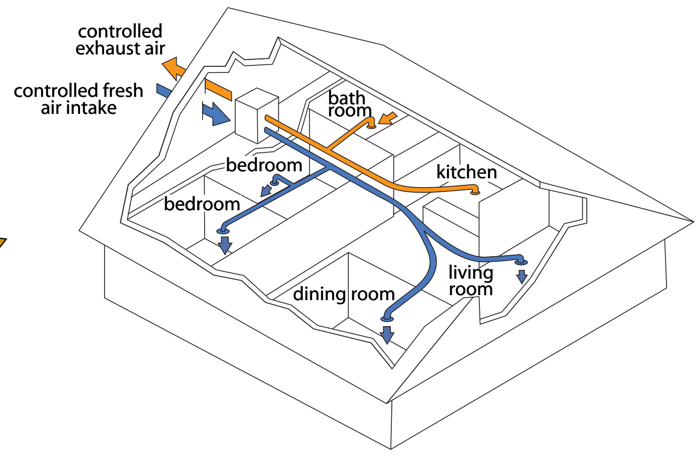
Envelope Efficiency Problems Contractors Didn't Know They Had

Even when contractors installed equipment to a strict Manual J, they often got call backs because the units appeared to be undersized. The reason was that the performance of the home was often less than the input values into the software. Insulation did not perform to its stated R-value because of improper installation and air movement and convection through the material. Duct leakage was found to be a major load that was not accurately taken into account in older versions of Manual J. Chases, knee walls and open flooring systems were often left essentially uninsulated, although they were rarely accounted for in that way.



Supply Ventilation

For the supply ventilation technique, the best way to bring air into the house under positive pressure is to run a small duct (usually 4 or 6 inches) from the return plenum of the air conditioner to a gable end or eave of the house. When the thermostat calls for cooling/heating, fresh air is drawn into the return plenum. It is then mixed with the large flow from inside the house, and is then filtered. Lastly, the cooled/heated and dehumidified air is warmed as it crosses the heat exchanger in winter and cooled in summer. If the air handler fan is used for ventilation, it is important to specify an electrically commutated blower motor (ECM). This is because they are so much more efficient than traditional motors, greatly reducing the cost of ventilation. Supply ventilation can also be provided through a stand-alone combined dehumidifaction/ventilation system tapped into the supply plenum.



Balanced Ventilation

Ventilation can occur using a balanced flow by introducing a HRV or an ERV. Both units pass the exiting and incoming air through a heat exchanger to moderate the temperature difference, thus reducing the energy impact of the ventilation. The ERV, unlike an HRV, will also transfer some humidity from one air stream to the other. Manufacturers allow these systems to be ducted in several ways, including directly from the house to the outside or connected from the outside into the air ducts of the house. The system should always be ducted in a way approved by the manufacturer.

The table at the bottom of the page summarizes ventilation techniques and preferred methods.

	HOUSE PRESSURE	PROS	CONS
Exhaust	Negative	• Simple Installation	• Uncontrolled Quality and Distribution of Fresh Outside Air • No Energy Recovery
Supply	Positive	• Simple Installation • Control and Distribution of Fresh Outside Air	• No Energy Recovery
Balanced - HRV	None	• Energy Recovery • Lower Operating Cost • Control and Distribution of Fresh Outside Air • Control of Expelled Inside Air	
Balanced - ERV	None	• Energy Recovery • Lower Operating Cost • Humidity Control • Control and Distribution of Fresh Outside Air • Control of Expelled Inside Air	

DUCTS & REGISTERS

Sealed Attics and Crawlspaces

The national building codes now allow contractors to build sealed (unventilated) attics and crawlspaces.

One question that is often posed regards placing returns and supply grilles in sealed attics and crawlspaces. The answer on returns is that a return air pathway is code-required in crawlspaces, but not attics. In the case of crawlspaces, the 2006 International Residential Code (IRC) Section R408.3 calls for either a continuously operated mechanical exhaust fan providing 20 CFM/1,000 square feet of floor space or a supply of conditioned air at a rate of 20 CFM/1,000 square feet of conditioned space. Both options are required to have a return air pathway to the conditioned space and a continuous vapor barrier on exposed earth.

There is no requirement in the IRC for providing conditioned air to the sealed attic, so there is no requirement for a return air pathway.

Duct System Design and Register Placement

For many years, the basic duct system design paradigm was to run the ducts out to the perimeter of the home and place the supply registers at the windows. This was often called washing the wall with supply air. The concept was one of placing the supply air as close to the location where the large amount of heat gain or heat loss was occurring.

This long-held paradigm has been changed by the advent of the super efficient thermal envelope like that provided by SPF. Walls sprayed with SPF and high-efficiency, low-emissivity windows (low-e) with improved solar heat gain co-efficients (SHGC) and U-factors have greatly reduced the impact of both the exterior walls and windows on the total loads on our homes.

Another impact of the reduced sensible load has been the reduction in total CFM of airflow supplied to the house as a ratio of the square footage of the house. Previously, most homes would have about 1 CFM of air conditioning supply air per square foot of conditioned floor space. Today, with reduced sensible loads we often only have 0.5 or even 0.3 CFM per square foot of conditioned space. This has led to many problems including insufficient mixing to distribute supply air and create comfort for the occupants – what some contractors call “stagnant air.”

With more efficient envelopes, the exterior walls and windows don’t need to be washed with massive amounts of supply air to offset the high heat gain/loss at these locations. The amount of mixing of air in the rooms needs to be increased to even out the temperatures throughout the space with a reduced airflow. The solution to these two design issues lies in a single new concept, the compact duct system.

By placing the supply grilles high on the inside wall or the ceiling near it, and throwing the air at the exterior wall with enough throw and velocity, the heat gains or losses can still be offset. Additionally, a good mixing effect can be created in the room without drafts. Throw is defined as the distance that a given register will blow the air before the air slows to a defined speed. The duct runs can be shortened to reduce the total friction losses in the duct system. This is often called a compact duct design strategy and been well researched by the ENERGY STAR Home program[4].

The compact duct design requires that supply registers be carefully selected to have low friction loss, and sufficient “throw” to do the job. HVAC register manufacturers publish the tested throw and spread of each supply register unit in their catalogs. HVAC contractors must review and select registers that will mix the air well to ensure comfort.

CONCLUSIONS

The SPF home is inherently very thermally efficient with a tight envelope. This means that sensible (temperature) loads will be greatly reduced, but latent (humidity) loads will remain where they have been. Adequate fresh air ventilation and design for good humidity removal to address these changes are essential. This often means selecting an evaporator coil with a better sensible heat ratio and variable speed ECM blowers with thermidistat controls (in humid climates, adding standalone dehumidification equipment will successfully solve these issues). Ventilation can be addressed by high efficiency, super quiet exhaust fans, providing supply air to the return plenum, or a balanced airflow approach using ERV or HRV technology.

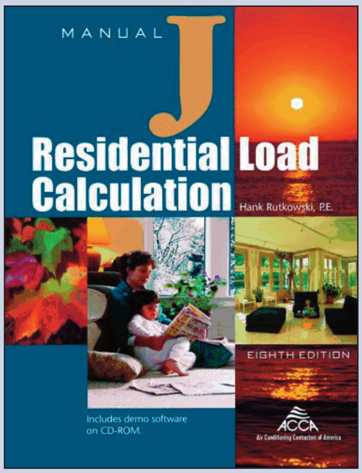
In all tightly sealed homes, including those insulated with SPF, only sealed combustion or power vented combustion appliances should be installed to ensure safe operation. The new *ACCA Manual J, Eighth Edition* must be used to perform our loads because it is the only version capable of handling these homes correctly and equipment must be selected using ACCA Manual S.

With these changes, HVAC equipment can be safely installed in SPF homes with confidence. These steps allow for optimized indoor air quality, moisture control, combustion safety, air mixing and equipment sizing.

Spray Foam Solves These Envelope Problems

Spray foam insulation when properly installed can be counted on to reliably deliver the R-value that the Manual J8 calculations assume are there. It expands to provide a total wall fill, and it doesn't compress or settle over time. SPF is its own air barrier, too. It stops convection in the insulation and stops outside wind intrusion, so it produces a tight envelope air barrier and positive control of air infiltration. Now, sizing and installing equipment strictly to the Manual J8 load can be done with confidence. In fact, it is essential with these homes.

Builders would be wise to always require that their HVAC contractor provide the room-by-room ACCA Manual J8 before the equipment is installed, especially in SPF-insulated homes. For spray foam homes, sizing must be done with the most current version of *ACCA Manual J, Eighth Edition*. This is the only version of Manual J that can accurately model and determine the true heat gain/heat loss of spray foam insulated homes. It is the only version of Manual J to feature SPF insulation as a selection on the drop down menus, to accurately model the impact of having the equipment and ducts fully in a sealed, unventilated attic, as so many spray foam homes do, and to allow input of the actual, tested duct leakage and air infiltration rate.



ACCA MANUAL J, EIGHTH EDITION (J8)

ACCA Manual J load calculations are critical for spray foam houses because the loads themselves are considerably lower than the rule of thumbs often used in the industry. As building envelopes continue to improve, this will be necessary for all homes. In fact, under 2009 codes, performing an ACCA Manual J8 heating/cooling sizing software calculation and selecting equipment according to ACCA Manual S are mandatory.

Sizing must be done with the most current version of *ACCA Manual J, Eighth Edition*. This is the only version of Manual J that can accurately model and determine the true heat gain/heat loss of spray foam insulated homes. It is the first version of Manual J to feature spray foam insulation as a selection on the drop down menus. And, it is the only version that can accurately model the impact of having the equipment and ducts fully in a sealed, unventilated attic as so many spray foam homes do.

Actual field tested air change rates should be inputted in Worksheet E > Infiltration > Option 3, instead of choosing from three standard air change rates that are all too leaky to reflect the tightness of a spray foam home.

Actual duct leakage to the outside should be inputted as well in this version. If the ducts and equipment are all in conditioned space, as they often are in spray foam homes, this duct leakage should be set to zero. Otherwise, the actual tested value should be entered.

Mechanical ventilation is an important load in spray foam homes. These inputs can be found on standard input page of MJ8 software in the box label "Ventilation." Enter the number of cubic feet per minute of outside air that will be introduced to ensure excellent indoor air quality. The sensible and latent loads that this air will introduce will automatically calculated by the software and added to your load using design day conditions.

The software links to AHRI/GAMA databases so equipment can be selected with confidence. It links to REM/Rate and FSEC EnergyGauge – the software tools used by the RESNET and Home Energy Raters (HERS), and IECC REScheck energy code compliance software. These are all capabilities contractors will need and value, because they are required now by many cities, utilities. Clients will also demand these for super efficient and green homes.

The *ACCA Manual J, Eighth Edition* is a must in an HVAC contractor's toolbox, particularly for spray foam insulated homes. Taking these steps will ensure that the sizing of the equipment is best suited to the home resulting in lower first cost for equipment, lower operating costs for the owner and better comfort and humidity control in the home.

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3) www.buildingscience.com/documents/reports/rr-0505-residential-dehumidification-systems-researchfor-hot-humid-climates/view?searchterm=humidity%20control
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Ventilation Considerations for Spray Polyurethane Foam

Guidance on Ventilation During Installation of Interior Applications of High-Pressure Spray Polyurethane Foam

Spray Foam Coalition
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American Chemistry Council | Spray Foam Coalition

This document is intended to provide general guidance on ventilation during installation of interior applications of spray polyurethane foam (SPF) in new residences and buildings and during renovation and weatherization projects in existing homes and buildings. SPF is a widely used and highly effective insulation and sealant material that is spray-applied to walls, ceilings, attics, basements, and crawl spaces.

SPF is a highly effective sealant, and its application could seal the building enclosure below the minimum ventilation rates required by building codes or recommended design requirements. *This document does not discuss permanent mechanical ventilation systems, but in certain cases the use of such systems may need to be considered.* Consult with a design professional to determine if it is appropriate.

Why use work zone mechanical ventilation during and shortly after SPF installation

Work zone mechanical ventilation during and after SPF installation is designed to prevent workers and others in the area from being exposed to SPF chemicals above recommended or permissible levels. Potential health effects from exposure above recommended levels can range from no effects to slight irritation of the eyes, skin or respiratory system to the development of chronic lung or pulmonary disease depending on the individual person and level and duration of overexposure.[1, 2]

SPF chemical components include isocyanates (A-side material), which are irritants (causing effects on eyes, skin, and respiratory system) and sensitizers that may produce an allergy-like response in some people after re-exposure. Exposure of a sensitized individual has the possibility to result in skin and/or respiratory reactions. Respiratory effects (asthma attacks) can be severe (or fatal) even at very low levels of exposure in sensitized individuals.

The B-side material (polyol or resin blend) used in SPF is a formulated product that contains polyols, blowing agents, catalysts, flame retardants, surfactants and other additives. These component materials could also result in irritation of eyes, skin and respiratory system from overexposure. A temporary condition referred to as “Blue Haze” or “Halovision” could also result from exposure to catalysts. For more information on chemical health and safety, see “Health and Safety Product Stewardship Workbook for High-Pressure Application of SPF.”[2] Important information concerning health and safety is available online for free, including the CPI Chemical Health and Safety Training for both high-pressure SPF and low-pressure SPF here: www.spraypolyurethane.org.

When SPF is applied using high-pressure application equipment, some SPF component chemicals may be present in the form of aerosol mists and vapors over the occupational exposure level (OEL) or at levels that could be harmful to some individuals.[a] Engineering controls including containment and properly designed ventilation systems should be used *in tandem* with proper personal protective equipment (PPE).[3] These protective measures can help prevent SPF applicators, helpers, and others who may be working in adjacent areas from potential exposures. In addition, taking steps like access restrictions and evacuation of the home are important during and shortly after installation to minimize potential exposures.

[a] Not all SPF component chemicals have OELs.

Current studies show use of engineering controls alone (containment and ventilation systems) during high-pressure SPF application do not sufficiently reduce airborne chemicals to below levels needed to eliminate the use of recommended PPE for those in the work zone during and shortly after spraying.[4,5] Use engineering controls and proper PPE together when applying high-pressure SPF in interior applications.

When to consider using a mechanical ventilation system during installation

Airborne SPF chemicals can rapidly accumulate in enclosed interior spaces, depending on the ambient conditions, size of the work zone and the amount of SPF applied. Enclosed work zones include the interior space of buildings, especially in areas with minimal natural ventilation like attics and crawlspaces. Isolating and ventilating the areas of SPF application should be considered so that other trade workers and building occupants are not potentially exposed to SPF chemicals. The need for mechanical ventilation systems during application and shortly after should be reviewed in all applications of high-pressure SPF.

Who is responsible for constructing and using containment and mechanical ventilation systems

According to OSHA regulations,[6] SPF contractors have a legal responsibility to provide a safe workplace for all employees. In the case of high-pressure SPF application, use of engineering controls and proper PPE in the work zone during and after spraying is an important consideration to help achieve a safe workplace. In addition, it is a good practice for the SPF contractor to advise the building owner (homeowner or general contractor) of all hazards associated with SPF application. Conduct a meeting between the SPF contractor and the building owner before SPF application to discuss potential hazards, containment and ventilation methods, the importance of vacating, and when it is safe to reoccupy the building during and after SPF application.

What does a SPF contractor consider when designing and constructing a containment and mechanical ventilation system

Application of SPF to walls, ceilings, attics, and basements within buildings of varying size and geometry creates some challenges for designing containment and ventilation configurations because every job site will be different. Work zones vary in size, geometry and ambient conditions, and the delivery rate and position of the contaminant source (i.e. spray gun), as well as air flow, will change throughout the job as the applicator moves around the room.

Applicators, helpers, occupants, and adjacent workers should avoid inhalation of, and skin and eye contact with, SPF chemicals.[7] The following practices, including engineering controls, work practices, and PPE, are intended to reduce the potential for overexposure to SPF chemicals via inhalation, skin or eye contact. Consider a combination of engineering controls, work practices, and PPE for SPF applications. Individuals not involved in the application process vacate the area and return after informed that it is safe to do so.

Engineering Controls: Proper containment and ventilation techniques can help prevent workers and building occupants from potential exposure due to SPF application, particularly in interior applications when buildings cannot be vacated. This can occur in large, commercial buildings where vacating the entire building is not feasible. Containment creates a restricted work zone while the ventilation system removes SPF chemicals from the work area by drawing the air out of the work zone through the use of a fan. In addition to the engineering controls, the use of PPE further reduces the potential for exposure.

- **Work Zone Containment:** Work zone containment is used in conjunction with ventilation to isolate and remove chemicals from the work area. Work zone containment is most effective when a space is as close to airtight as can practicably be achieved. If a work zone is contained, clearly mark the area externally, and take appropriate steps to restrict entry into the work zone to personnel wearing proper PPE.
- **Ventilation Design:** Ventilation used with work zone containment removes chemicals from the isolated area via negative pressure. Having negative pressure in a contained work zone will draw in air from small cracks and gaps around the work zone boundary and exhaust the work zone air. Active ventilation is achieved by using one or more fans to draw air from the work zone and create a negative pressure inside the work zone. Give careful consideration to the location of the exhaust. Release exhaust to an unoccupied space where it is not drawn through an air intake. This also helps protect occupants and workers in adjacent areas from potential exposure.

A. Work Zone Containment

Prior to application of high-pressure SPF within a building, construct a containment or enclosure system to isolate the work zone from other parts of the building. This containment system serves several important functions:

- Prevents airborne mists and particulates from migrating to other parts of the building. Minimizing air and particulate migration not only helps prevent unwanted deposits (i.e. overspray) on finished surfaces outside of the work zone, but also prevents the spread of contaminants to those areas. Containment can minimize the need for additional ventilation outside of the work zone.
- Minimizes the total volume of the work zone for ventilation, thus reducing the size and number of fans, and helps to direct airflow across the point of SPF application.
- Establishes a defined boundary between the work zone and other areas in the building, when properly marked with hazard signage at all entrance points, thus helping to prevent unwanted entry by persons not wearing PPE.

An example of a material used to build a containment area in SPF applications is 4-6 mil polyethylene sheeting. Sheeting can be purchased in roll widths corresponding to the interior wall height, usually 8-10 feet high. This sheeting should be installed to provide a negative pressure in the work zone.

In addition, all penetrations and openings to other parts of the building, including open areas between the ceiling joists above the interior walls, are temporarily blocked with faced fiberglass batts, plastic sheeting or other materials and tape to minimize air flow as shown in Figure 1. All finished surfaces, such as windows and immovable furnishings and appliances, are masked to prevent overspray.

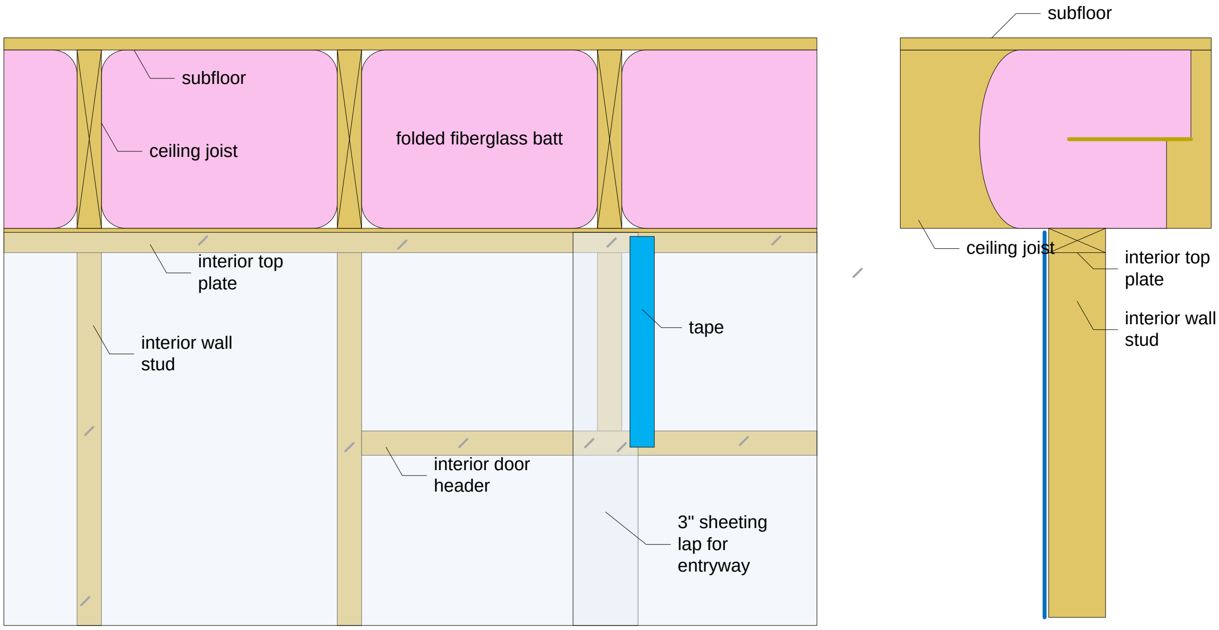

FIGURE 1 – Example of using batts to seal openings in ceiling joists

It is also important to deactivate the HVAC system and cover HVAC registers and grilles (see Figure 2) during installation and ventilation of the work zone. Use OSHA's lock-out/tag-out (LOTO) procedures to de-energize and secure the HVAC system breakers or sub-panel and/or use a sign/tape over the switch, as shown in Figure 3. Turn the HVAC system back on after ventilation is stopped and prior to re-occupancy.

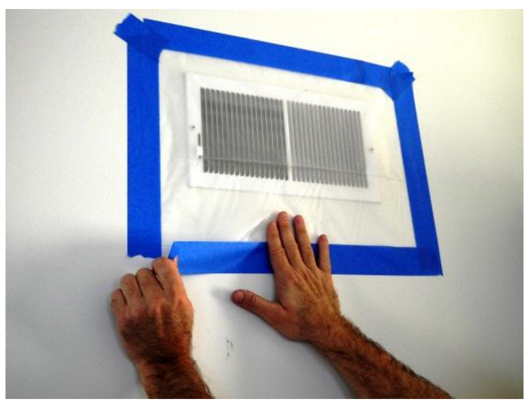

FIGURE 2 - Cover and taping all grille and register openings into containment

FIGURE 3 - Deactivate and mark HVAC system at electrical panel (use LOTO procedure and indicate date, time and name of person applying the tag)

An adequately-sealed containment system will provide a negative-pressure enclosure around the work zone when proper ventilation fans are used.

B. Ventilation Design

During SPF application, the main source of chemical vapor and particulate emissions is the spray gun. The location of this source (the spray gun) moves as the point of application progresses throughout the work zone. This moving of the source creates unique challenges in designing and implementing an effective containment zone and ventilation system. If a single, immobile fan is used, the system may resemble a simple exhaust-only system. To maximize the system's effectiveness, one must understand the following components and how they work together:

- **Contaminant Source:** In the case of SPF, this is the spray gun and curing foam.
- **Work Zone:** The space, room or enclosure to be ventilated, within the containment area.
- **Exhaust Air System:** The exhaust air system includes an exhaust point, ductwork and an exhaust fan that captures contaminates at the source and sends them to a location outside the building away from occupied areas and air inlets.
- **Supply Air System:** The supply air system provides a source of fresh outside air into the work zone that is needed to replace the air removed by the exhaust system. This make-up air can be provided passively through various penetrations in the containment (such as windows, doors, exterior vents and other openings) or through a dedicated active forced-air inlet system consisting of a supply point, ductwork and second supply fan. Supply air systems can be comprised of both passive and active systems.

One way to think about this is to consider the exhaust and supply air systems as a "push-pull" system. The supply air system pushes air into the contained space, delivering a positive pressure inside. The exhaust air system pulls the air from the containment, creating a negative pressure. To assure that a net negative pressure is created in the containment, the exhaust air pulled from the containment should always be more than the supply air pushed into it.

How one designs or places each of these components will determine the effectiveness of a ventilation system. One can employ a single-fan, exhaust-only system which, by default, generates a negative pressure in the work zone or containment. However, such systems may provide limited ventilation and air flow to some points in the work zone due to the source (spray gun) moving in the work zone. More importantly, exhaust-only ventilation may gradually become less effect as SPF is applied, as the foam seals sources of passive make-up air. Fixed, passive supply air sources such as open windows and doors are also problematic in that the ambient air temperature and humidity may be hard to control, and the fixed location may create dead air sites within the containment.

A ventilation system consisting of both active exhaust and supply air systems can address these issues. Figure 4 shows such a two-fan system. There are several key points to consider when designing this type of system:

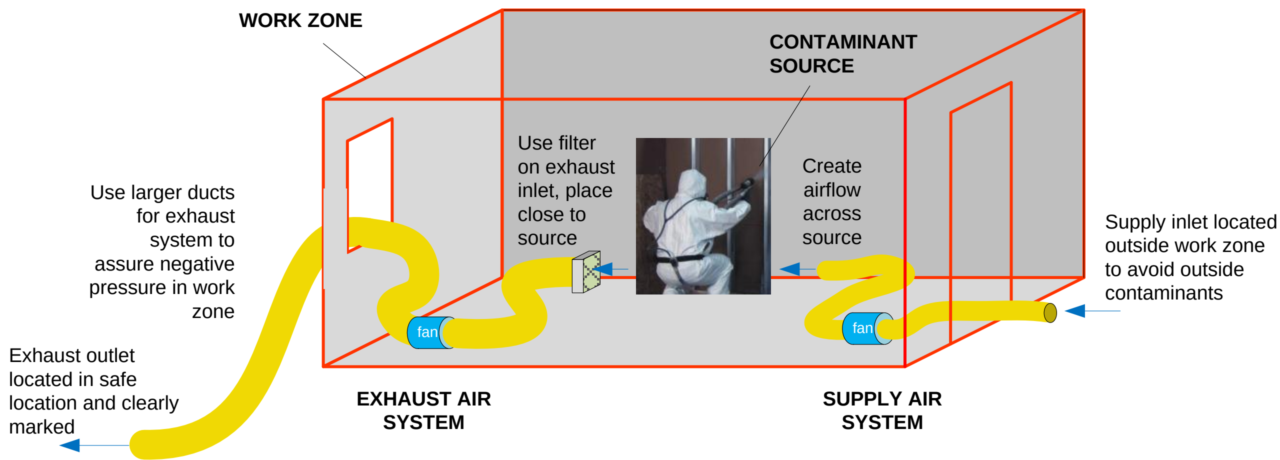

FIGURE 4 – Example of a Two-Fan Ventilation System (active exhaust and supply systems) for interior SPF Application

- **Maintain a negative pressure in the work containment zone.** A negative pressure within the containment zone assures that contaminants are not forced into other areas of the building. With a two-fan system, negative containment pressures can always be achieved when the exhaust fan capacity (e.g., CFM rating) is greater than the supply fan capacity. For most systems, it is suggested that the capacity of the exhaust fan exceeds the capacity of the supply fan. Use caution with multi-speed fans so that the supply fan rate does not exceed the exhaust fan rate. A smoke-pencil is often used to visually confirm that the containment is always under a state of negative pressure. Observing an inward billowing of the plastic film used for containment can also confirm a negative pressure in the containment area. If the plastic sheet billows outward, there is too much supply air or insufficient exhaust air. Remember, to create a net negative pressure the air pulled from the containment exceeds the air pushed into the containment.
- **Check placement and direction of fans.** Direct fans in the appropriate direction: use the larger-capacity exhaust fan for pulling air from the containment area to the outdoor and the smaller supply fan to bring air indoors.
- **Generate and maintain air flow across the spray area.** Position the inlet of the exhaust system and the outlet of the supply system at locations on both sides of the spray foam application site (contaminant source). This position helps to assure maximum airflow across the application site. Move the exhaust inlet along with the applicator as necessary as the job progresses to help move contaminants away from the applicator, and to help have the applicator (contaminant source) lined up on a straight line between the supply air outlet and the exhaust air inlet.
- **Avoid unwanted openings in the work zone.** Unwanted or unknown openings through the work containment zone can make the ventilation system less effective. If a negative pressure exists in the work zone, make-up air will enter the containment from these passive openings. If these openings are large enough, a direct flow of air between these openings and the exhaust air system will occur, which may create dead-air spaces in other parts of the containment zone. If the SPF application site is not between these openings and the exhaust system (e.g., if the spray gun is in a dead space), the ventilation system will not work efficiently.
- **Exhaust contaminants to a safe outside location.** Air from the outlet of the exhaust system may contain elevated levels of SPF component chemicals and

What to consider when determining how long to continue ventilation after installation

After foam is applied, continue to follow the manufacturer's instructions regarding ventilation rate and duration to ventilate the work zone. Some of the factors affecting the ventilation period include specific foam formulations and cure times, ventilation rate and ambient temperature and humidity inside the containment. During this time, reentry includes only persons with appropriate PPE. Occupants can re-enter after the manufacturer's stated reentry time.

What to consider when thinking about extended ventilation

In some cases, extended ventilation may be helpful or desired. For example, older homes may have odors in the attic from mold, rodent and bat droppings and small animal carcasses. In these cases, extended ventilation may be helpful. Contractors may opt to leave the existing ventilation system in place, or may choose to use an alternate system such as an exhaust-only system. Check with the SPF manufacturers for extended ventilation rates, which may be much lower than the rate used during and shortly after SPF application.

For extended ventilation, a smaller exhaust-only system may be used where the outlet of the exhaust only system is positioned in a safe location. Another option is to use a heat recovery ventilator (HRV) or energy recovery ventilator (ERV) installed inside the containment area, which is an example of an energy-efficient means to provide extended ventilation (shown in Figure 9). If this option is utilized, the exhaust line is disconnected from the vent opening (A), a fire-damper grille is installed on the opening, and the exhaust line is positioned in the attic (B) far from the disconnected vent. Read and follow the HRV/ERV manufacturer's recommendations if this extended ventilation option is utilized. This configuration can provide extended ventilation for several days after which the contractor re-installs the exhaust duct when the extended ventilation is complete.

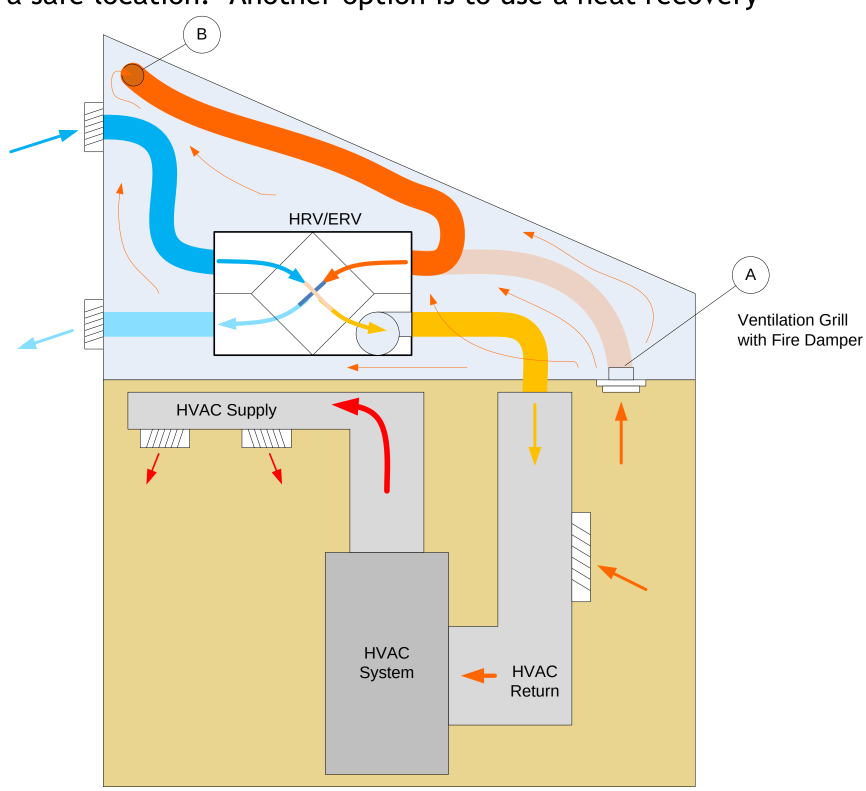

FIGURE 9 - Extended Ventilation using HRV/ERV System

particulates. Direct the exhaust air outside, far away from the air inlet point and away from occupied areas. Cordon the outlet off with physical barriers to prevent access and mark it.

- **Use filtration on the inlet of the exhaust system.** During the ventilation process, mists and particulates are collected by the exhaust system. Over time, these materials can accumulate and reduce the effectiveness of the ductwork and fan of the exhaust system. To reduce this accumulation of particulates in the equipment and minimize the contaminants at the exhaust outlet, filtration is often used. A box with a replaceable filter can be used. Regularly inspect and replace the filter media for proper function of the exhaust system.

What to consider when selecting the fan size necessary for the exhaust and supply ventilation

The effectiveness of a ventilation system is determined by the design of the containment and the ventilation rate. The containment ventilation rate is measured by the number of air changes per hour (ACH). ACH is how many times per hour the volume of air within the containment area is completely replaced with fresh air.

Use the SPF manufacturer's recommended containment ventilation rate to determine the size of the ventilation system fans. Generally, consider the following:

1. Determine the total volume of the containment to be vented. This can be done by taking the floor area in square feet (length x width of the containment floor in feet) and multiplying it by the average height in feet of the containment. This provides the total volume of the containment in *cubic feet*.
2. Take the recommended ventilation rate in ACH (air changes per *hour*) and divide it by 60. This is the recommended air changes per *minute*.
3. Multiply the recommended containment ventilation rate in air changes per *minute* by the total volume of the containment in *cubic feet*. This number provides the minimum required capacity of the exhaust fan needed in cubic feet per minute (CFM).

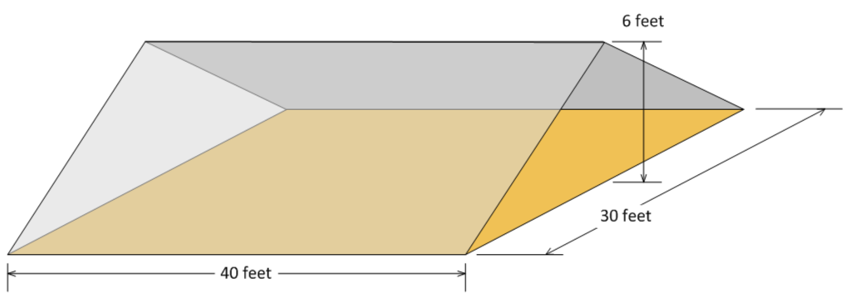

FIGURE 5 - Diagraph of Attic

Example:
An individual is applying SPF to create an unvented attic in a home, as shown in Figure 5. The floor space of the attic is a simple 30' wide by 40' rectangle. The peak of the roof is 6 feet above the attic floor. Assume a ventilation rate of 30 ACH is specified by the SPF manufacturer. What size fan is needed? Assume the entire attic defines the containment zone.

1. *Determine the attic (containment zone) volume in cubic feet:*
   a. *Area of attic floor = 30' x 40' = 1200 sq. ft.*
   b. *Volume of attic = 1200 sq.ft. x (½) x 6' = 3600 cu.ft.*
2. *Convert the recommended ventilation rate to air changes per minute:*
   a. *30 ACH / 60 = 0.5 air changes per minute*

3. *Calculate the minimum fan size (larger is better):*
    a. *0.5 x 3600 = 1800 CFM*

This information is provided as an example only.

Remember the following:
1. Attachments and accessories such as ductwork, ductwork fittings and filters can substantially reduce the rated air flow performance of any fan system. Check with the fan manufacturers to confirm how to properly size the fan.
2. The size of the containment and the desired ventilation rate may exceed the rated performance of the fan systems. In this case, multiple exhaust and supply fans may prove necessary to achieve the required air flow (supply and exhaust) or the size of the containment may need to be reduced.

Contractors can purchase the necessary fans, ductwork and other equipment to create a complete ventilation system. For example, compact, portable and powerful fans are axial blower fans as shown in Figure 6. These fans, typically about 8-12" in diameter are easy to move around the jobsite, and provide a direct controllable air flow pattern. Axial fans of this size can provide unrestricted flow rates of over 2,000 CFM that may be adequate for small homes or partitioned containment areas in larger homes and buildings, but users need to review the manufacturer's recommendations.

FIGURE 6 – Flexible Duct Attached to Axial Fan

Portable axial blower fans can be connected to flame-resistant flexible ducts that can be easily positioned inside the containment area, as shown in Figure 8. Duct lengths of around 25 feet help to be able to reach more points within the containment area to reduce the number of stagnant air spaces.

If there is no easy access to fans with two different flow rates, one can use different size ducts to provide different fan flow rates for the same fan. For example, a 12" diameter fan may be rated at 2,200 CFM of free air flow (using a 12" duct with no 90 degree elbows). The same 12" diameter fan may have a reduced flow rate of 1,700 CFM when connected to an 8" hose with an adapter. For example, using a 12" duct for the exhaust system, and an 8" duct and adapter for the supply system could provide the necessary flow rate difference. Alternately, the same duct sizes can be used on both the exhaust and supply system when a damper or 'valve' is placed in the supply system to throttle the supply air flow. Observe the plastic film used to isolate a spray area to see if negative pressure is being created (film tends to move inward to the space being sprayed) or use a smoke stick to check proper air flow.

FIGURE 7 – Filtration Box for Exhaust System Inlet

Also, a good worksite hygiene practice is to consider using and labeling specific fans and ducts for supply or exhaust system use only.

Consider how to filter the exhaust air. For example, some fan manufacturers provide filter boxes as accessories as shown in Figure 7. Remember that the purpose of this filter is to protect the downstream equipment, not to remove allergens and dust.

The example provided about using separate supply and exhaust systems is representative. There are other ways to deliver sufficient ventilation rates and negative containment pressurization on a given SPF jobsite. Truck or rig mounted ventilation systems may be used. Another example is the use of an axial exhaust system with a blower-door fan to provide supply air.

What to consider when using an exhaust and supply ventilation system during installation

The setup of the ventilation system can be challenging, especially when working in the attic or crawlspace of an existing home. When applying SPF in a typical room, a configuration as shown in Figure 4 may be used.

When working in an attic or crawl space of an existing home, finding the needed openings for the supply and exhaust ducts can be difficult. Consider whether it is difficult or unsafe to run both the exhaust and supply ducts through a small scuttle hatch into the attic or crawl space. If the hatch is not used for both the exhaust and supply, consider connecting the supply duct to an existing external opening, such as a gable or soffit vent or an attic fan opening, and not foam over it initially. If this option is undertaken, consider spraying a piece of foam (or use boardstock foam) that can be cut to fit into the opening after the ventilation time period is completed. Consider using a low-pressure spray foam system to adhere the foam “patch” in place and caulk the crack between the patch and the remainder of the surface. An additional option is to create a supply duct opening in the ceiling of a concealed area like a closet (with the owner’s permission). With any option chosen, direct the exhaust duct to a safe outside location. An example is provided in Figure 8.

Remember that the ducts in the work zone could create excessive trip hazards or limit emergency egress.

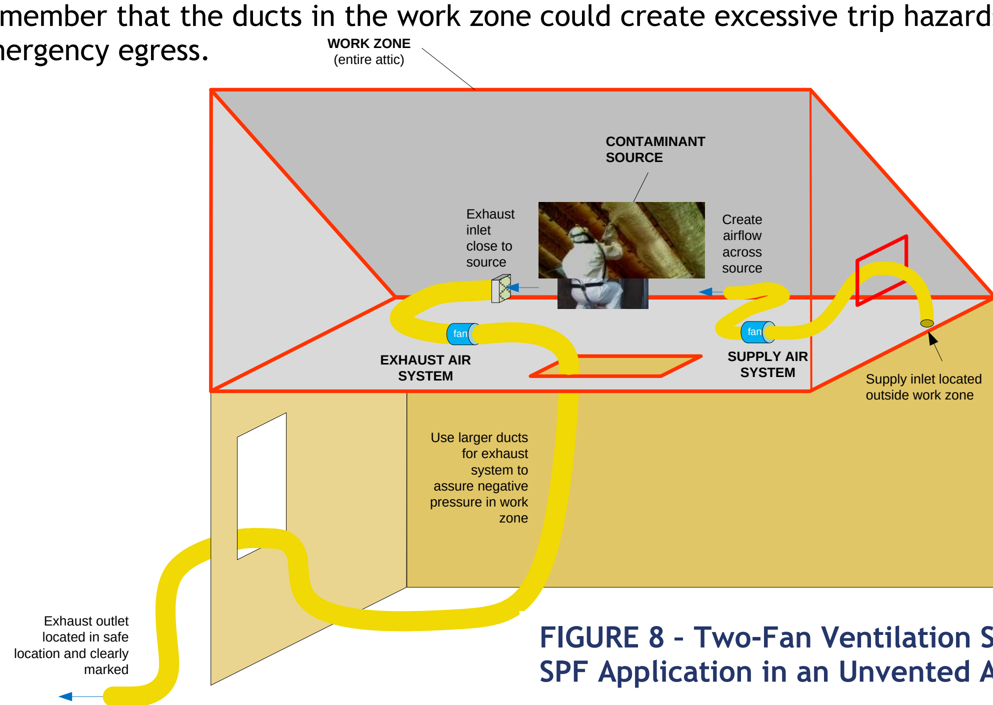

FIGURE 8 – Two-Fan Ventilation System for SPF Application in an Unvented Attic

In Summary:

- During and shortly after high pressure SPF installation in indoor applications aerosol mists and vapors can be generated at levels over the occupational exposure level (OEL) or at levels that could be harmful to some individuals.[b]

- To protect workers and others against exposure, the SPF contractor is required by OSHA to establish engineering controls and ensure proper personal protective equipment is utilized by their employees in the work zone.

- Engineering controls for high-pressure SPF application can include establishing a containment zone that is mechanically ventilated using adequately-sized exhaust and supply air systems.

- Ventilate the SPF work zone during application and after spraying based on SPF manufacturer's installation instructions.

- Consult with the SPF manufacturer to determine the recommended reentry and re-occupancy times for the particular job and SPF in use.

- Consider extended ventilation to remove odors.

How Can I Get More Information on SPF Ventilation

- Contact the SPF product manufacturer or supplier, or contact an industrial ventilation equipment supplier.
- Refer to information posted on CPI's SPF chemical health and safety website at www.spraypolyurethane.com.
- Consult the National Institute for Occupational Safety and Health (NIOSH) by either calling 1-800-CDC-INFO or by visiting the NIOSH website.
- Refer to EPA's Ventilation Guidance for Spray Polyurethane Foam Application[1]
- Guidance on Best Practices for the Installation of SPF[8]

Disclaimer: This guidance document was prepared by the Spray Foam Coalition of the American Chemistry Council's Center for the Polyurethanes Industry. It is intended to provide general information to professional persons who may be involved in installing spray polyurethane foam. It is not intended to serve as a substitute for in-depth training or specific construction requirements, nor is it designed or intended to define or create legal rights or obligations. It is not intended to be a "how-to" manual, nor is it a prescriptive guide. All persons involved in construction projects including spray polyurethane foam have an independent obligation to ascertain that their actions are in compliance with current federal, state and local laws, codes, and regulations and should consult with legal counsel concerning such matters. The guidance is necessarily general in nature and individuals may vary their approach with respect to particular practices based on specific factual circumstance, the practicality and effectiveness of particular actions and economic and technological feasibility. Neither the American Chemistry Council, nor the individual member companies of

[b] Not all SPF component chemicals have OELs.

References

[1] "Ventilation Guidance for Spray Polyurethane Foam Application," published by the U.S. Environmental Protection Agency (EPA), online at www.epa.gov/dfe/pubs/projects/spf/ventilation-guidance.html

[2] "Health and Safety Product Stewardship Workbook for High-Pressure Application of SPF," published by the American Chemistry Council's Center for the Polyurethanes Industry, available online at www.spraypolyurethane.org/Workbook/

[3] "Personal Protective Equipment Sheet," published by the American Chemistry Council's Center for the Polyurethanes Industry, available online at http://www.spraypolyurethane.org/ppe_sheet

[4] Wood, Richard. "CPI Ventilation Project Phase 1 and Phase 2 Update." Presented at the CPI Technical Conference, September 2012.

[5] Robert, William, James Andersen, Richard Wood, and Mary Bogdan. "Ventilation and Re-Occupancy of a Residential Home Sprayed with High Pressure Polyurethane Foam." Presented at the CPI Technical Conference, September 2012.

[6] Code of Federal Regulations Title 29 CFR §1926.20 Safety and Health Regulations for Construction: General Safety and Health Provisions available online at www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=10606

[7] "Good Practices – Engineering Controls and Ventilation," published by the American Chemistry Council's Center for the Polyurethanes Industry, available online at: www.spraypolyurethane.org/GoodPractices#EngineeringControls

[8] http://polyurethane.americanchemistry.com/Spray-Foam-Coalition/Guidance-on-Best-Practices-for-the-Installation-of-Spray-Polyurethane-Foam.pdf