Enriching lives through innovation

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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 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 to 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

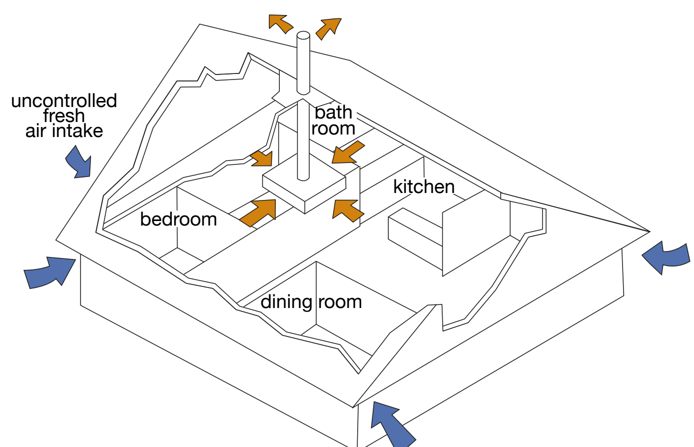
Ventilation for residential homes can be provided naturally or mechanically. Because SPF houses are tightly constructed, mechanical ventilation must be used. A home can be mechanically ventilated by either:

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

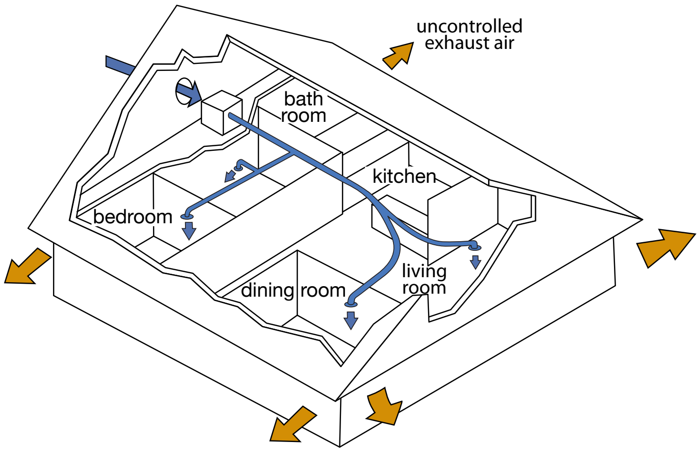
Balanced Ventilation - Providing an equal flow in both directions, exhausting as much air as brought in, creating no pressure at all. This is accomplished with a heat recovery ventilator (HRV) or an enthalpy recovery ventilator (ERV).

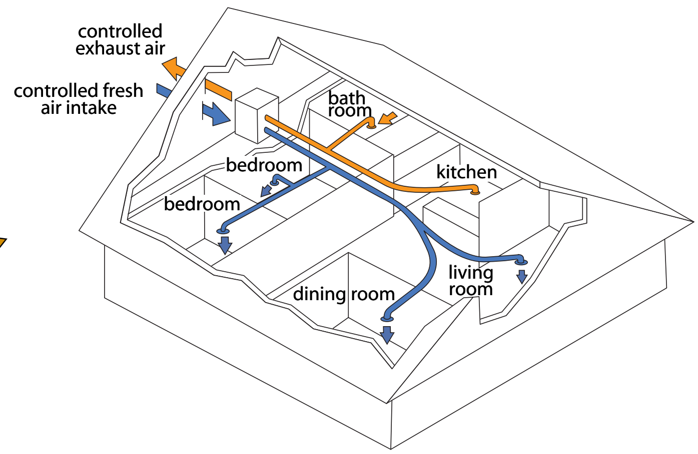
Either way, one cubic foot of air coming in equals one cubic foot of air going out and vice versa.



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.





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	

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 rules of thumb states that one ton of air conditioning equipment was needed for each 400 to 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 1/4 of the conditioned air and other common attributes of older homes needed a ton of capacity for each 400 to 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 to 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 dehumidication, 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.

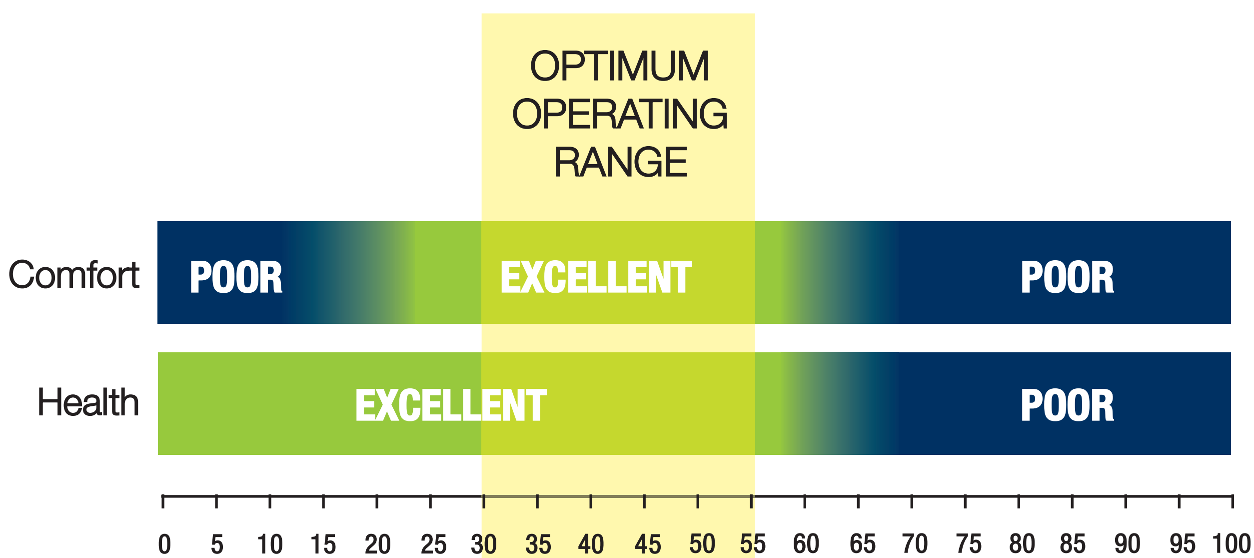
Moisture control is critical to both human comfort and to our health. ASHRAE studies have shown that most people are comfortable when the relative humidity is between 30 to 60 percent. When the indoor humidity exceeds 60 percent, owners will try to address this discomfort by lowering the temperature 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 to 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 dehumidification. 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.

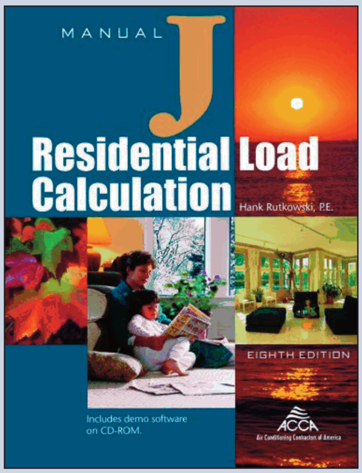
Envelope Efficiency Problems Contractors Didn't Know They Had

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.

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 rules of thumb 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 the 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 be calculated by the software and added to the 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.

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 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 stand-alone 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 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.

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