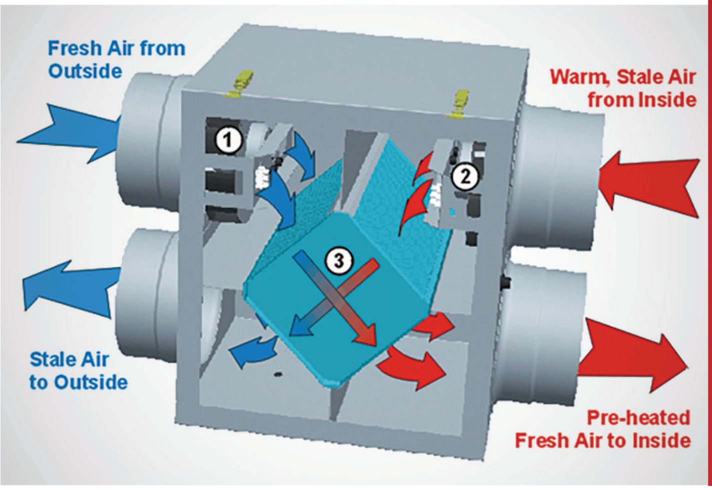
SIP DESIGN-BP 2: HVAC Systems with SIPs



Structural Insulated Panel Association

SIP DESIGN-BP 2:

HVAC Systems with SIPs

This document is created specifically for design professionals by the manufacturing members of the Structural Insulated Panel Association (SIPA). It dives deeper and provides more background into each of the summarized topics presented in the *Design with SIPs: DESIGN CONSIDERATIONS* overview which highlights important considerations during the design phase of a Structural Insulated Panel (SIP) structure. Decades of combined knowledge from SIPA manufacturers will help reduce the learning curve and leverage SIPs' exceptional qualities to achieve the high-performance results owners expect when building with SIPs. The considerations of how and why the best practices were developed as the common industry platform for SIP design are explored here.

The index below outlines ten topical areas, listed in sequence to match the order of design considerations and construction. The details in each chapter provide a deeper understanding of the subject matter to facilitate successful SIP design and later implementation. The current chapter is highlighted in blue.

1. High-Performance SIP Building Envelope
2. **HVAC Systems with SIPs**
    - **2.1. Oversizing equipment jeopardizes building and equipment durability while needlessly increasing expenses.**
    - **2.2. SIP building designers, HERS raters and HVAC professionals must accurately calculate thermal performance of SIP envelopes.**
    - **2.3. An energy model using ACCA Manual J or REM/Design software should be used to verify proper equipment sizing.**
    - **2.4. Airtightness: actual performance is best determined by a pre-drywall blower door test. A pre-construction estimate of less than 2.0 ACH is appropriate, and it is common to achieve less than 1.0 ACH50. Airtightness can be compromised if similar attention is not given to the other system components (e.g., windows, HVAC, plumbing, etc.).**
    - **2.5. Understand the R-value of the SIP provided. SIP R-value changes with thickness and R-values increase when temperatures drop. Code-required R-values are provided at 75˚F, but additional information is available at colder temperatures.**
    - **2.6. High-performance structures designed and built extremely airtight must have make-up air. There are several options with varying degrees of complexity and cost ensuring an HVAC system that will introduce fresh air.**
    - **2.7. Penetrations in the SIP envelope should be sealed to maximize airtightness.**
3. SIP Structural Capabilities
4. SIP Sizes
5. SIP Shop Drawings
6. SIP Fabrication
7. SIP Installation
8. SIP Roof and Wall Assemblies
9. SIP Electrical
10. SIP Plumbing

SIP DESIGN-BP 2:

HVAC Systems with SIPs

SIP DESIGN-BP 2.1: Oversizing equipment jeopardizes building and equipment durability while needlessly increasing expenses.

Bigger is not always better, neither are old rules of thumb. HVAC systems need to be designed for building performance. Leaky and poorly insulated buildings need larger heating, ventilation and air-conditioning systems (HVAC). High-performance buildings need significantly smaller HVAC systems. SIP buildings are very well-insulated and tighter, which results in HVAC systems easily being oversized if old rules of thumb are used to size equipment.

When the HVAC system is oversized, it tends to run for only short periods or 'short cycles.' When an air conditioner short cycles, it will not run long enough to reach peak efficiency and does not effectively reduce humidity (latent load) to a range of 40 percent – 60 percent relative humidity (RH) depending on outside temperature.[1] Lower than 40 percent RH dries mucous membranes and eyes making it easier for viruses to enter the body. Above 60 percent promotes mold growth which can irritate lungs. Another disadvantage of an oversized air conditioner is the system tends to be noisier and require more maintenance due to frequent starting and stopping.

Similar problems also occur if the heating system is oversized since equipment is often matched, and similarly oversized air conditioning coils can result, requiring larger ductwork to accommodate larger air flow. Again, the system short cycles causing uneven temperatures, more noise, and early shut-off from the wave of warm air making the building less comfortable. In the end, oversized equipment is not only more costly but can reduce operating performance, greatly shortening the equipment's lifespan.

SIP DESIGN-BP 2.2: SIP building designers, HERS raters and HVAC professionals must accurately calculate thermal performance of SIP envelopes.

Avoid using outdated rules of thumb (i.e., estimating 1-ton a/c per 600 sq. ft. area), which do not consider (1) the well-insulating and airtight nature of SIPs as compared to traditional framing, and (2) frequent substandard insulation installation methods.

The key to sizing HVAC equipment is matching capacity to load requirements. While many people focus on R-value, additional important elements are airtightness and properly installed insulation.

SIPs outperform most envelope systems due to their low air leakage, stable R-values, and low framing factor (about 3 percent) by eliminating embedded dimensional lumber, reducing thermal bridging. When lowering the air leakage rate, less outside air needs to be conditioned. Refer to ***SIP DESIGN-BP 2.4*** for typical SIP air leakage rates.

Installed cavity insulations, whether friction fit fiber batts, sprayed foams or blown-in cellulose, all have potentially degraded performance from poor field installation quality. Due to frequently bad quality insulation installation (QII) easily lowering the performance, code inspectors verify it visually and provide a score to pass. This score is used in the modeling and rating software to properly predict loads. SIPs do not suffer from this installation deficiency since they are factory built with rigid foam insulation eliminating cavities.

[1] For additional information, see online resources such as www.hvac.com.

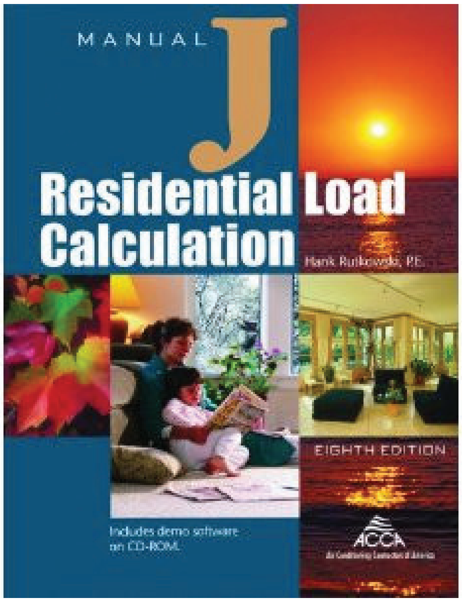
If a designer just calculates from simplified inputs, it distorts the end report. Entering a basic wall R-value, without identifying how the insulation is installed and the accurate amount of thermal bridging in the wall, will result in overvaluing a poor wall system and undervaluing a better system. When the envelope performance is not accurately calculated, it distorts the HVAC sizing causing the problems previously discussed. If designers and raters are not familiar with SIPs or how to model and design high-performance enclosures, they should research carefully how to input or seek help. These designs are critical to the workings of the entire project. See ***SIP DESIGN-BP 2.5*** in this chapter for more information.

SIP DESIGN-BP 2.3:
An energy model using ACCA Manual J or REM/Design software should be used to verify proper equipment sizing.

Consider an independent professional to perform an energy model using ACCA (Air Conditioning Contractors of America) Manual J and other software like REM/Design or Ekotrope to determine realistic loads for equipment sizing, because comfort, cost and proper HVAC performance are all interrelated. By using an independent professional, you are not relying on the same company which has a financial interest to sell you more equipment than you need.

Verify the system designer's record of accomplishment with installed systems and see if they are performing properly. Moreover, if a home is to be ENERGY STAR certified, the rater will have to enter the house design parameters into the REM/Rate system. This process should be done before the project is started, and the rater can give you the loads from the software to compare with the mechanical/HVAC supplier's recommendations. Do not be afraid to challenge or ask your mechanical/HVAC supplier questions and see proof that they completed the ACCA Manual S for equipment sizing and ACCA Manual D for proper duct design. The ACCA website (www.acca.org) can provide examples. Without completion of a detailed Manual S, there is no way to guarantee that the dehumidification (latent load) demands are properly taken into consideration. If the supplier cannot answer your detailed questions, they should not be installing or designing HVAC for your project. RESNET HERS Raters offer independent, third-party performance ratings to provide load designs.

Once the envelope is completed, the overall airtightness is confirmed by a blower door leakage test, which is typically done after drywall is hung and taped. Of course, installation and quality of other key envelope system components like windows, plumbing and HVAC equipment must be addressed to achieve these low airtightness levels. These leakage results feed back to both the ACCA Manual J calculations and REM/Rate software for adjustment with the actual verified enclosure performance to properly predict the modeled loads based on the installed HVAC equipment.



SIP DESIGN-BP 2.4:

Airtightness: actual performance is best determined by a pre-drywall blower door test. A pre-construction estimate of less than 2.0 ACH50 is appropriate, and it is common to achieve less than 1.0 ACH50. Airtightness can be compromised if similar attention is not given to the other system components (e.g,. windows, HVAC, plumbing, etc.).

HVAC professionals can account for airtightness in the design of the mechanical systems in SIP homes provided they have the proper information. Mechanical professionals use ACCA Manual J as the design guide to calculate the requirements for the heating and cooling systems in structures. Today, these calculations are computer based, but two important SIP properties need to be input into the software to provide meaningful results.

Manual J based calculations require the R-value of the insulation material and the air infiltration rate, or air leakage rate. The R-value is relatively straightforward. However, the air infiltration rate for SIPs must be addressed properly. Design guidelines for Manual J calculations suggest a reasonable air leakage assumption between 0.35 to 0.50 natural air changes per hour (ACHnat) unless a builder has data specific to their construction practices indicating they build tighter or looser. The Manual J recommendation is for stick built homes.

SIP manufacturers have blower door test data that has been generated from structures using SIPs for the exterior walls and roof of the building that test out at 0.04 to 0.06 ACHnat. These values for SIP structures are on the order of ten times better than what the Manual J design guidelines suggest.

SIPA recommends that a value of 0.05 ACHnat be used when performing Manual J heat loss calculations on structures using SIPs as the exterior walls and roof. If the software being used does not allow for numerical input, select the tightest option.

Be aware that blower door air leakage tests are also conducted by creating a pressure difference of 50 pascals between the inside and outside of the structure being tested. The leakage rate is often referred to as air changes per hour at 50 pascals of pressure or ACH50. Properly installed SIP structures regularly achieve leakage rates below 2.0 air changes per hour at a pressure of 50 pascals (ACH50), to as low as 0.3 ACH50 which is below the Passive House standard of 0.6 ACH50.

It is very important, since software systems often accept both of these testing system values (ACH50 and ACHnat), that the values are not confused or entered incorrectly since they differ by a factor of ten. It is easy to misplace or confuse the decimal place between the two by a factor of ten and have a resulting system design ten times too big.

Also be aware: when modeling software asks for input on air leakage rates for various assembly types, always enter the tightest construction (least leaky) option for SIPs. This is especially important when actual tested air leakage values are not able to be entered into the software. Air leakage rates dramatically affect energy load calculations, more than insulation values. Wrong data entered or software choice selections can easily oversize mechanical equipment and negatively affect building comfort, health and material durability.

SIP DESIGN-BP 2.5: **Understand the R-value of the SIP provided. SIP R-value changes with thickness and R-values increase when temperatures drop. Code-required R-values are provided at 75˚F, but additional information is available at colder temperatures.**

Insulation is one of the key components of any energy-efficient home or commercial building. One of the common metrics used to evaluate the energy efficiency of various building systems, such as SIPs vs. conventional stick framing, is to compare R-values which measure a material’s thermal resistance. An insulating material with a higher R-value forms a more effective thermal barrier between the outside temperature and the conditioned space inside the home.

In the U.S. the R-value of insulation is determined using a standard testing method conducted in a controlled environment where there is no air movement and at a temperature of 75°F. However, for colder climates the R-value should be evaluated at typical winter temperatures as shown in Table 2.1. It is noted that R-values may vary slightly from manufacturer to manufacturer.

TABLE 2.1

SIP R-VALUES AND U-FACTORS IMPROVE WITH FALLING WALL TEMPERATURES (MINIMUM INDUSTRY VALUES)

SIP Total Nominal Thickness (EPS Type I)	R-value @ 75°F	U-factor @ 75°F	R-value @ 40°F	U-factor @ 40°F	R-value @ 25°F	U-factor @ 25°F	R-value @ 0°F	U-factor @ 0°F
4 1/2”	13.9	0.072	15.3	0.065	16.0	0.062	17.1	0.058
6 1/2”	21.1	0.047	23.3	0.043	24.4	0.041	26.1	0.038
8 1/4”	27.4	0.036	30.3	0.033	31.8	0.031	34.0	0.029
10 1/4”	34.6	0.029	38.3	0.026	40.2	0.025	43.0	0.023
12 1/4”	41.8	0.024	46.3	0.022	48.6	0.021	52.0	0.019

NOTES:

1. EPS foam core minimum R-values used based on the ASTM C-578 standard at the lowest density (0.90 lb/ft3) in the Type I foam range. Higher density EPS and other foam types with associated higher R-values are typical for SIP applications. Consult specific SIP manufacturers for actual higher values and options. These values are provided as industry minimums for conservative, preliminary modeling purposes.
2. Listed SIP R-values are based on average wall temperatures (inside wall temperature + outside temperature divided by 2). In most U.S.-based designs, R-values above 00 F will be most common.
3. OSB R-values of 1.085 based on two 7/16” facers.
4. SIP thicknesses are nominal inches.

However, it is important to note that a comparison of R-values doesn't tell the whole story. While laboratory tests that determine R-values provide a relative measure for comparing the thermal performance of roof and wall assemblies, there are many factors that affect the building's performance. When real-world factors such as air infiltration, extreme temperatures and thermal bridging are present, field-installed fiberglass insulation can lose more than half its R-value. Research has repeatedly shown that SIPs with EPS core insulation provide a stable R-value over the life of the building.

The Department of Energy's Oak Ridge National Laboratory (ORNL) has studied and tested the performance of entire wall assemblies in large sections. The resulting whole-wall R-value data reveals that a 4-1/2-inch SIP wall rated at R-14 performed equally with a 2-inch x 6-inch wall with R-19 fiberglass insulation. For comparison, the whole-wall R-value of SIPs versus conventional 2x stick framing is shown in Table 2.2.

TABLE 2.2

Wall assembly thickness	Whole-wall R-value
4-1/2" SIP	14.1
2" x 4" wall at 16" on center	9.8
6-1/2" SIP	21.6
2" x 6" wall at 24" on center	13.7/11.0*

*The ORNL study shows how typical installation imperfections such as batts with rounded shoulders, 2% cavity voids, compression around wiring, and paper facer stapled to inside of studs, change the whole-wall R-value of fiberglass rated at R-19 to R-11 in a 2" x 6" wall with studs spaced 24" o.c.

A comparison of the whole-wall R-values from Table 2.2 for the two most common thicknesses of walls shows that SIPs perform 140 percent to 200 percent better than the conventional stick framed walls. This is due to low thermal bridging and low air leakage.

By supplying panels with varying thicknesses and corresponding R-values, the SIP industry allows design professionals to easily specify SIPs that will meet any end use energy code demands.

SIP DESIGN-BP 2.6:
High-performance structures designed and built extremely airtight must have make-up air. There are several options with varying degrees of complexity and cost ensuring an HVAC system that will introduce fresh air.

The list below represents some of the typical building systems intended to provide make-up air defined by ASHRAE as "any combination of outdoor and transfer air intended to replace exhaust air and exfiltration." Outdoor air is defined by ASHRAE as "ambient air that enters a building through a ventilation system, through intentional openings for natural ventilation or by infiltration."

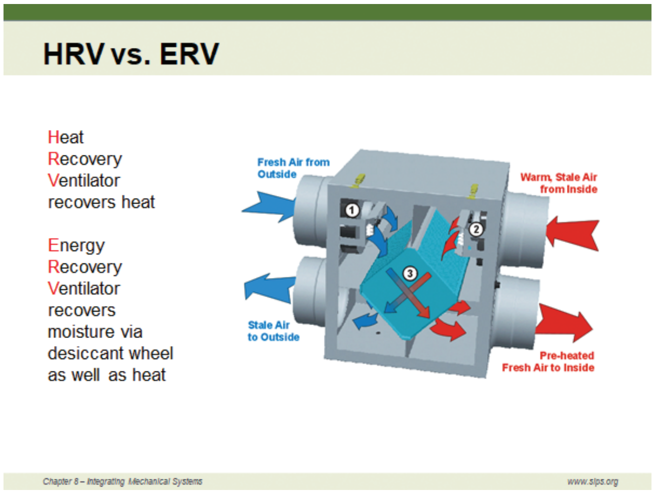
The list is in order of priority with the first (air to air exchangers) being the recommended approach for SIPs. Whatever ventilation strategy is chosen, a design professional with experience in the proper design of tight building envelopes should be involved in the HVAC design. Experts at Building Science Corporation recommend homes with air leakage rates less than 3.0 ACH50 should have mechanically driven make-up air for satisfactory indoor air quality. This is especially important for single story homes with typically little stack effect and homes with high occupancy built over a slab on grade. Since SIP homes are typically tighter than 3.0 ACH50, mechanical ventilation of some kind is always recommended.

1. **Air to air heat exchangers:** these small units generally draw air from source areas like kitchens and bathrooms where excess humidity is created. Moisture-laden warm air is carried through ducts to the unit where it transfers the heat through a core, similar in function to the radiator of a car, while carrying the moisture out of the structure. Thus, the exhaust air tempers or pre-heats the cold unconditioned but fresh air that is coming in from outside. These units are also known as Heat Recovery Ventilators (HRV) or Energy Recovery Ventilators (ERV).

2. **Exhaust-only systems:** these units come in many shapes and sizes, from simple one-room units to multiple-duct whole-house exhausts. This type of unit typically exhausts the stale air and relies upon natural infiltration to replace the exhausted air. Exhaust-only systems can create a negative pressure in the structure. As a health and safety precaution, it is always important to install only sealed combustion appliances in high-performance homes. If not, back drafting can lead to carbon monoxide poisoning and death for occupants.

3. **Ventilating windows:** these windows use a small grille to both exhaust and replace air in a house. They are manually operated and can be used in selected windows or in every window in a home.

4. **Air cleaners:** these units run the gamut from inexpensive tabletop versions to very sophisticated whole-house systems. They are used to remove particulate pollutants but generally are not designed for the removal of gaseous pollutants. Typically, these are not recommended for either humidity or radon control.



SIP DESIGN-BP 2.7: Penetrations in the SIP envelope should be sealed to maximize airtightness.

Building science has taught us that a tight building envelope significantly contributes to the energy efficiency of the structure. Building science has also shown us that SIPs can significantly reduce air leakage through the building envelope. This reduction in air leakage contributes greatly to the energy efficiency of a SIP structure. Please reference ***SIP DESIGN-BP 2.4*** for additional information.

If a structure using SIPs is going to realize the reduced air leakage that contributes to the energy efficiency of the SIP system, the details relating to the sealing of the SIP joints, connections and penetrations through the SIP envelope need to be followed. Designers and contractors are encouraged to become thoroughly familiar with the SIP manufacturers' technical bulletins and details that describe proper use of sealants, SIP tape and expanding foam sealants used to minimize the effects of joints in the panels and penetrations through the envelope.

Expanding foam sealants compatible with EPS must be used to seal penetrations made in the SIP envelope during the construction process. This would include any penetrations from the construction process as well as penetrations for openings, HVAC, plumbing and electrical systems. These penetrations need to be thoroughly and completely sealed. Proper sealing of the electrical chases in panels as well as the electrical boxes within the panels would be included in this process.

By paying attention to the sealing of openings, penetrations, SIP joints and connections in a SIP structure, you will ensure that the structure has minimal air leakage through the exterior envelope, thus helping to maximize the energy efficiency of the SIP system.

Glossary of Terms

ACCA: Air Conditioning Contractors of America.

ACH50: the abbreviation for air changes per hour at 50 pascals (Pa) pressure differential and one of the most important metrics used to determine the energy efficiency of a house. It is the measurement of the rate of air leakage; the number of times the air volume in a building exchanges per hour at 50 Pa of pressure from a blower door test. It is considered equal to wind of approximately 25 miles per hour blowing on the outside of a building.

ACHnat: the natural air changes per hour in a building, as calculated by dividing ACH50 by the LBL Factor.

ASHRAE: the American Society of Heating, Refrigerating and Air-Conditioning Engineers (www.ashrae.org) is an American professional association seeking to advance heating, ventilation, air conditioning and refrigeration systems design and construction.

EPS: expanded polystyrene foam insulation.

ERV: Energy Recovery Ventilator.

HERS: Home Energy Rating System. The HERS index measures energy consumption from heating, cooling, water heating, lights and some appliances. The lower the index, the less energy a building is consuming. A HERS rating of zero signifies a net-zero energy building.

HRV: Heat Recovery Ventilator.

HVAC: heating, ventilation and air conditioning.

LBL Factor: a factor based on climate region, number of stories of a building, and sheltering from wind which is used to convert to estimated air changes in a building by natural means, without a fan.

Manual D: ACCA Manual D duct design distributes the correct amount of heating and cooling to each room based on the Manual J load calculation results. The furnace and A/C selected during the ACCA (Air Conditioning Contractors of America) Manual S process will determine the duct CFM for your exact humidity and winter and summer design temperatures.

Manual J: the HVAC load calculation method recommended by the Air Conditioning Contractors of America (ACCA) to determine the amount of heating and cooling that a home requires to keep its occupants warm in the heating months and cool and dry in the cooling months.

Manual S: ACCA Manual S provides specific procedures for selecting HVAC equipment against a set of Manual J loads and design conditions. Manual S uses OEM data and specifies how large or small the selected HVAC equipment capacity can be for exact humidity and winter and summer design temperatures when compared to the Manual J load calculation.

Natural air changes: the natural air changes per hour in a building, as calculated by dividing ACH50 by the LBL Factor.

QII: quality insulation installation.

R-value (thermal resistance): the inverse of the time rate of heat flow through a body from one of its bounding surfaces to the other surface for a unit temperature difference between the two surfaces, under steady state conditions, per unit area ($h*ft^2*^0F/Btu$).

REM/Rate: a residential energy analysis, code compliance and HERS software used to calculate heating, cooling, hot water, lighting, and appliance energy loads, consumption and costs for single and multifamily homes.

Short cycling: a condition in which an air conditioner goes through its on-and-off cycles too frequently, resulting in an uncomfortable environment, energy drain, and undue stress on the equipment itself.

SIPA: Structural Insulated Panel Association (www.sips.org), a non-profit trade association representing manufacturers, suppliers, dealer/distributors, design professionals, and builders committed to providing quality structural insulated panels for all segments of the construction industry.

SIPs: Structural Insulated Panels, a high-performance building component for residential and light commercial construction.

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