HOME AIR LEAKAGE SOLUTIONS BY OWENS CORNING:

Isolating critical joints through research and improving them with groundbreaking product systems

OWENS CORNING®

INNOVATIONS FOR LIVING®

In a typical residence, there are nearly one mile of exterior joints that can leak air – 5,280 feet of potential problems. In addition to increased heating and cooling costs, air leakage can allow moisture, cold drafts and unwanted noise to enter a house, leading to a far less pleasant living experience. The solution comes down to proper sealing. With that in mind, Owens Corning has approached air leakage head-on, conducting extensive research to identify and prioritize the offenders where leakage is concerned. The result: an "air-leakage-bang-for-your-buck" ranking of every opening and joint in a home. This groundbreaking research not only shows the company's commitment to continuous innovation for the customer, it also supports and validates the strengths of the Owens Corning EnergyComplete™ System.

While it's well known today that a properly insulated building uses less energy for heating and cooling than the same un- or under-insulated building, air infiltration is also a major factor in how much energy a building uses for heating and cooling. Air will leak through a building envelope that is not well sealed. This leakage of air decreases the comfort of a residence by allowing moisture, cold drafts and unwanted noise to enter and may lower indoor air quality by allowing in dust and airborne pollutants. This leakage can also account for between 25 to 40 percent of the energy used for heating and cooling in a typical residence.[1]

To reduce air infiltration and achieve an energy-efficient building, the gaps in the building's thermal enclosure must be sealed. Installing high-quality, tightly sealed windows and doors is a good start, but it's also important to seal gaps in the walls, ceiling and flooring/foundation. In order to properly address the negative effects of air leakage, such as wasted energy, occupant discomfort (thermal & noise), moisture accumulation and ingression of exterior pollutants, **all of the gaps and openings in the building enclosure should be air sealed.** However, some builders or building owners may only have very limited funds available to devote to air sealing. With that near-mile of exterior joints in a typical residence that can leak air (**Figure 1**, for example), knowing which joints leak the most air allows for the most strategic placement of sealant.

Owens Corning funded an extensive investigation to quantify the leakage characteristics of various types of joints and openings in a residential structure and to prioritize them in terms of the amount of air leakage per unit cost to seal it – an "air-leakage-bang-for-your-buck" ranking of the joints/openings.

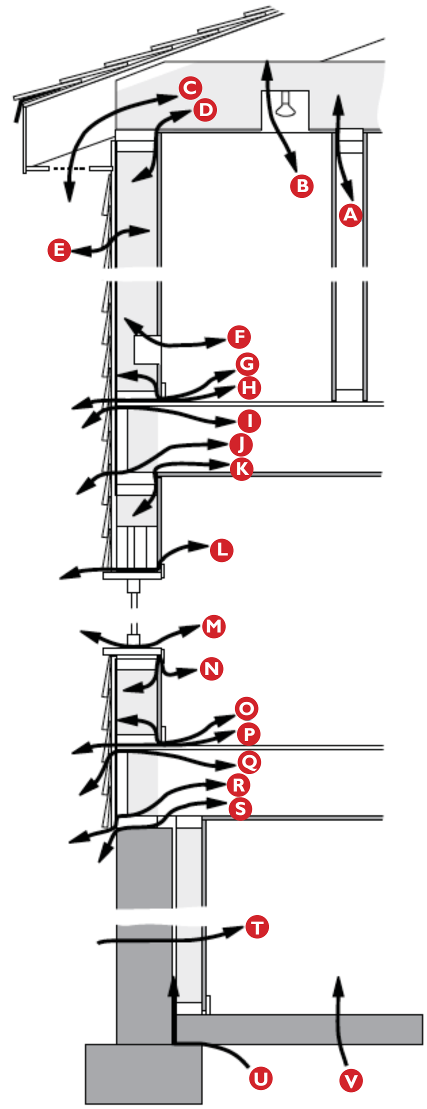


Figure 1

Schematic of a house cross section showing the various air leakage paths (Image from Conservation Technology).

[1] *Building Envelope Improvement: Air Sealing, U.S. Environmental Protection Agency.*

TESTING APPROACH

This study involved two forms of testing, both at 50 pascal pressure difference across the enclosure to mimic typical blower door conditions for a residential building. One form was to test individual components and wall/ceiling assemblies in a laboratory setting, where 8' x 8' assemblies were connected to a pressurized chamber with very accurate flow measuring capabilities. The other form tested these same elements in a whole-house (or real-house) setting using a blower door apparatus – the setting being a 1,400 square foot ranch-style house with basement at Owens Corning's research facility.

The lab setting had its advantages in that it provided well-controlled conditions and made it easy to isolate individual joints/openings and measure small leakage quantities. The lab's disadvantages were that the test assemblies could inadvertently be constructed to a higher quality than is typical of site-built construction. The whole-house setting had its advantages in that it provided field-prototypic conditions, more joint length and typical construction quality; on the flipside, the testing was conducted under uncontrolled conditions (e.g., wind) and held more difficulty in isolating joints. In short, one form's strength was the other form's weakness, which is why both forms of testing were pursued.

All in all, this investigation measured the air leakage for 17 of the most important joints/openings in a house, requiring more than 1,000 individual leakage measurements spanning a 12-month period.

RESULTS

All of the leakage results are expressed in terms of CFM50 (cubic feet per minute of flow at 50 pascal pressure difference) per foot of joint or per component, such as a recessed light, duct boot or electrical outlet. Various house plans[2] were used to generate a takeoff of the length of various types of joints (e.g., bottom plate-to-subfloor) and the quantity of various types of components (e.g., recessed lights). This enabled the whole-house leakage associated with those joints/components to be determined and, with knowledge of the volume of the house, also allowed the results to be expressed in terms of air changes per hour at 50 pascal pressure difference (ACH50).

Recall that the main objective of this study was to prioritize the joints/openings in terms of the amount of air leakage per unit cost to seal it (**Figure 2**). The vertical axis is the amount of air tightening that results from applying the joint sealant (the blower door flow rate is going down); the horizontal axis is the amount of cost that is being incurred to seal those joints and achieve that tightness. If every joint in the house leaked comparably and required the same amount of sealant to address it, then the relationship would be linear. But that's not the case. Our measurements have shown that, indeed, some joints do leak more than others and can be addressed more efficiently than others with a sealant. The non-linear curve shows three regions of "bang-for-your-buck" effectiveness: *most, moderately* and *least effective*. The joints that fall within the *most effective* region will yield the greatness amount of air tightening for a blower door test for the least amount of applied sealant, meaning that the cost versus reward is optimal. By contrast, the joints that fall within the *least effective* region will require that far more joint length be sealed to achieve a comparable amount of air tightening.

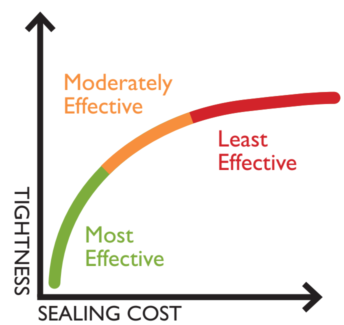


Figure 2

Conceptual graph of the "biggest bang for the buck" approach to air sealing where the most effective joints to seal are those that create the largest amount of enclosure tightening with the least amount of linear footage of applied sealant.

[2] *Four different houses were analyzed – two 1-story (1,200 & 2,900 square feet) and two 2-story (1,600 & 4,000 square feet); all with slab construction.*

It is important to understand that this prioritization is based on whole-house leakage as measured by a blower door apparatus. This was done because many builders are challenged with achieving certain levels of whole-house air tightness, as measured by the blower door apparatus, through energy programs (e.g., ENERGY STAR) and/or building code requirements. There are other manifestations of air leakage, such as thermal comfort, noise, indoor air quality and others that may not be major contributors to a blower door result and could be de-emphasized in these rankings, which is why it is important to seal ***all*** joints/openings, if possible. **Footnote 3** captures some other things to keep in mind regarding these results.

Table 1 provides a summary of the results.

JOINT/OPENING	CFM50*	ACH50†
top plate-to attic	0.29 to 0.68 per foot	0.29 to 1.6
duct boot	7.7 per boot	0.13 to 0.26
recessed light	9.1 per light	0.15 to 0.31
band joist (top & bottom)	0.86 per foot	0.37 to 0.42
garage-house common wall	0.60 per foot	0.14 to 0.26
sheathing-to-plate (top & bottom)	0.074 to 0.62 per foot	0.040 to 0.38
window/door framing-to-sheathing	0.031 to 0.11 per foot	0.020 to 0.10
between exterior top plates	0.10 to 0.11 per foot	0.033 to 0.046
corners (interior pointing)	0.024 to 0.21 per foot	0.0021 to 0.032
corners (exterior pointing)	0.054 to 0.45 per foot	0.0069 to 0.11
bottom plate-to-subfloor	0 to 0.11 per foot	0 to 0.11
vertical sheathing joints	0.010 to 0.090 per foot	0.011 to 0.11
sill plate-to-foundation†	0 to 0.030 per foot	0 to 0.025

** Assumes all other joints in the wall cavity are sealed † Assumes the presence of a sill gasket*

Most Effective

- ***Top Plate-to-Attic:*** This joint is shown in **Figure 3**, where the red arrow depicts the inward leakage path, as well as a photograph of this joint looking down from the attic. This joint was shown to leak in the range of 0.3 to 0.7 CFM50 per foot of joint. This range is driven by differences in how well the drywall is sealed to the interior finishes (window/door and base trim), which dictates the exit path of the air from the wall cavity. For an average-sized house, there can be upwards of 500 feet of this joint; the size of the gap between the drywall and framing at this location can be relatively large due to misalignment in framing (stud-to-plate) or the presence of top plate-to-rafter ties (hurricane ties), which can create a localized offset of 3/16" to 1/4" between the drywall and plate. The cumulative air leakage for this joint is significant, resulting in normalized results in the range of 0.3 to 1.6 ACH50.

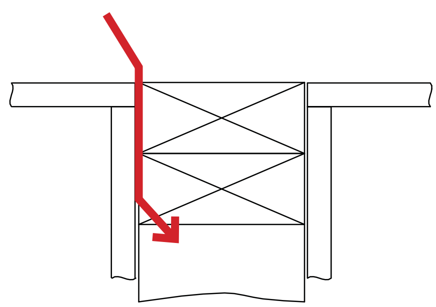
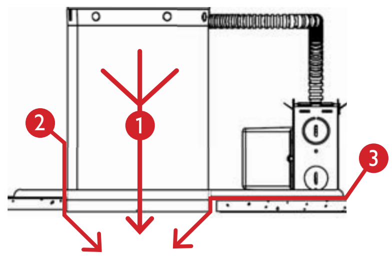


Figure 3

The sketch shows the leakage path from the attic to the wall cavity, and the photograph shows this joint when viewed from the attic.

[3] (1) This study focuses on small joints/openings only (i.e., the big holes, such as chases, are presumed to be blocked & sealed). (2) The wall cladding is assumed to be air permeable (e.g., vinyl/cement/wood siding and brick, but not stucco or stone veneer). (3) The exterior sheathing used throughout this study was oriented-strand board (OSB), which is the most common form of exterior sheathing in the U.S. new construction market. The results of this study do not necessarily apply to cases where the exterior sheathing is insulating foam board, due to the large difference in stiffness, which could affect the tightness of the joint that it forms with framing members. (4) These results should be considered directional only, not absolute, since construction quality varies from house to house. (5) Don't abandon common sense – if you can see daylight through a joint, it should be sealed, regardless of what this study may indicate.

RESULTS (continued)



• ***Recessed Lights:*** This joint is shown in **Figure 4**. Even so-called "air tight" recessed lights, which are mandated by many building codes, can leak an appreciable amount of air at the juncture between the light housing and the mounting flange (red arrow 2), as well as the mounting flange and the drywall (red arrow 3). Leakage through the light housing (red arrow 1) is fairly tight, as is required by many building codes. All paths combined showed an average leakage of 9.1CFM50 per light, which could amount to upwards of 0.2 ACH50, depending on the number of lights penetrating the ceiling into an unconditioned space.

• ***Duct Boots:*** For cases where the HVAC duct work is located in the attic, there will likely be duct boots that penetrate the ceiling drywall to supply or return air to/from the living space. The leakage at the interface between the duct boot and the drywall contributes 7.7 CFM50 per boot, which could amount to upwards of 0.2 ACH50, depending on the number of duct boots present.

• ***Band/Rim Joist:*** This joint was shown to leak an average amount of 0.86 CFM50 per foot of band joist (includes the leakage from both the upper and lower joints), which results in approximately 0.4 ACH50 for the whole-house result. It is notable that the band joist joints are the only wall joints that are not meaningfully constrained by drywall, which makes them important contributors to air leakage. The air leakage associated with all other exterior wall joints must negotiate the joint on the exterior skin of the wall (the sheathing layer) ***and*** the interior skin of the wall (the drywall layer). Once the air passes the exterior skin associated with the band joist, it typically encounters a large, open space in the floor system, where it travels relatively unimpeded.

• ***Garage-to-House Common Wall:*** This wall is unique in that it is an exterior wall (separating the conditioned living space from the unconditioned garage space) that is sheathed on the exterior side with drywall, as opposed to some form of structural sheathing, like oriented-strand board (OSB) or plywood. This is significant in that drywall has far less stiffness than OSB/plywood, which adversely affects the air tightness of the joint that is formed between the drywall and the framing members. This joint was shown to leak an average amount of 0.6 CFM50 per foot of joint, which results in approximately 0.1 to 0.3 ACH50 for the whole-house result. While this is fairly high leakage on a per foot basis, its implication on the whole-house leakage is not as large because there are typically not many feet associated with a garage wall. However, such a joint could be very important from the standpoint of indoor air quality, since it connects the living space to an area where harmful gases can be found.

Moderately Effective

• ***Top & Bottom Plate-to-Sheathing:*** This joint was shown to leak an amount that ranged from 0.07 to 0.6 CFM50 per foot of joint (includes the leakage from **both** the top and the bottom joints), which results in approximately 0.04 to 0.4 ACH50 for the whole-house result. This range is driven by differences in how well the drywall is sealed to the interior finishes (window/door and base trim), which dictates the exit path of the air from the wall cavity. This matters because of what was stated above – namely, the air leakage associated with most exterior wall joints must negotiate the joint on the exterior skin of the wall (the sheathing layer) and the interior skin of the wall (the drywall layer). Once the air passes the exterior skin associated with the plate-to-sheathing joint, it must also pass the interior skin through drywall penetrations (electrical outlets and switches, plumbing fixtures, etc.) and terminations (bottom of the wall, windows, doors, etc.). However, these terminations can occasionally (and unintentionally) be well-sealed with caulk by the painter or finish carpenter for aesthetic reasons. Such sealing, however, is of questionable durability, since such caulks are almost always low performing (i.e. low flexibility, resulting in cracking).

• ***Bottom Plate-to-Subfloor:*** Numerous independent measurements in this investigation showed the leakage associated with this joint to be relatively small (0.1 CFM50 on average and up to 0.1 ACH50 for the whole house). It is interesting to note that many builders and building code officials expect/require this joint to be sealed, often ignoring far more important joints. It is possible that this joint can be quite large/leaky in some localized cases where the wall is constructed on the floor, tilted up into place and potentially have some construction debris (wood chips, fasteners, etc.) lodged between the bottom plate and the subfloor. While this should be uncommon or very localized, the joint should obviously be sealed in this case ("If you see daylight, seal it!").

Least Effective

• ***Corners, Window/Door Framing-to-Sheathing, Vertical Sheathing Joints and Between Exterior Top Plates:*** These are four very different types of joints, but the thing that they have in common is that they are not significant contributors to whole-house leakage (ACH50) for one or more of the following reasons: (1) small amount of overall joint length, (2) not a large amount of leakage and/or (3) the leakage is constrained to some extent by the drywall, which was mentioned above. However, the leakage from any one of these joints could still cause thermal or acoustic comfort issues.

• ***Bottom Plate-to-Slab:*** This study did not make measurements for the case where the bottom plate mated with a slab, so this least-effective categorization is an extension of the relatively low leakage comments above for the bottom plate-to-subfloor joint as well as the reality that the bottom plate-to-slab connection typically has two advantages related to air tightness: one, that the slab is often very smooth because of the finish flooring requirements for uniformity (e.g., ceramic tile, wood laminate flooring, etc.); the other being that this joint is often addressed with a sill gasket by the framer (e.g., Owens Corning's FoamSealR™), which is sandwiched between the bottom plate and the smooth slab for the very purpose of air sealing.

HOW THE OWENS CORNING ENERGYCOMPLETE™ AIR INFILTRATION BARRIER ADDRESSES THE LEAKAGE ISSUES

The EnergyComplete™ Air Infiltration Barrier with Flexible Seal Technology is a two-part, high performance latex-based foam used to seal cracks and penetrations through a building enclosure. While there are many sealants available today that can be used to address the various leakage paths discussed here (caulk is a common example), the EnergyComplete™ Air Infiltration Barrier provides three very important and unique benefits.

1) **Flexibility.** The joints of wood-framed structures expand and contract with moisture changes to the wood that occurs from the initial house construction (green lumber and/or weather-related wetting) and from the climate-related moisture changes that occur throughout the year. The EnergyComplete™ Air Infiltration Barrier is designed to have very good flexibility in order to accommodate this joint movement without cracking.

2) **Compressibility.** Two of the most important joints mentioned previously – the top plate-to-attic and garage-to-house common wall cannot be easily sealed at the rough framing stage of construction. Both of these joints occur at the interface of the framing and the drywall, where the latter is not present at the rough framing stage. A very effective way to seal these joints is to apply the EnergyComplete™ Air Infiltration Barrier to the face of the framing members, which is so compressible and compliant that it functions as a gasket when the drywall is eventually applied.

3) **Durability.** Most of the air seals on a house are concealed within the wall or attic, making them practically unserviceable for the life of the structure, making it is so important to use a sealant that is expected to endure. The EnergyComplete™ Air Infiltration Barrier has been shown to maintain its flexibility, compressibility and overall air sealant properties through accelerated aging tests designed to represent typical wood frame movement and climatic changes throughout the United States over 50 years. The EnergyComplete™ Air Infiltration Barrier also maintains an air seal after being subjected to the pressure from three-second gust hurricane wind speeds of up to 150 mph.

In addition, the EnergyComplete™ Air Infiltration Barrier is safe to install and **does not** require a chemical mask or fresh air ventilation suit; other trades can work in the house while the barrier is being applied.

The EnergyComplete™ Air Infiltration Barrier is recognized for use as an alternative to the methods prescribed by the code for maintaining the integrity of penetrations of fireblocking, tested in accordance with ASTM E 814.

CONCLUSION

There's no way around leakage in a residential structure. But knowledge is power. And with nearly a mile of exterior joints in a typical residence that can leak air, recognizing which ones leak most allows for that leakage to be prevented or alleviated. In this case, exclusive Owens Corning research created an "air-leakage-bang-for-your-buck ranking" of every opening and joint in a home. It's a powerful demonstration of exactly what can be achieved with Owens Corning innovation and products like the EnergyComplete™ System.

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