Supersealing a House

By Ty Newell, Member ASHRAE; and **Ben Newell,** Associate Member ASHRAE

In this column, we describe our efforts to superseal Equinox House. As with our previous discussions on walls and windows, there is a point at which too much effort and cost can occur. While there is information available in the general literature of the excellent sealing characteristics of structural insulated panels (SIPs), we found that these studies did not provide the basic information we were seeking to characterize the cost to seal the different features of our house. That is, what is the infiltration through the sill plate region, or the wall-to-wall panel joints, or the wall panel-to-roof panel joints, and similar building elements?

Supersealing a house is important for a number of reasons. First, energy and comfort are improved as a house is sealed. Second, deterioration of a structure by moisture movement through infiltration paths to regions where condensation can occur is minimized if properly sealed. Third, the same infiltration paths where moisture may condense, forming molds and mildew, are the airflow paths that conventionally constructed homes rely on for "fresh air." Fourth, these infiltration paths are also used by insects and rodents to enter a home.

By minimizing infiltration and using a controlled ventilation system, one gains the benefits of ventilating a residence at a proper rate (ASHRAE Standard 62.2), filtering the controlled ventilation air, which reduces the input of various allergens and dirt into the house, and performing beneficial energy exchanges between the fresh air and exhaust airstreams.

Our nominal goal was to seal Equinox House to a level achieving "Passive House" requirements of 0.6 ach at 50 Pa. The Passiv Haus Institut (www.passiv.de) bases this level of sealing as one in which infiltration is minimized to a point where controlled fresh air ventilation rates can be conditioned (heated or cooled) to a level matching the building's load under most climatic conditions. The internal volume of Equinox House is 28,000 ft^3 (790 m^3), which is large for the size of the house due to nearly 20 ft (6.1 m) high ceilings. The high ceilings are a direct result of the SIPs construction, which eliminated the space normally occupied by roof trusses. Based on the size of Equinox House, a blower door flow rate less than 280 cfm (132 L/s) at 50 Pa is desired.

To gain some perspective on the impact of this level of sealing relative to other building shell energy impacts, we can assess the overall heat transfer

Photo 1: Blower door in garage door.

coefficient (UA value) for the primary house components. The SIPs walls and roof (approximately 4,800 ft^2 [444 m^2]) have a combined UA value of 50 W/K (95 Btu/h·°F). The windows have a total UA value of 26 W/K (49 Btu/h·°F). The three "double" doors have an estimated combined UA value of 2.5 W/K (4.7 Btu/h·°F). Finally, the ICF (insulated concrete form) foundation wall that extends 8 in. (0.2 m) above the concrete slab floor has an estimated UA value of 4 W/K (7.6 Btu/h·°F). The total of these parallel heat transfer paths through the building shell is 82.5 W/K (156 Btu/h·°F).

Infiltration is an additional "parallel" load factor, and can be combined with the total UA value for the house. Formally, infiltration effects also add

This is the fifth in a series of columns. Find previous columns at www.ashrae.org/ashraejournal.

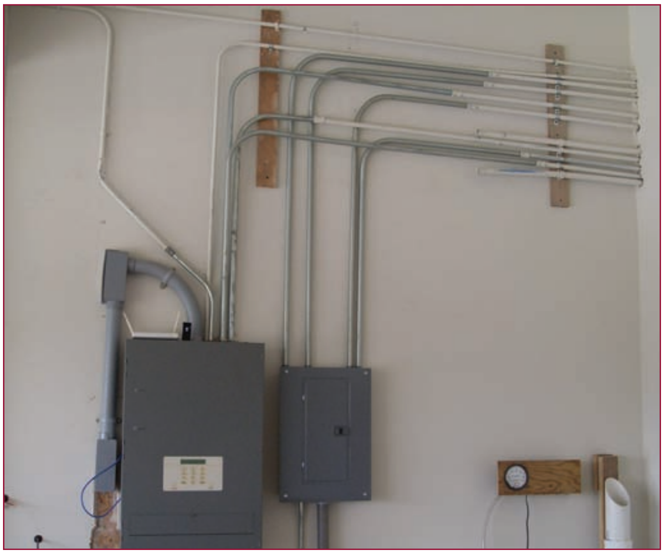

Photo 2: Electrical and plumbing access from the garage to the conditioned attic space. Note the computerized circuit breaker with cell phone modem, which monitors all house electrical circuits and allows circuit control anytime, anywhere.

Photo 3: Electrical, plumbing and exhaust ventilation duct inside the conditioned attic space. Plumbing on the left side of photo are rainwater (white pipe), hot water (red) and city water (blue). Uninsulated exhaust air duct on right side of photo removes air from kitchen, bathrooms, and laundry room.

latent loads (e.g., using infiltration degree-days; see *2009 ASHRAE Handbook—Fundamentals*, Section 16.12). Assuming an infiltration of 100 cfm (2.8 m^3/min), the associated air mass flow rate times air's constant pressure specific heat results in a sensible load due to infiltration of 57 W/K (108 Btu/h·°F). Based on this, 40% of the building envelope load would be due to infiltration. Reduction of the infiltration to 0.6 ach at 50 Pa would be an infiltration of approximately 12 cfm (5.6 L/s) at normal conditions, or 6.8 W/K (12.9 Btu/h·°F), reducing the total building UA to less than 90 W/K (171 Btu/h·°F).

Equinox House requires 75 cfm (35 L/s) of controlled continuous ventilation per Standard 62.2. Combining this with an effective energy recovery system that exchanges a minimum of 50% of recoverable energy when conditions are favorable, the controlled ventilation system adds a loss factor of 21.2 W/K (40 Btu/h·°F) to the building shell load.

Photo 4 (left): Exterior view of the fresh air supply vent (lower) and exhaust air vent (upper) on the north side of the house. Note the specially designed downspout at the end of the house for rainwater harvesting from Equinox's steel roof. **Photo 5 (right):** Remote control switch used for zero wall penetration, exterior lighting circuits.

After erecting the house shell, we began an extensive series of blower door tests and house sealing activities on March 2, 2010. We are very grateful for the mentoring we received from our friend and colleague, Paul Francisco, Member ASHRAE, (Standard 62.2 committee member) from the University of Illinois Building Research Council (http://brc.arch.uiuc.edu).

Photo 1, (Page 54) shows our blower door set up in the door to the garage. Electricians and plumbers were not allowed to penetrate exterior walls of the house shell. *Photo 2* shows the access point between the garage and the attic space where electrical, plumbing and ventilation ducts are located. The attic space is within the thermal envelope of the house interior and is shown in *Photo 3*. Conduits entering the house from the unconditioned garage were plugged with non-hardening putty that can be removed for additional wire

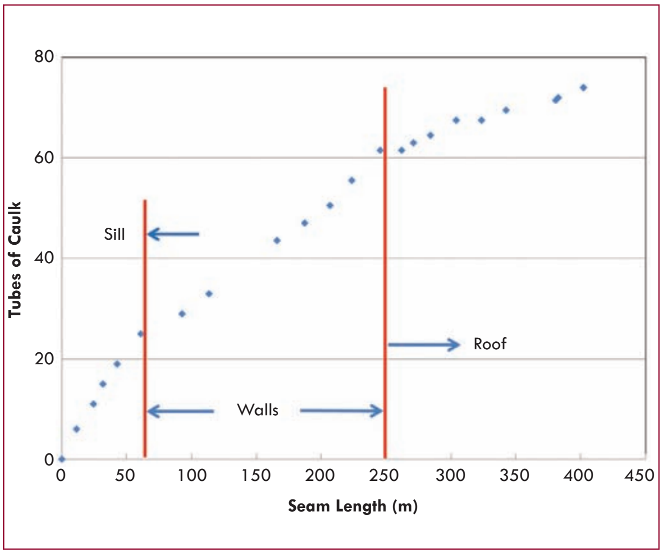

Figure 1: Amount of sealant used vs. seam length sealed. Note that one tube of silicone caulk is equal to 0.283 kg (10 oz) of sealant.

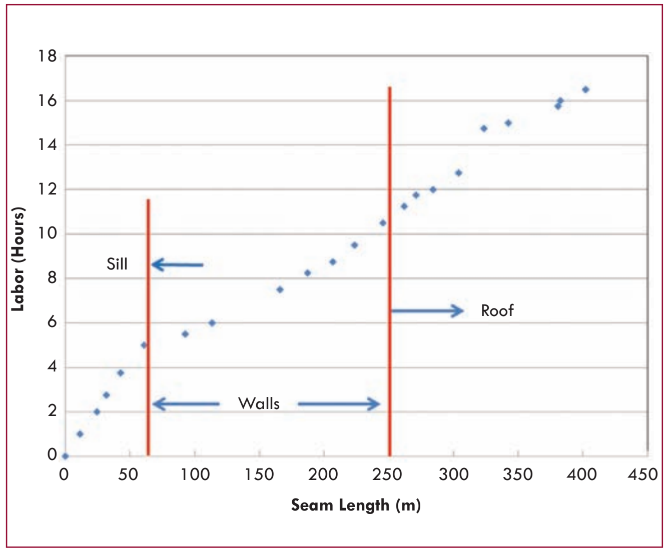

Figure 2: Labor effort expended to seal different regions of the house seams.

pulls. The conditioned attic space is located directly above the three bathrooms and laundry room, and adjacent to the kitchen for efficient distribution of utilities.

The blue pipe in *Photo 3* is "city" (potable) water, the red pipe is for hot water, and the white pipe is rainwater. We were given approval by the State of Illinois Department of Public Health to use rainwater for toilets.

In addition to a plumbing vent, the two 4 in. (100 mm) diameter holes for fresh air supply and return air exhaust shown in *Photo 4* (Page 55) are the only holes cut through the exterior shell of the house. *Photo 5* (Page 55) shows a batteryless remote control switch for the backyard LED spotlights that eliminates electrical access holes through the house envelope.

Blower door tests were conducted in which the amount of caulk, the time required to apply the caulk, and the change of air changes at 50 Pa (ACH50) were measured. The 50 Pa test is widely accepted and amplifies small leaks to aid in detection and is not too high of a pressure where distortion of building structures occurs. *Figure 1* shows the amount of silicone caulk applied to the panel seams, expressed in terms of tubes of caulk. A tube of caulk contains 10 oz (0.283 kg) of silicone caulk. The sill plate seam required 0.5 tubes of caulk per meter of seam, while the rest of the seams required approximately 0.18 tubes of caulk per meter of panel seam. *Figure 2* shows the labor hours as a function of panel seam length. The sill plate seam required 0.1 hours of labor per meter of seam length while the other seams required approximately 0.04 hours of labor per meter of seam.

Figure 3 shows the change of ACH50 as a function of panel seam length sealed. On average, leakage dropped 0.0067 ACH50 per meter of panel seam length. Some panel seams did show variations in the amount of leakiness. For example, the first 195 ft (60 m) of seam sealing was the sill plate seam around the perimeter of the house. The sill plate seam shows 0.01 ACH50 reduction per meter of seam

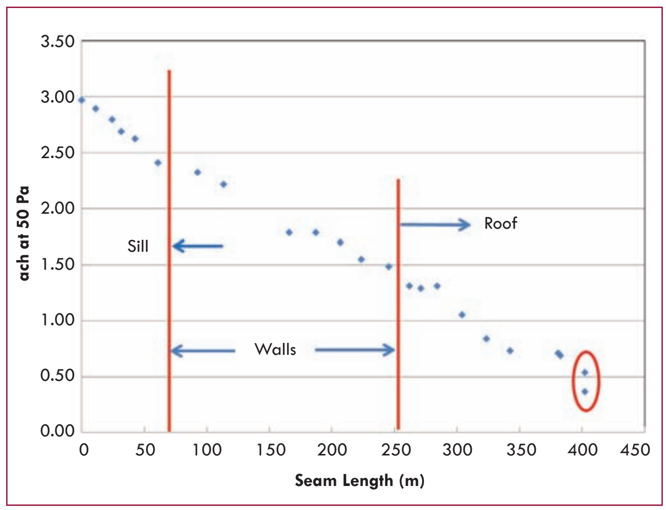

Figure 3: Air changes per hour variation versus the seam length sealing activities. The final two points indicate the impact of drywall on house sealing.

length, which is due to some waviness between the layers of wood in the sill plate and the connection to the bottom of the SIPs wall panels. The vertical seams between wall panels with the spline connections have a change of 0.0046 ACH50 per meter length, and are the data series from 60 m to 200 m (195 ft to 656 ft) in *Figure 3*. The additional seams consist of the wall to roof panel seams, and the roof to roof panel seams.

The relatively "flat" regions of the *Figure 3* plot at 150 m, 250 m, and 350 m (492 ft, 820 ft, and 1,150 ft) are locations represented by a region of roof panel seams, window perimeter seams, and door perimeter seams that did not display significant leakiness. The windows and doors were foam sealed when installed, and these seals performed well. The last data point shown in *Figure 3* represents the last blower door test

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performed after drywall was added. The drywall did reduce the infiltration, and most likely the effect of cladding the interior with drywall would have been more significant if the extensive panel seam sealing had not been performed. While this may have saved some cost, the danger of not sealing the panel seams is that moisture can move into various isolated regions of the panel seams and create rot at some time in the future.

The cost related to the sealing effort can be quantified to determine the payback of the sealing effort. For Central Illinois, the cooling and heating seasons consist of 3,900 C-day. On a simple basis, assuming that the air infiltration under normal conditions can be estimated as ACH50 divided by 20, the uncontrolled house infiltration has been reduced from 70 cfm to 8.5 cfm (33 L/s to 4 L/s). This represents a reduction of 3,300 kWh of sensible thermal energy conditioning, which with a heat pump having an average coefficient of performance of three, represents a reduction of 1,100 kWh of electric energy. With a value of $0.12 per kWh, the savings is $130 per year.

The silicone caulk costs $4 per tube for a total of $300 for 75 tubes of caulk. Construction labor for caulking is valued at $20 per hour, with a total cost of $340 for 17 hours of labor. The total sealing cost of $640 for caulk and labor therefore, results in a simple payback of five years. Assuming this energy savings is displaced by the controlled ventilation with energy recovery, the payback is longer. However, the payback relative to the lifetime of the house and the other benefits associated with sealing the house makes the effort cost effective, as well as beneficial, on bases difficult to measure on economic terms (fewer bugs, rodents, allergens, etc.). Of course, the longevity of this sealing and materials needs to be studied. Blower door tests as the house ages are planned so these effects can be tracked and measured. Additionally, the process we used to seal the panels was quite inefficient. We feel that our next project will be better sealed during the erection phase. Increasing the seal quality and reducing sealing efforts with more efficient caulking (using a larger caulk dispenser), will reasonably reduce our estimated costs to less than half.

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