Air Infiltration Data Analysis for Newly Constructed Homes Insulated with Icynene Spray Foam

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Introduction

It is generally accepted within the building science industry that, with all else being equal, a stick framed house insulated with spray foam will be more resistant to air infiltration than a house insulated with other conventional insulation materials. Proper installation of Icynene insulation and good air sealing practices can provide an exceptionally air-tight building and, along with proper ventilation, will generally improve quality of the indoor environment and durability of the structure. However, the Energy Star® program has chosen to provide an exception for the air tightness testing requirement exclusively to homes constructed with both wall and roof structural insulated panels (SIPs) even though spray foam insulated homes can provide equal or better air sealing capabilities.

Background on Energy Star

Energy Star is a joint program of the U.S. Environmental Protection Agency (EPA) and the U.S. Department of Energy (DOE), designed to save energy and protect the environment using energy-efficient products and practices. The Energy Star program is both highly respected and a well recognized name in energy-efficient home construction. Over the last 15 years over 800,000 homes have been certified to the Energy Star Guidelines, and, it is estimated that 12 percent of all new homes will be Energy Star Certified[1] in 2007.

For a home to become Energy Star Certified, it needs to have energy-efficiency features that enable the home to reduce its total energy consumption by 15-20 percent (depending on climate) over a home built to the local energy code. Improvements typically made to achieve this target include: high performance windows, increased insulation levels, high-efficiency heating, cooling and water heating equipment, fluorescent lighting, Energy Star appliances, duct sealing, and air sealing of the building envelope.

Certification is performed by a Home Energy Rating System (HERS) Rater. The rater will analyze the characteristics of the house via computer modeling, field inspect for proper installation of insulation, verify that required thermal bypasses are properly air sealed, and finally, field test the completed home for the tightness of the duct system and overall tightness of the building envelope.

The only exceptions to the field testing requirements are 1) duct testing is not necessary if the ducts are completely contained within the house (and visible) and the assumed duct leakage to outside is zero, 2) if the wall and ceiling panels are constructed of SIPs panels, the whole house will not require infiltration testing and the assumed air leakage is 0.35 natural air changes per hour.

[1] Energy Star and Other Climate Protection Partnerships 2006 Annual Report, U.S. Environmental Protection Agency, 2007

If a home's construction design is inherently airtight, testing could be considered unnecessary, especially when combined with a pre-close-in inspection. In addition, extra cost and potential scheduling issues compound problems associated with blower door testing.

Blower Door Testing

The most common method to test the air tightness of a home is commonly referred to as a blower door test. The Residential Energy Services Network (RESNET), the independent body that oversees the procedures and quality control for the Energy Star program, requires that the ANSI/ASHRAE 136 Standard *A Method of Determining Air Change Rates in Detached Dwellings* be used to measure air tightness. Figure 1 below shows an example of a blower door test being performed.

Figure 1: Blower Door Test

Blower door test results are presented in a variety of ways. A leakage rate directly measured from the testing is CFM50, which is the flow rate, in cubic feet per minute, at a pressure difference of 50 Pascals between the house interior and the outside. However, the CFM50 does not allow comparison between homes of different sizes. This can be done by converting the flow rate (CFM50) into an air exchange rate per hour (ACH50) with a 50 Pascal pressure difference which is done using the following equation:

Equation 1:
ACH50= CFM50*60/House Volume

ACH50 will allow comparison between houses of different square footage or volume within the same region, but homes in different climates and homes with different heights cannot be compared as to how much they will leak due to weather conditions and stack effect under natural conditions. This makes it necessary to convert ACH50 into ACH natural.

Equation 2: ACHnat= ACH50/LBL Factor

The LBL Factor was developed by the Lawrence Berkeley National Laboratory and takes into consideration special climate zones, the number of stories in the house, and how well the house is shielded from wind by other buildings and/or trees. ACH natural is generally considered the most representative number that indicates how much energy is lost from a particular house due to air infiltration. A table containing the LBL Factors can be found at:

http://www.energystar.gov/ia/home_improvement/home_sealing/ES_HS_Spec_v1_0b.pdf

Typical Blower Door Test Results

According to a study performed by the Lawrence Berkeley National Laboratory in 2002[2], average air tightness of all houses, new and existing, in the United States is 1.18 ACHnat. All new homes (post 1993) that were tested within a year of construction have a mean ACHnat of 0.55. Homes that were constructed under some local or national energy-efficient homes program have a mean ACHnat of 0.31 (excluding Alaska which averaged 0.23 ACHnat).

Energy Star has established a natural infiltration target threshold of 0.35 air changes per hour. Homes that are tighter than this will not get any additional credit toward Energy Star certification unless ASHRAE Standard 62.2 *Ventilation and Acceptable Indoor Air Quality in Low-Rise Residential Buildings* ventilation requirements are met.

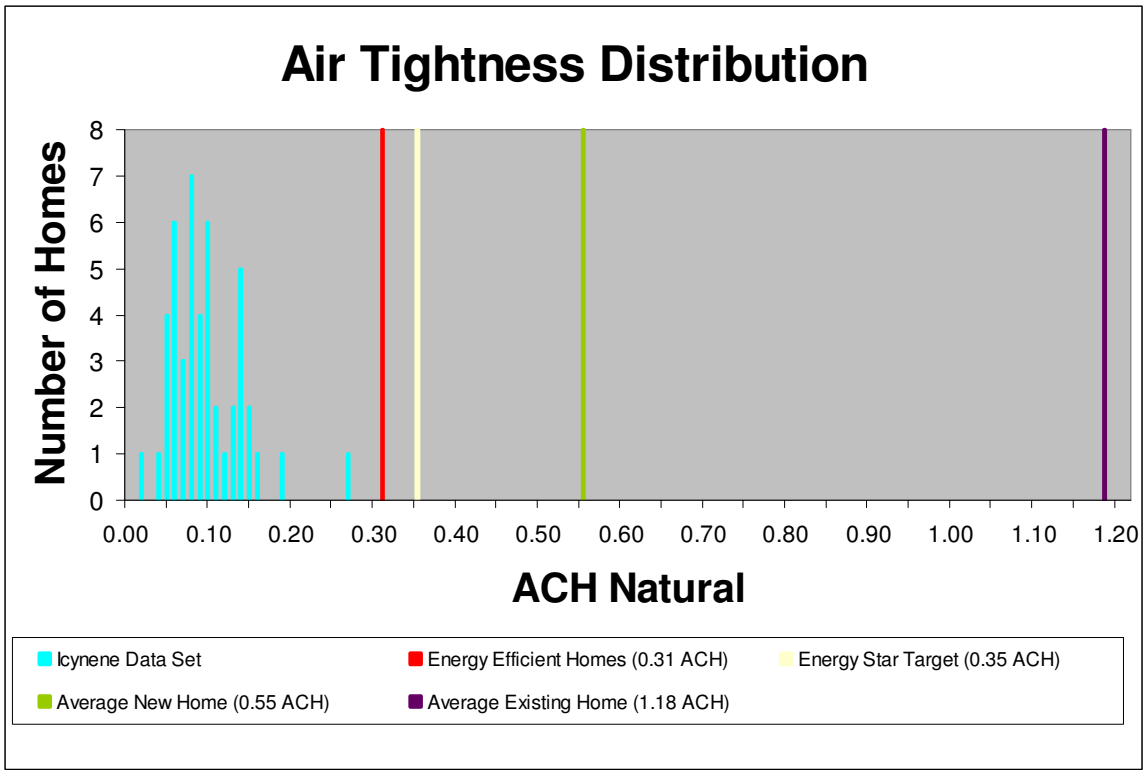

Figure 2: Spray-in-foam House Air Tightness Relative to National Averages

[2] Sherman, M, Matson, N, "Air Tightness of New U.S. Houses", LBNL-48671, 2002

Data Analysis

Icynene, Inc. supplied a list of 56 homes from 13 states that had been tested for air tightness. Of the 56 data sheets (see Appendix A); only 47 contained the ACH natural leakage rate necessary for the analysis. It was assumed that the data supplied was random in nature and representative of homes insulated with Icynene insulation. Based on the shape of the histogram (Figure 2) it appears as if the small sample has the beginnings of a bell shaped curve that resembling a normally distributed sample; although not a normal distribution. All of the homes submitted were well below the 0.35 ACHnat, and all but two (of the 47 submitted) were less than half the threshold.

Average natural air infiltration of the 47 homes was 0.10 air changes per hour. Distribution was fairly tight with the standard deviation ranging from 0.06 to 0.14 ACH natural. The leakiest house was over four standard deviations above the mean, indicating that if this is a random distribution using Chebyshev's inequality, only 1 house in 194 would be leakier than the 0.35 ACH nat. If the distribution was truly normal, which is not possible given the relative proximity to zero of the mean, the chances of the infiltration being above 0.35 would be grater than 1 in one billion.

	All Homes
Min Air Tightness	0.02
Max Air Tightness	0.27
Average Tightness	0.10
Standard Deviation	0.04
Number of Homes	47

Table 1: ACH Natural for Data Supplied

Conclusion

Data supplied to the NAHB Research Center shows a consistent pattern of homes using Icynene spray foam insulation testing over three times tighter than the Energy Star target air tightness as well as the average newly constructed energy-efficient house. A larger data set from a more diverse geographic area would provide a more convincing argument to have the testing requirement for homes completely insulated (walls, ceiling and floors over unconditioned space) with spray foam insulation.

This does not mean that the use of Icynene alone is sufficient to guarantee a tight house, but builders who are using Icynene appear, based on the data, to address other leakage locations in order to construct a tight building envelope.

The SIPs industry has been able to gain an exemption for air tightness testing of their houses if the proper pre-close-in thermal bypass inspection is performed. Based on the data from the 47 houses submitted with an average air tightness rating or 0.10 ACHnat, it appears that homes insulated/sealed using Icynene (or other) spray-in-place foam insulation should be afforded the same exemption. A proposed pre-drywall inspection sheet along with evidence within this report may be sufficient to gain a blower door exemption for homes with spray foam insulation.

Appendix A:
Data Set for Icynene Insulated Homes

City	State	CFM @ 50 Pa	CFM @ 50 / s.f.	ACH @ 50 Pa	Natural ACH	House Volume (ft^3)	Floor Area (ft^2)
Spencer	WI	109	0.05	0.18	0.02	36,000	2,050
Hermantown	MN	482	0.12	0.77	0.04	37,558	4,017
Stratford	WI	416	0.21	0.80	0.05	31,000	1,950
Bovey	MN	537	0.15	0.85	0.05	38,016	3,472
Sioux Falls	SD	380	0.11	0.75	0.05	30,500	3,358
Sioux Falls	SD	380	0.11	0.75	0.05	30,500	3,358
Janesville	WI	876	0.20	1.36	0.06	38,737	4,420
Janesville	WI	574	0.15	0.94	0.06	36,684	3,852
Boyd	WI	444	0.18	0.65	0.06	41,000	2,500
Duluth	MN	311	0.16	1.08	0.06	17,278	1,944
Bartonville	IL	720	0.15	1.10	0.06	39,273	4,800
Bartonville	IL	720	0.15	1.10	0.06	39,273	4,800
Duluth	MN	407	0.19	1.23	0.07	19,792	2,184
Metamora	IL	815	0.23	3.32	0.07	14,729	3,543
Metamora	IL	815	0.23	3.32	0.07	14,729	3,543
Stratford	WI	369	0.21	0.56	0.08	39,600	1,800
Jersey Village	TX	1,055	0.28	2.11	0.08	30,040	3,755
Pekin	IL	1,158	0.20	1.41	0.08	49,277	5,790
Morton	IL	1,175	0.26	1.75	0.08	40,286	4,519
Westville	IN				0.08	53,561	5,290
Pekin	IL	1,158	0.20	1.41	0.08	49,277	5,790
Peoria	IL	1,175	0.26	1.75	0.08	40,286	4,519
Amhearst Junction	WI	489	0.28	1.86	0.09	15,750	1,750
Wausau	WI	963	0.25	1.70	0.09	34,000	3,824
Rexburg	ID	1,188	0.27	1.79	0.09	39,788	4,332
Montgomery	TX	1,096	0.36	2.67	0.09	24,632	3,079
Arbor Vitae	WI	316	0.22	0.79	0.10	24,000	1,450
Mosinee	WI	450	0.26	0.83	0.10	32,500	1,710
Iron River	WI	794	0.20	1.00	0.10	47,600	3,900
Colby	WI	494	0.32	1.11	0.10	26,656	1,568
New Hope	PA				0.10		
Colby	WI	494	0.32	1.11	0.10	26,656	1,568
Lac DU Flambeau	WI	735	0.27	0.64	0.11	69,100	2,764
Mosinee	WI	748	0.30	1.04	0.11	43,000	2,500
Littleton	CO				0.12		
Stratford	WI	537	0.31	1.01	0.13	32,000	1,750
Deer River	MN	766	0.25	1.19	0.13	38,611	3,118
Janesville	WI	736	0.23	1.54	0.14	28,687	3,148
Tomahawk	WI	449	0.36	0.80	0.14	33,800	1,250
Duluth	MN	463	0.31	2.05	0.14	13,527	1,503
Farmington	IL	1,253	0.49	3.37	0.14	22,309	2,557
Peoria	IL	1,253	0.49	3.37	0.14	22,309	2,557
Junction City	WI	1,024	0.43	1.92	0.15	32,000	2,400
Duluth	MN	630	0.29	2.14	0.15	17,672	2,146
Cambridge Falls		1,347	0.53	3.98	0.16	20,320	2,540
Iron River	WI	744	0.39	0.93	0.19	48,000	1,900
Union Springs	NY				0.27	12,720	1,590
Mooresville	NC	1,458	0.42	2.10		41,694	3,464
Ankeny	IA	937	0.23	1.47		38,185	4,040
Huxley	IA	682	0.18	1.19		34,416	3,824
Louisville	KY	900					
Louisville	KY	1,750					
Fisherville	KY	1,100					
Webb Lake	WI	957	0.25	1.03		55,800	3,836
Westville	IN					53,561	5,290

Appendix B: SIP Visual Inspection Form

ENERGY STAR Qualified Homes
Structurally Insulated Panel (SIP) Visual Inspection Form

ENERGY STAR Qualified Homes constructed with structural insulated panels (SIPs) for all exterior walls ***AND*** roof construction may choose to verify air infiltration requirements with a blower test or visual inspection. If a blower door test is performed as part of a complete HERS rating, this form is not needed. If a visual inspection is used to verify air infiltration requirements, this form must be completed, signed and accompany all other applicable HERS rating documentation.

Builder Company Name: _____

Builder Address: _____ Home Address:_____

_____ _____

SIP Manufacturer Field Rep.: _____ HERS Rater: _____

I attest that I have inspected the home at the address noted above for air infiltration and verified that:

ALL interior and exterior seams are sealed with either expanding foam, manufacturer approved sealing mastic or tape. Depending on the manufacturer, this might be in addition to the sealing or taping required in the interior of the SIP joints. Sealant is continuous and flush against both interlocking / touching surfaces. This includes the seams between:

a. SIPs aligned horizontally and at corners
b. SIPs stacked vertically (between top and bottom plate of two or more story building)
c. SIPs and the concrete foundation
d. SIPs and windows / skylights
e. SIPs and rim-joist panels
f. SIPs intersecting at the roof-peak are sealed externally and internally
g. SIPs and the eaves

_____ _____

HERS Rater Signature Date

I attest the following installation procedures have been followed:

1. The expanding foam or manufacturer approved sealing mastic applied into the SIP joints, has been installed continuously in the SIP center or center groove (as applicable) on one of the interlocking surfaces such that the sealant creates an un-interrupted barrier between the two surfaces:
    a. Two SIP panels
    b. A SIP panel and a bottom-plate
    c. A SIP panel and a top-plate
    d. A SIP panel and an end-plate
    e. And any other joints as manufacturer's instructions indicate

2. When carving out foam to fit dimension lumber for top plate, bottom plate, end-plate, or other location, the SIP core foam is flush against the lumber. Expanding foam or manufacturer approved sealing mastic has been applied to any inconsistencies created while carving out foam, such that the wood is flush with the SIP core foam. This expanding foam or sealing mastic is in addition to the continuous bead of expanding foam or sealing mastic used to seal the plates to SIPs.

3. Any through-wall penetrations of SIPs such as (but not limited to) HVAC duct work, electrical wiring, and plumbing have been sealed with expanding foam or sealing mastic, such that the full thickness of the SIP panel-void is filled. Scrap insulation has not been used to fill in the void.

_____ _____

SIP Manufacturer Field Representative Signature Date