PERFORMANCE OF SIDE-BY-SIDE SOUTH TEXAS HOMES

Isolating the Contribution of Spray Polyurethane Foam Insulation

INTRODUCTION

As the use of spray polyurethane foam (SPF) insulation is increasing in both new and existing homes, prospective users often ask the question: "How much can SPF impact my heating and cooling costs?" To provide the most accurate answer to this question, one would need to construct two identical homes with the same location and orientation: one with and one without SPF insulation. The homes would need to remain vacant and monitored for energy use for at least one year. A recent study came very close to using this type of approach.

As part of the U.S. Department of Energy Building America program, the Florida Solar Energy Center (FSEC), CPS Energy, and Woodside Homes of South Texas worked together to build and measure the energy performance of three homes in San Antonio, TX.[1] All three homes had an identical floor plan and orientation as shown in Figure 1. The differences among the homes were the energy efficiency measures. The first home, CP1, was constructed to meet the existing building and energy codes using current practices for home insulation. The other two homes, CP2 and CP3, included spray foam insulation and energy efficient windows and doors, HVAC system, hot water heating, major appliances and lighting. A summary of these improvements is provided in the first three columns of Table 1.

Figure 1 – Photos of Three Homes in the South Texas Study

DETAILS OF THE SIDE-BY-SIDE TEXAS HOME STUDY

One notable difference among the study homes was the design of the building envelope. While each home used the same caulking and sealing techniques around windows, doors and framing connections, the type of insulation varied among the homes.

- CP1: The baseline home used R30 blown in fiberglass on the attic floor to create a vented attic. A roof deck with a factory-applied radiant barrier was used. R13 fiberglass batts were installed in all exterior wall cavities, without insulated sheathing.

- CP2: The second home used R28 of open-cell spray foam under the roof deck to create an unvented attic (UVA). This design moved the ductwork in the attic into the conditioned space (inside building envelope). In addition, the exterior wall cavities were insulated to R15 with loose-fill fiberglass, and R3

Figure 2 – Spray Foam under a Roof Deck

insulated sheathing on the outside was used to reduce thermal bridging from the framing.

- CP3: This home included the same unvented-attic design as CP2 using open-cell spray foam. Instead of fiberglass insulation in the walls, this home filled the 2x4 exterior wall cavities with R12 of open-cell spray foam. R4 insulated sheathing was used to prevent thermal bridging.

Figure 3 – Spray Foam being applied to an Exterior Wall Cavity

Figure 4 – Spray Foam in an Exterior Wall Cavity

Figure 5 – Blower Door Apparatus

SUMMARY OF RESULTS OF THE SIDE-BY-SIDE TEXAS HOME STUDY

The study found a significant reduction in building envelope air leakage in CP2 and CP3 compared to CP1, which was primarily attributed to the use of open-cell spray foam in the attic and walls. Using a blower door apparatus, shown in Figure 5, the air leakage of each home was measured, and recorded as the number of building air changes per hour (ACH) at a 50 Pascal (0.011 psi) pressure difference between the inside and the outside of the building (ACH_{50}). The baseline CP1 had a measured leakage of 5.84 ACH_{50}. CP2, using spray foam to create an unvented attic, had a measured leakage of 3.64 ACH_{50}. CP3, using spray foam to create an unvented attic and to insulate the exterior walls, achieved an air leakage rate of 1.95 ACH_{50}. This three-fold decrease in measured air leakage from CP1 to CP3 is consistent with similar air leakage data compiled for different homes using both fibrous and open-cell SPF insulations.[2 3 4]

In the existing study, there were many other energy efficiency improvements that contributed to better performance for homes CP2 and CP3. As shown in Table 1, energy improvements unrelated to the building envelope were used, and contributed to significant energy savings. The three homes had progressively decreasing Home Efficiency Rating System (HERS) scores of 86, 54 and 37.

ADDITIONAL ANALYSIS THROUGH ENERGY MODELING: Building Envelope Improvements

Since reduced air leakage contributes to improved energy efficiency, it is important to determine how the use of spray foam specifically reduced the energy use of each home. To isolate the effects of spray foam, energy modeling software was used. Using the energy models from the original Texas study and energy modeling software (REM/Rate[5]), the three homes were analyzed using the same features of the baseline CP1 home with the following improvements to the building envelope entered into the modeling software:

1. The attic was completely sealed from the exterior environment by installing barrier walls.
2. Spray foam was applied under the roof decks of both homes and the walls of one home. Insulated sheathing was also applied to the walls.
3. Ductwork is now in the conditioned space, due to the use of the spray foam.
4. Energy-recovery ventilation was used in the model to maintain indoor air and control air flow. (While the CP2-High Performance and CP3-PV test homes had run time ventilation, this is a feature that could not be modeled.)

Figure 6 – Spray Foam in an Attic

Results from Energy Modeling

The results from this additional modeling are shown in the last two columns of Table 1. The modeling found that the use of spray foam to create an unvented attic (Home CP2a) lowers the HERS score from 84* to 79, and results in a net annual energy savings of 16%. When spray foam is used to provide an unvented attic and insulate the exterior walls (Home CP3a), the HERS score is reduced from 84 to 78, and the annual energy savings increases to 22%. These results apply directly to the homes built in International Energy Conservation Code (IECC) Climate Zone 2, which is the climate zone in Texas where the actual homes were located.

The same homes in colder climate zones, such as in IECC Climate Zone 4 (i.e. Richmond, VA), would be required by the building codes to have increased insulation values and would need larger heating systems due to the colder temperatures during the winter. The same three homes were modeled using REM/Rate with the assumption of insulation levels and properly sized HVAC systems for Climate Zone 4. When modeled in Climate Zone 4 similar percentages of combined heating and cooling energy (17% for CP2a and 21% for CP3a) were saved in the two homes using SPF to insulate and air-seal. The heating energy required, and thus the overall energy required, in colder climate zones is typically more, relative to warmer climate

* All of the modeling in this paper used a more recent version of the REM/Rate software (Version 12) which reported a HERS score of 84 for the baseline home data file provided by the authors of the Texas home study. The earlier version of REM/Rate used by the authors of the Texas home study reported a HERS Score of 86 using the same model file.

zones, so while the energy savings percentages are similar, the total energy savings will be greater in colder climates.

CONCLUSIONS

For both new and retrofit applications, the use of SPF to create unvented attics that bring ductwork into conditioned space and provide improved air-sealing can significantly reduce energy usage, which in turn reduces heating and cooling costs, and additional reductions can be achieved when SPF is used to insulate and air seal exterior walls.

Table 1 – Summary of Energy Modeling Results

	Analysis from Original Study			Extended Analysis - Control + Improved Envelope	
FEATURE	CP1 - Control	CP2 - High Performance	CP3 - PV	CP2a - Control with High Performance Envelope (UVA)	CP3a - Control with PV Envelope (UVA + SPF Walls)
Foundation	Uninsulated slab on grade	Uninsulated slab on grade	Uninsulated slab on grade	Uninsulated slab on grade	Uninsulated slab on grade
Roof cladding	Brown asphalt shingle	Brown concrete tile	Brown concrete tile	Brown asphalt shingle	Brown asphalt shingle
Attic	Vented	Sealed	Sealed	Sealed	Sealed
Attic Insulation	R-30 blown fiberglass in ceiling plane, Roof deck radiant barrier, 1979 SF	R-28 open cell spray foam under roof deck, 2216 SF	R-28 open cell spray foam under roof deck, 2216 SF	R-28 open cell spray foam under roof deck, 2216 SF	R-28 open cell spray foam under roof deck, 2216 SF
Wall Type	2x4 frame/brick veneer	2x4 frame/brick veneer	2x4 frame/brick veneer	2x4 frame/brick veneer	2x4 frame/brick veneer
Wall Insulation	R-13 fiberglass batts	R-15 blown-in fiberglass + R3 insulated sheathing	R-12 open cell spray foam + R4 insulated sheathing	R-15 blown-in fiberglass + R3 insulated sheathing	R-12 open cell spray foam + R4 insulated sheathing
Windows	SHGC: 0.37, U-factor 0.53	SHGC: 0.33, U-factor 0.34 + roofline extension	SHGC: 0.33, U-factor 0.34 + roofline extension	SHGC: 0.37, U-factor 0.53	SHGC: 0.37, U-factor 0.53
Heating	80% AFUE Gas Furnace	9.5 HSPF heat pump + 5kW b/u strip heat	94% AFUE Gas Furnace	80% AFUE Gas Furnace	80% AFUE Gas Furnace
Cooling	14 SEER	17.8 SEER	17.7 SEER	14 SEER	14 SEER
Water Heating	Water Heating 40 gal Gas Tank, EF=0.59	Tankless Gas, EF=0.82	Tankless Gas, EF=0.82	Water Heating 40 gal Gas Tank, EF=0.59	Water Heating 40 gal Gas Tank, EF=0.59
Ventilation	None	Passive Run Time	Passive Run Time	Passive Run Time	Passive Run Time
Lighting	Incandescent + 5% Fluorescent	100% Fluorescent, timers and occupancy sensors	100% Fluorescent, timers and occupancy sensors	Incandescent + 5% Fluorescent	Incandescent + 5% Fluorescent
Cooktop	Electric	Natural Gas	Natural Gas	Electric	Electric
Refrigerator	775 kWh/yr	Energy Star, 505 kWh/yr	Energy Star, 505 kWh/yr	775 kWh/yr	775 kWh/yr
Washer	Standard Top-loader	Energy Star, Tier 3	Energy Star, Tier 3	Standard Top-loader	Standard Top-loader

Dishwasher	EF=0.46	EnergyStar, EF=0.66	EnergyStar, EF=0.66	EF=0.46	EF=0.46
Dryer	Electric	Natural Gas	Natural Gas	Electric	Electric
Thermostat	Non-programmable	programmable	programmable	Non-programmable	Non-programmable
PV	None	None	2.4 kW roof tiles	None	None
HERS Index (from Reference 1)	86	54	37		
Envelope Leakage	5.84 ACH50	3.64 ACH50	1.95 ACH50	3.64 ACH50	1.95 ACH50
Insulation/AB	All loose-fill or batt fiberglass	LF-FG walls, ocSPF UVA	All ocSPF	LF-FG walls, ocSPF UVA	All ocSPF
Duct Leakage	70 CFM25, Qn=0.035	47 CFM25, Qn=0.024	65 CFM25, Qn=0.033	70 CFM25, Qn=0.035	70 CFM25, Qn=0.035
Envelope Leakage	**5.84**			**3.64**	**1.95**
CFM at 50 Pa	**1860**			**1159**	**621**
HERS Index (REM/Rate v12)*	**84**			**79**	**78**
HERS Index Reduction (%)				6%	7%
Annual Heating (MMBTU/yr)	25.3			19.5	18.6
Annual Heating Savings (%)				**23%**	**26%**
Annual Cooling (MMBTU/yr)	12.1			11.7	11.7
Annual Cooling Savings (%)				**3%**	**3%**
Total Heating/Cooling (MMBTU/yr)	37.4			31.6	29.3
Total Heating/Cooling Savings (%)				**16%**	**22%**

* All of the modeling in this paper used a more recent version of the REM/Rate software (Version 12.97). This version of REM/Rate determined a HERS score of 84 for the baseline home data file provided by the authors of Reference 1. The earlier version of REM/Rate used Reference 1 reported a HERS Score of 86 using the same model file, and scores of 54 and 37 for the CP2 and CP3 homes.

The Center for the Polyurethanes Industry (CPI) of the American Chemistry Council serves as the voice of the polyurethanes industry in North America and works with polyurethane trade associations across the globe. CPI members are companies that produce and sell the raw materials and additives that are used to make polyurethane products, equipment used in the manufacture of polyurethanes, and companies engaged in end-use applications and the manufacture of polyurethane products.

The Spray Foam Coalition (SFC) champions the use of spray polyurethane foam in U.S. building and construction applications and promotes its economic, environmental and societal benefits while supporting the safe manufacture, transport, and application of spray polyurethane foam. SFC consists of manufacturers of spray polyurethane foam systems as well as suppliers of raw materials and machinery used to apply the foam.

Disclaimer: This paper was prepared by the Spray Foam Coalition with data that was obtained from the report "Measured Performance of Side-by-Side South Texas Homes." Neither the

REFERENCES

[1] D. Chasar, J. Sherwin, V. vonSchramm, S. Chandra, "*Measured Performance of Side-by-Side South Texas Homes*," DOE Buildings XI Conference, December 2010.

[2] "*Air Infiltration Data Analysis for Newly Constructed Homes Insulated with Icynene Spray Foam*." Upper Marlboro, MD 20774: NAHB Research Center, November 2007.

[3] Chan, Wanyu R., et al. "Analysis of U.S. Residential Air Leakage Database." Rep. no. LBNL-53367. Berkeley, CA: Lawrence Berkeley National Library, July 2003.

[4] Sherman, Max H., and Nance E. Matson. "*Air Tightness of New U.S. Houses: A Preliminary Report*." Rep. no. LBNL-48671. Berkeley, CA: Lawrence Berkeley National Library, March 20. 2002.

[5] REM/Rate™ Residential energy analysis, code compliance and rating software, Architectural Energy Corporation, http://www.archenergy.com/products/remrate.