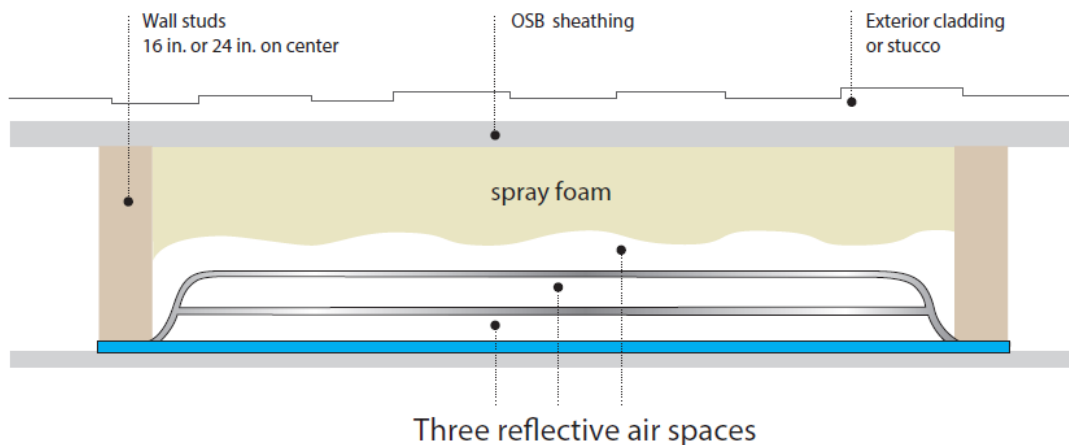




R-values for a Hybrid Insulation System for Frame Walls that Combines Spray-Applied Polyurethane Foam and HY-Fi Reflective Insulation

Description of Assembly

A hybrid assembly consisting of a layer of spray-applied polyurethane foam that partly fills a wall cavity with HY-Fi reflective insulation in the remaining space has been evaluated. R-values for hybrid assemblies in nominal 2 by 4 in. and nominal 2 by 6 in. frame-wall cavities have been calculated. In each case, polyurethane foam insulation or a similar cellular plastic insulation is installed on the exterior side of the cavity with HY-Fi reflective insulation installed in the remaining space on the interior side of the cavity to form two or three enclosed reflective air spaces as shown in the following figure. The total R-value of the insulated cavity is the sum of the thermal resistance of the foam and the thermal resistances of the enclosed reflective air spaces. HY-Fi reflective insulation is manufactured by the Fi-Foil Company located in Auburndale, Florida.



Conditions and Properties

The R-value calculations are based on specified average foam thicknesses. When two enclosed air spaces are formed irregularities on the foam surface do not affect the reflective air spaces since they are interior to the HY-Fi insulation. When a third enclosed air space adjacent to the foam surface is present, its thickness is calculated as the total cavity thickness minus the specified foam thickness and the space occupied by HY-Fi. All calculations were done with an average cavity temperature of 75 °F and a temperature difference across the cavity of 30 °F in order to be consistent with ASTM C1224¹ and a Federal Trade Commission requirement that thermal resistances used for labeling be determined at 75°F.² Foam thermal resistivities (R^* or R per inch) from 3.5 to 6.8 ft²·h·°F/Btu·in. were included in the evaluation. This range of R^* values includes both open-cell and closed cell foams. The thermal emittance of the reflective surfaces that are part of HY-Fi were determined to be 0.034 while the thermal emittance of the non-

reflective surfaces was taken to be 0.9. This results in an effective emittance of 0.0339 for the enclosed reflective air spaces.

Calculated R-values

R-values for the hybrid insulation assemblies in wall cavity were calculated using the procedure described in ASTM STP 1116³ with a two-dimensional adjustments for radiative transport according to Glicksman.⁴ The calculation is iterative because the thermal resistance of enclosed reflective air spaces depends on average air gap temperature and temperature difference. These temperatures depend on the thermal resistances of all of the materials in the cavity being evaluated. Table 1 contains the temperatures at the interface between the foam and HY-Fi for each of the seven assemblies that were evaluated. The R-value for the reflective air space is obtained when the iterative process converges to a constant value. The results for the R-values of the foam component and the reflective component are shown in Table 2. Table 2 also contains a “Rounded R-value” in accordance with Paragraph 460.11 of the Federal Trade Commission Rule for Residential Insulation Labeling.⁴

Table 1. Temperatures at Interface Between Foam and HY-Fi Reflective Insulation

| <u>Nominal 2 by 4 in. Framing</u> | R* foam (ft ² ·h·°F/Btu·in.) | | | | |
|-----------------------------------|---|-------------|-------------|-------------|-------------|
| | <u>3.50</u> | <u>4.00</u> | <u>6.00</u> | <u>6.20</u> | <u>6.80</u> |
| 1.0-inch of Foam | 81.64 | 80.85 | 78.22 | 78.00 | 77.37 °F |
| 1.5-inches of Foam | 79.00 | 78.08 | 75.18 | 74.94 | 74.27 |
| 2.0-inches of Foam | 75.70 | 74.71 | 71.76 | 71.53 | 70.89 |
| 2.5-inches of Foam | 71.10 | 70.20 | 67.70 | 67.51 | 67.01 |
| <u>Nominal 2 by 6 in. Framing</u> | | | | | |
| 2.0-inches of Foam | | | 73.21 | 72.99 | 72.36 °F |
| 3.0-inches of Foam | | | 70.72 | 70.52 | 69.95 |
| 4.0-inches of Foam | 70.68 | 69.79 | 67.35 | 67.17 | 66.68 |

Table 2. Calculated R-values (ft²·h·°F/Btu) for Hybrid Insulations

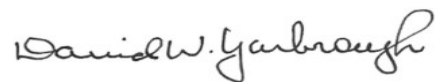
| <u>Nominal 2 by 4 in. Framing</u> | R* foam (ft ² ·h·°F/Btu·in.) | | | | |
|-----------------------------------|---|-------------|-------------|-------------|-------------|
| | <u>3.50</u> | <u>4.00</u> | <u>6.00</u> | <u>6.20</u> | <u>6.80</u> |
| 1.0-inch of Foam | | | | | |
| R _{foam} | 3.50 | 4.00 | 6.00 | 6.20 | 6.80 |
| R _{HY-Fi} | 8.31 | 8.36 | 8.51 | 8.52 | 8.56 |
| R _{total} | 11.81 | 12.36 | 14.51 | 14.72 | 15.36 |
| R Rounded | 12 | 12 | 15 | 15 | 15 |
| 1.5-inches of Foam | | | | | |
| R _{foam} | 5.25 | 6.00 | 9.00 | 9.30 | 10.20 |
| R _{HY-Fi} | 8.47 | 8.50 | 8.61 | 8.62 | 8.65 |
| R _{total} | 13.72 | 14.50 | 17.61 | 17.92 | 18.85 |

(Table 2 –continued)

| | | | | | | |
|-----------------------------------|--------------------|-----------|-----------|-----------|-----------|-----------|
| | R Rounded | 14 | 15 | 18 | 18 | 19 |
| 2.0-inches of Foam | | | | | | |
| | R _{foam} | 7.00 | 8.00 | 12.00 | 12.40 | 13.60 |
| | R _{HY-Fi} | 7.32 | 7.33 | 7.37 | 7.37 | 7.38 |
| | R _{total} | 14.32 | 15.33 | 19.37 | 19.77 | 20.98 |
| | R Rounded | 14 | 15 | 19 | 20 | 21 |
| 2.5-inches of Foam | | | | | | |
| | R _{foam} | 8.75 | 10.00 | 15.00 | 15.50 | 17.00 |
| | R _{HY-Fi} | 4.91 | 4.91 | 4.93 | 4.94 | 4.94 |
| | R _{total} | 13.64 | 14.91 | 19.93 | 20.44 | 21.94 |
| | R Rounded | 14 | 15 | 20 | 20 | 22 |
| <u>Nominal 2 by 6 in. Framing</u> | | | | | | |
| 2.0-inches of Foam | | | | | | |
| | R _{foam} | | | 12.00 | 12.40 | 13.60 |
| | R _{HY-Fi} | | | 8.70 | 8.72 | 8.77 |
| | R _{total} | | | 20.70 | 21.12 | 22.37 |
| | R Rounded | | | 21 | 21 | 22 |
| 3.0-inches of Foam | | | | | | |
| | R _{foam} | | | 18.00 | 18.60 | 20.40 |
| | R _{HY-Fi} | | | 9.43 | 9.46 | 9.53 |
| | R _{total} | | | 27.43 | 28.06 | 29.63 |
| | R Rounded | | | 27 | 28 | 30 |
| 4.0-inches of Foam | | | | | | |
| | R _{foam} | 14.00 | 16.00 | 24.00 | 24.80 | 27.20 |
| | R _{HY-Fi} | 7.51 | 7.52 | 7.55 | 7.55 | 7.56 |
| | R _{total} | 21.51 | 23.52 | 31.55 | 32.35 | 34.76 |
| | R Rounded | 22 | 24 | 32 | 32 | 35 |

The R* (R-per-inch) values in the range 3.5 to 4.0 are characteristic of open-cell foams and many fibrous and particulate insulation materials. The R* values 6.0 to 6.8 are characteristic of closed-cell cellular plastic foam insulations containing a gas other than air. The R* values 6.0 to 6.8 are taken to be the “Long-Term Thermal Resistance” values.

The thermal resistances shown for HY-Fi (R_{HY-Fi}) are linear with respect to R_{foam} for each of the seven sets of results in Table 2. This means that linear interpolation in the tabulated values will yield accurate results.



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September 29, 2014

References

- ¹ ASTM C1224, "Standard Specification for Reflective Insulation for Building Applications" Annual Book of ASTM Standards Vol. 04.06 (2013) pp 698-702.
- ² Federal Trade Commission, 16 CFR 460, "Labeling and Advertising of Home Insulation".
- ³ Andre O. Desjarlais and David W. Yarbrough, "Prediction of the Thermal Performance of Single and Multi-Airspace Reflective Insulation Materials", ASTM STP 1116 (1991) pp 24-43.
- ⁴ Leon R. Glicksman, "Two-Dimensional Heat Transfer Effects on Vacuum and Reflective Insulations", *J. of Thermal Insulation* 14 281-294 (1991).