Summary

Proper characterization of the building envelope is critical to any energy reduction plan that includes changes in insulation. This Tech Tip describes how to calculate the effective U-value of a building assembly and discusses de-rating insulation.

Calculating the Effective U-Value of a Building Assembly

Many people are more familiar with R-values than with U-values because insulation comes labeled with R-value ratings. R-value expresses the resistance to heat transfer. The U-value is the rate of heat transfer per unit area per degree of temperature difference, and is the inverse of the R-value. That is, U=1/R and R=1/U.

If different cross-sections through a building assembly such as a wall, roof, or floor have different R-values, the effective R-value for that surface must be calculated by first calculating the U value of each different cross-section. TREAT and eQuest offer libraries with R-values for different building surfaces. Here is how those R-values can be calculated for a wood frame stucco wall with nominal 2" x 4" framing, 3.5" fiberglass batt insulation.

The R-value at a cross-section through the insulation is higher than the R-value of the insulation itself:

Material	R value[1]
Outside air film[2]	0.17
Stucco	0.08
Gypsum board	0.56
Batt insulation (nominal rating)	11.00
Gypsum board	0.56
Inside air film[2]	0.68
Total R	13.05
U value	0.08

The R-value of a cross-section at the framing is lower than the R-value of the insulation.

Material	R value[1]
Outside air film[2]	0.17
Stucco	0.08
Gypsum board	0.56
3.5" wood (nominal 2" x 4")	4.38
Gypsum board	0.56
Inside air film[2]	0.68
Total R	6.43
U value	0.16

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[1] R-values for insulation and building materials can be found in ASHRAE Fundamentals as well as many sources on the Internet.
[2] Different modeling tools handle air films differently. For TREAT, calculate R-values without interior or exterior air films, as they will be added later. For eQuest, omit the exterior air film from your calculation. For other tools, consult your manual.

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Assume (per ASHRAE 90.1-2004) that the studs, plates, sills and headers are 25% of the total area of a wood-framed wall, while the cavity insulation is 75% of the total area.

The effective U-value of this wall assembly would be calculated as:

Effective U-value = (0.75 x 0.08) + (0.25 x 0.16) = 0.1

The effective R-value for the wall assembly is 1/0.1 = 10, lower than the nominal R-value of the insulation.

ASHRAE Standard 90.1-2004 contains a series of tables that show the effective R-value of different wall, roof, and floor assemblies, including both cavity and continuous insulation. If you are considering a building whose construction is not described in the TREAT or eQuest libraries or the ASHRAE Standard 90.1-2004 tables, you can calculate its R-value using the procedure described previously. ASHRAE Fundamentals contains R-values for many building materials; these values are also widely available on the Internet. In addition, Oak Ridge National Laboratory offers free R-value calculation software at http://www.ornl.gov/sci/roofs+walls/AWT/InteractiveCalculators/index.htm.

Assumptions about the fraction of the total surface area that is insulated (compared to the fraction that consists of framing members) have a large effect on the effective U-value of the surface. According to Oak Ridge National Laboratory (ORNL), framing factors such as studs, wall/wall (corners), wall/roof, wall/floor, wall/door, and wall/window connections can occupy 10% to 40% of the wall area. Appendix A of ASHRAE 90.1-2004 recommends the following assumptions for wood-framed buildings:

Construction type	Material	% of surface area
Attic roof with wood joists, Standard framing (insulation tapers at perimeter)	Full-depth insulation Half-depth insulation Joists	85% 5% 10%
Attic roof with wood joists, Advanced framing	Full-depth insulation Joists	90% 10%
Single-rafter roof (ceiling and roof attached to the same rafter)	Full-depth insulation Joists	90% 10%
Wood-framed walls, Standard framing (16" on center)	Insulated cavity Studs, plates and sills Headers	75% 21% 4%
Wood-framed walls, Advanced framing (24" on center)	Insulated cavity Studs, plates and sills Headers	78% 18% 4%

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Metal Wall Studs

The attached table, reproduced from ASHRAE Standard 90.1-2004, Appendix A presents measured R-values for wall insulation installed between steel framing. Metal framing presents a special situation because of metal's high thermal conductivity. To calculate the overall U value for a wall with metal studs, use the R-value from this table and add the R-values of the rest of the wall assembly (e.g. masonry, interior gypsum board, interior and exterior airfilms), using the procedure described previously.

TABLE A9.2B Effective Insulation/Framing Layer R-Values for Wall Insulation Installed Between Steel Framing

Nominal Depth of Cavity (in.)	Actual Depth of Cavity (in.)	Rated R-Value of Airspace or Insulation	Effective Framing/Cavity R-Value at 16 in. on center	Effective Framing/Cavity at 24 in. on center
Empty cavity, no insulation				
4	3.5	R-0.91	0.79	0.91
Insulated Cavity				
4	3.5	R-11	5.5	6.6
4	3.5	R-13	6.0	7.2
4	3.5	R-15	6.4	7.8
6	6.0	R-19	7.1	8.6
6	6.0	R-21	7.4	9.0
8	8.0	R-25	7.8	9.6

The table below excerpts ASHRAE Standard 90.1-2004, Appendix A, Table A9.2A, which provides measured R-values for metal framed roofs. As with metal-framed walls, you should add the R-values of air films and construction materials to this base value.

Effective Insulation/Framing Layer R-Values for Roof and Floor Insulation Installed Between Metal Framing (4 ft on center)

Rated R-value of Insulation	Framing/Cavity R-Value
11.00	10.01
19.00	16.34
38.00	28.12
55	36.85

If your insulation is an intermediate R-value between those provided in the table, it is legitimate to interpolate between the framing/cavity R-values shown in the table.

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