

## Thermal Mass Beyond R-value

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R-values measure how readily heat moves by a process called "conduction" from the heated side of a material to cold under steady-state conditions, typically seen under peak loads for heating and cooling buildings.

The mass effect is a result of the dynamic process of a building components' "heat capacity," modulating heat flow over the course of a day. For example, on a summer afternoon with a 90-degree outside temperature and cooler inside temperature, the conduction heat flow moves toward the inside. At night, when the air temperature drops to 50-deg., and indoor temperature may be 75-deg., then the driving force for heat flow reverses back toward the outside. *The heat capacity of a building's walls -- such as logs, masonry or concrete -- accounts for variable energy needs over daily and annual cycles, an occurrence which engineers, standards and codes refer to as the thermal mass effect.*

Other energy benefits to building with mass versus insulated frame include:

- Consistent thermal value vs. gaps or thermal bridges in "light-frame" construction insulation cavities;
- Consistent volume vs. compression, compaction, settling, and aging of insulation products; and
- Natural moisture movement vs. the need to inhibit potential moisture (using costly vapor barrier materials) that will diminish the performance of many insulation products.

Mass-enhanced R-values (concept developed at Oak Ridge National Laboratory) are being recognized by the building codes, such as in Model Energy Code (MEC), Section 502. This model code section accounts for thermal mass in exterior walls having heat capacity equal to or exceeding 6 Btu/ft.<sup>2</sup> and establishes acceptable mass for solid wood walls at 20 lb./ft.<sup>2</sup> or more. MEC Table 502.1.2c, Required  $U_w$  for wall with a heat capacity equal to or exceeding 6 Btu/Ft.<sup>2</sup>-F° with integral insulation (insulation and mass mixed, such as a log wall), closes the R-value comparison gap.

To put this in simpler terms, the mass-enhanced R-values are based on the following:

- ❑ Temperature on one side (of a building assembly) is held constant and heat flow is measured while the temperature on the other side fluctuates up and down.
- ❑ R-values (actually the reciprocal of the U-factor, which is the engineering measure of heat flow through building assemblies) are a measure of the energy required to keep the other side at a given design temperature.
- ❑ Table 502.1.2c provides additional benefit to recognize that higher wood densities (greater mass) do not exhibit better R-value.

The following comparison can illustrate the discussion above. The information was generated using the *MECcheck* program that was written to perform the procedures and calculations defined in the Model Energy Code. This code is very similar to what is now adopted as the International Energy Conservation Code 2000. The data provided is based on the dimensions of a standard Southland Log Homes Saluda I model, calculated using three different exterior wall types. It compares the response of this particular home with the different wall types in three different climates: Greenville, SC; Boone, NC; and Minneapolis, MN.

In Table 1, the building is defined quantitatively and a thermal factor (R-value or U-value) is applied, resulting in the UA (U-value of the total assembly area).

The Total UA is the sum of all UAs. After arriving at the Total UA for the first building with Southern Yellow Pine 8" thick log walls (Exterior Wall 2A), the walls are changed to get comparative values.

Exterior Wall 2B represents an Eastern White Pine 6"-thick log wall while Exterior Wall 2C represents a standard 2x4 frame wall.

• Table 1: Definition of the Building by Assembly Type

Assembly Type	Gross Area or Perimeter	Cavity R-value	Glazing or Door U-Factor	UA	Effective R-value
Ceiling: All- Wood Joist/Rafter/Truss	1280	30.0		45	28.44
Exterior Wall 1: Wood frame, 16" o.c.	420	13.0		34	12.35
<b>Exterior Wall 2A: Log: 8" Diameter Southern Yellow Pine Logs</b>	1348	Nominal 8" log wall thickness = R-5.9 (R-0.8/in.)		63	21.40
Window 1: Wood frame, Double Pane w/Low-E	232		0.345	80	2.9
Door 1: Opaque	80		0.260	21	3.8
Floor 1: All-Wood Joist/Truss, Over Unconditioned Space	1280	21.0		56	22.86
<b>TOTAL UA</b>				<b>299</b>	
<b>Exterior Wall 2B: Log: 6" Diameter Eastern White Pine Logs</b>	1348	Nominal 6" log wall thickness = R-6.9 (R-1.25/in.)		69	19.54
<b>TOTAL UA</b>				<b>305</b>	
<b>Exterior Wall 2C: Wood Frame, 16" o.c. w/R-13 insulation in cavity</b>	1348	13		85	15.86
<b>TOTAL UA</b>				<b>321</b>	

Note that the "Effective R-Value" calculated by *MECcheck* shows that the UA is adjusted for thermal mass as defined in the Model Energy Code. In other words, the effective R-value of Exterior Walls 2A and 2B reflect the nature of thermal mass as opposed to the simpler measurements that result in R-values. Note also that Exterior Wall 2C has been adjusted by the program for the value of wall sheathing on both sides, resulting in a comparable R-16 (1348/85).

The actual code compliance statement produced by the *MECcheck* program further proves out the Effective R-value comparison above. Both log walls, even with different species and widths, actually perform better than the R-13 frame wall used in the comparison due to thermal mass.

• Table 2: Performance by Location and Total UA of Saluda I

Building Location	Heating Degree Days	Total <u>Calculated</u> UA	Max. UA Allowable	Compliance
Greenville, SC	3272	<b>299</b> for <i>Exterior Wall 2A: Log: 8" Diameter Logs</i>	459	Passes by 35%
Boone, NC	6003		340	Passes by 12%
Minneapolis, MN	7981		302	Passes by 1%
Greenville, SC	3272	<b>305</b> for <i>Exterior Wall 2B: Log: 6" Diameter Logs</i>	407	Passes by 25%
Boone, NC	6003		319	Passes by 4.4%
Minneapolis, MN	7981		292	Fails by 4.5%
Greenville, SC	3272	<b>321</b> for <i>Exterior Wall 2C: Wood Frame, 16" o.c. w/R-13 insulation</i>	407	Passes by 21%
Boone, NC	6003		319	<i>Fails by 0.6%</i>
Minneapolis, MN	7981		292	<i>Fails by 10%</i>

