

## DOE Warms Up to Thermal Mass in Log Walls

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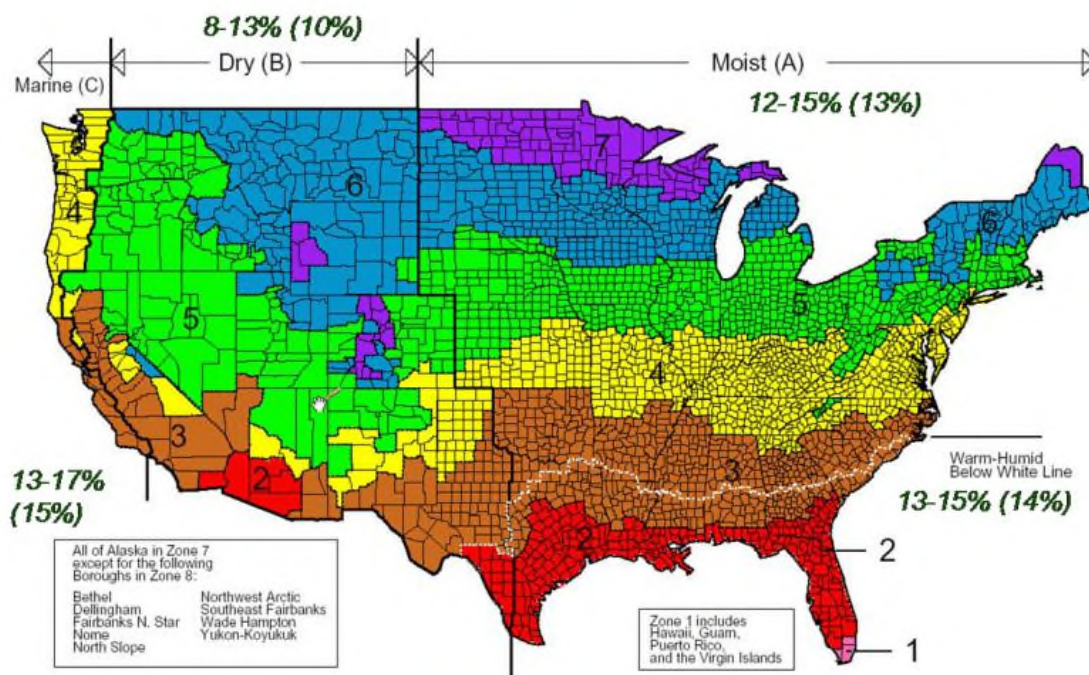
For the first time ever, the Log Homes Council has an independent third-party evaluation of how log wall construction compare to stick frame construction. The results of this effort have demonstrated known properties of solid wood but have provided the ability to assess log home energy performance in various climates and compare that performance to frame construction.

### The History

In 2001, the article “Thermal Mass Beyond R-Value” examined the relationship of thermal mass and R-value in an effort to demonstrate the thermal performance of log walls. Since then, a considerable amount of research, testing, and analysis, largely sponsored by the Log Homes Council (LHC) of the National Association of Home Builders (NAHB), has been completed to improve our understanding of the effects of the integrated mass and R-value of log walls.

The log home industry has been dealing with thermal calculations since the building energy codes evolved. In fact, this was one of the driving forces for the founding of the Log Homes Council in 1977. The response of engineers was to apply the ASHRAE *Handbook of Fundamentals* to calculate the steady state u-factor for the log wall. The log wall u-value was multiplied by the opaque wall area, then added to the window and door UA (u-factor x area) to calculate the overall wall UA. In response to prescriptive minimum insulation requirements in the building energy codes, log home designers became accustomed to specifying higher roof/floor insulation levels and greater fenestration performance to offset the log wall values specified by ASHRAE.

R-values were used to compare materials of various densities on the assumption that they behave the same way in all climatic conditions, but the performance estimated in analysis did not match the experiences of log home owners. The application of static R-value to log walls was challenged in the 1980’s through testing under the auspices of the National Institutes of Standards and Technology (NIST). It demonstrated the concept of thermal mass by monitoring six prototype buildings of identical size, shape and solar orientation with the only variation being the specification of the wall assembly. This study became crucial to the evolution of the thermal mass credit in the 1989 Model Energy Code (MEC).



**Figure 1 - U.S. Dept. of Energy Climate Zone Map with Calculated Equilibrium Moisture Content Ranges (Average)**

In 2003, the developers of REScheck® (for the U.S. Department of Energy) were approached to make changes to the options for log home construction in order to better represent the industry. Coinciding with the development of

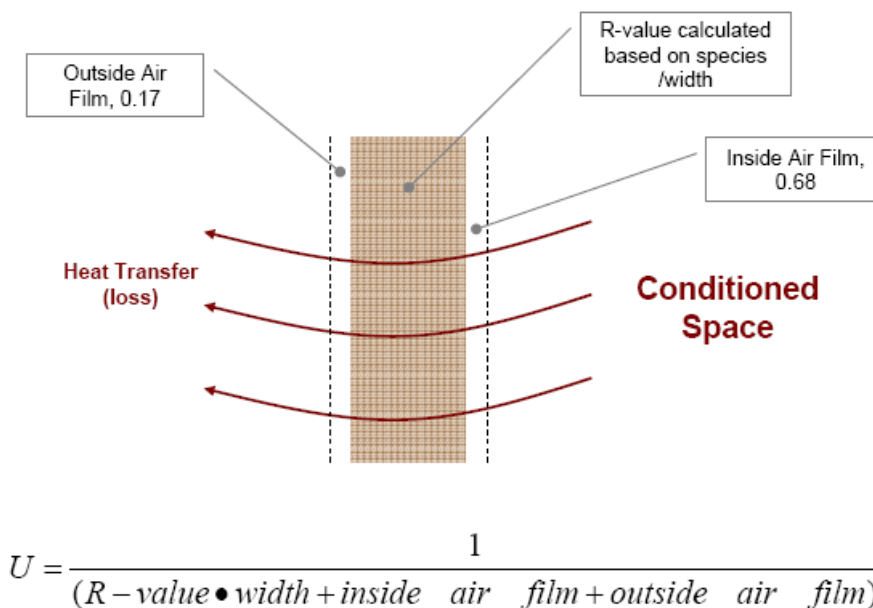
ICC 400, *Standard on the Design & Construction of Log Structures*, new information was organized into a form that the developers could integrate into the REScheck program. In 2004, REScheck was released with log wall features that permitted the user to select a representative wood species. Also, the log wall thickness was modified to match the dimension established in ICC400 (average log width for evaluating R-value is the area of the log profile divided by its stack height). Future log wall developments in REScheck may be to calculate R-value based on average equilibrium moisture content for the different climate zones noted in ICC400 (see map below) and to model thermal mass more accurately for those climate zones.

During 2006 and 2007, full-scale testing was performed at Oak Ridge National Labs (ORNL) in Oak Ridge, TN on log walls from various LHC member companies. For two decades, ORNL had been testing building technologies (roof and wall). The work produced a database of over 200 different types of walls, but it did not yet include solid wood/log wall systems. These tests and associated computer simulations generated a large portion of the information that follows. It is the hope of this author that these tests result in further improvements to REScheck, building energy codes, and the log home industry.

## R-Values

Thermal resistance is quantified in terms of R-value, which is the inverse of the U-factor. The U-factor is a measure of heat transmission in unit time through unit area of a material or construction and the boundary air films, induced by the unit temperature difference between the environments on each side.<sup>1</sup> In simple terms, better thermal performance of a material or assembly is represented by a lower u-factor and a higher R-Value. Heat transmission is tested under steady-state conditions following ASTM C1363 hot-box procedure (when one side is exposed to 100°F while the other one to 50°F and the mean temperature of the test specimen is around 75°F).

R-Values (estimated for steady-state heat transfer conditions) are advantageous to lightweight insulating materials, and the reference to a certain “R” has become the norm for describing the thermal performance of a building. As a relatively easy concept to grasp, the R-value approach has been written into the building energy codes and standards. Where R-13 and R-19 represent nominal R-values of cavity insulation, prescriptive minimum insulating requirements for conventional wood frame walls have been simplified to a specification of merely, R-13 or R-19 walls.



*Example of Thermal Flow Calculation from “Log Homes in REScheck Calculations and Demonstration,” presented in the DOE Building Energy Codes - REScheck Log Homes Web-based Training Video. The webcast video can be accessed from [www.energycodes.gov](http://www.energycodes.gov).*

### Figure 2 - Determining R-Value for Walls

The equation in Figure 2 illustrates the method of establishing the opaque wall u-value. The issue with this arises when a single wall section is used to establish the thermal properties of the entire wall area. The issue is exemplified by the prescriptive sections of the building energy code that only specify insulation R-values. This

<sup>1</sup> ANSI/ASHRAE/IESNA Standard 90.1, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., 1791 Tullie Circle, NE, Atlanta, GA 30329

was done to simplify specification and enforcement by code officials, however the use of the rated R-value is only an appropriate point of comparison or specification when comparing center-of cavity R-values. For simplicity, the building community has become accustomed to calling for an R-13 frame wall, but testing and computer simulations show this wall technology performs as an R-9.65!

The prescribed insulation requirements that will achieve the goals of the energy code were modeled by ORNL with a use of computer simulations that included assumptions for the contributions of the framing, sheathing elements and air films from the ASHRAE *Handbook of Fundamentals*. The average wood-framed building in the US is a complex three-dimensional network of wood structural members, thermal insulation, and finish materials. The concept of whole wall thermal performance follows later, but the point of this discussion is that alternative wall systems (a.k.a., technologies, configurations) that vary from the frame wall specification in the building codes very often cannot be directly compared to these prescriptive rated R-values.

For solid wood walls, the equation in Figure 2 above requires additional modification. “R-value” in the equation is further quantified by the density of the wood, which varies with species, and moisture content. Because there is tremendous variability of density within a given species, between trees, and even between different parts of a single tree, standards have been established by testing thousands of wood samples to prescribed test procedures and then completing a statistical analysis. With wood performance data provided in ASTM Standard D2555 for the various commercially available wood species, one can calculate the R-value for a one-inch thick segment of wood using the equation,  $k = G [B+C (MC)] + A$ , where A, B, and C are constants, G is the specific gravity of the wood, and MC is the moisture content (assumed at 12%).<sup>2</sup> This R-value can also be established through testing in accordance with ASTM Test Methods C177, C518 or C1363.

The established R-value per inch thickness of a given wood species is then multiplied by the thickness of the log to establish an overall R-value as indicated in Figure 2’s equation. But what is the appropriate measure of thermal and energy performance of log wall technologies? There are three elements of log walls that should be compared rather than looking solely at the R-value.

1. Calculation of average width and application of shape factors
2. Whole wall R-value
3. Thermal mass effect

## ***Establishing Log Wall Width***

With the publishing of the ANSI consensus standard, ICC400 *Standard on the Design and Construction of Log Structures* (June 2007), log home designers now have a common basis for evaluating their designs. ICC 400 defines the average log thickness as the area of the log profile divided by its stack height and uses this measurement to calculate the R-value of the wall for use in static thermal performance analysis (e.g., REScheck). The average log width was a result of debate over how to account for the vast variation throughout the industry in log dimension or shape.

In REScheck, the developers had to find a common ground that could be managed in the software. Rather than allow the user to enter any number for the average log width, they chose to offer nominal widths in 1-inch increments. This incremental variation also manages the fact that there is a difference between the nominal size, the actual size, and the affects of log shape.

The testing of wall assemblies at ORNL further amplified the concept that the shape of the log has an affect on thermal performance. The test results of rectangular shapes with relatively simple, flat surfaces supported the performance that would be expected by calculation. This is because the ASHRAE equations assume a consistent wall thickness and do not account for surface variation unless the engineer applies the variation at some interval. When more complex shapes were tested, it was found that the traditional approaches to calculating the log wall R-values were significantly less accurate. A perfectly rectangular wall-log is a very unlikely configuration, as even those profiles involve chink grooves and/or interior chamfers to create a V-match appearance.

## **Size & Shape**

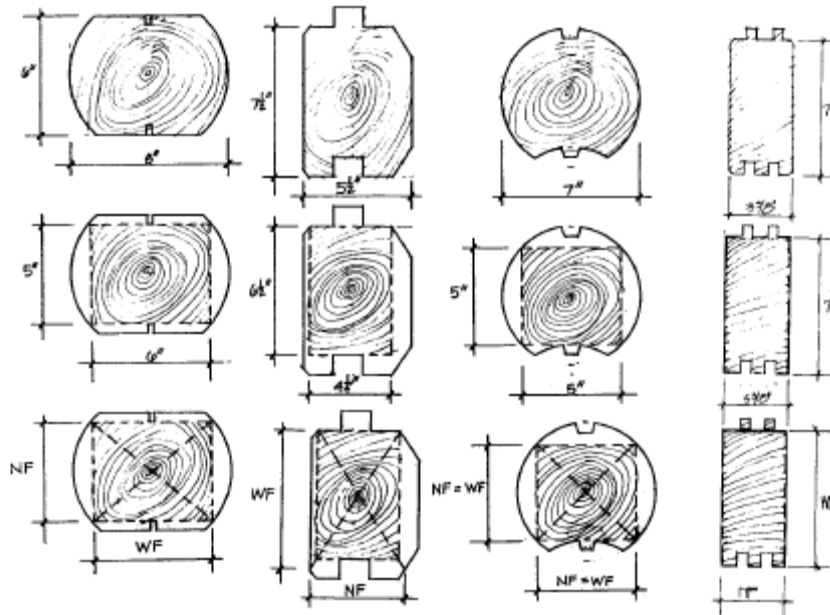
Used throughout the wood industry, nominal sizes provide a convenient reference and may be closer to the size of the original piece (round or rectangular cant) from which the log profile is made. The actual size can be reduced by hand-peeling (1/4” per face), planing (1/8” to 1/4” per face), etc. Remembering that the building energy code developers are focusing on simplifying rather than complicating the process, the use of the nominal log callout would be the preference. However, wide variation from nominal to actual seen in the log home industry also

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<sup>2</sup> ICC400 Standard on the Design and Construction of Log Structures (ICC 400-2007 IS LOG), International Code Council 500 New Jersey Avenue, NW, 6<sup>th</sup> Floor, Washington, D.C. 20001, June 2007

requires approximation to arrive at a reasonable response to thermal performance. The concept of a shape factor would be a better representation of the finished log profile in thermal analysis and should be considered. Some examples of potential shape factors would be as follows:

- Square logs – rectangular shape with vertical interior and exterior faces and slight profiling = 0.97
- Beveled logs – a vertical interior and an angled exterior surface (to replicate a clapboard appearance) and slight profiling = 0.81 to 0.88
- D-logs – as the name implies, a vertical interior and a round exterior surface and slight profiling = 0.83 to 0.87
- Double D-logs – round interior and exterior surfaces with flat or patterned top and bottom faces = 0.65 to 0.83 (variation occurs due to log height and the curvature radius)
- Round logs – milled (a round log of uniform dimension its full length) or natural (round log with taper along its length, with the average width as the nominal reference), coped or notched for bearing = 0.50 without chinking
- Round chink logs – a hand-peeled log without cope or notch = 0.45 without chinking, 0.55 to 0.65 with chinking and 1/4" gasket, 0.70 to 0.75 with chinking over minimum 3/4" trapezoidal gasket



NF—Narrow Face  
WF—Wide Face

**Figure 3 Typical Wall-Log Sections Showing Wide and Narrow Faces as Determined by Inscribed Rectangle (from ASTM D3957—06 Standard Practices for Establishing Stress Grades for Structural Members Used in Log Buildings)**

The shape factors above would need to be analyzed using detailed finite difference modeling to confirm appropriate values. The computer models could be based on the series of hot-box tests performed by ORNL during 2006/07 on several log profiles, several gasket sizes, and several chinking styles. These tests offer a baseline for thermal analysis of different log profiles and sealing techniques. This profile-specific analysis and testing may be the answer to establishing more accurate numbers that can be added to ICC400.

## Whole Wall R-Value

The preceding discussion of R-values identified the difference between the rated R-value of the insulation prescribed by code and the actual performance of a frame wall overall. Computer simulations used to establish insulation levels for building energy code goals only permitted insulation R-value to be the variable. When the entire wall assembly is a variable, the simulations no longer apply and need to be run with the specific wall technology. This has been the premise upon which the ORNL team has been evaluating a variety of wall types. This research and the results of the various wall technologies that have been tested can be reviewed online at <http://www.ornl.gov/sci/roofs+walls/>. Their work demonstrates that the whole wall R-value is the only accurate comparison of the thermal performance of different types of walls. The discussion of insulation R-value alone is inappropriate except when the insulation is the only variable.

In 1994, ORNL recognized that the framing components of exterior walls had a dramatic effect on thermal performance and was understated in recognized practice, codes and standards. Based on hot-box test results and three dimensional heat conduction simulations, they developed a whole-wall R-value procedure. To demonstrate the effect of the total wall assembly versus accepted values for a 2x4 wood-framed wall with R-13 fiberglass insulation, a wall was constructed using code-compliant conventional framing practices. The result, pictured below, was

consistent with later ASHRAE project findings, that the actual area of framing in an average American house was 25%, compared to the framing factors (0% to 40%) that are used in evaluations of wall assemblies. When tested in the ORNL hot-box in accordance with ASTM Standard C1363, the 2x4 wall assembly with R-13 batt cavity insulation only produced a tested R-value of 9.65.



**Figure 4 - 2x4 frame wall with R-13 insulation for hot-box testing at ORNL.**

The ORNL whole-wall thermal performance research generated a list of details common to all exterior wall technologies that truly define the thermal performance of the opaque wall. By using these details in test and computer simulations, the true R-value for the whole wall can be confirmed. These details consist of

- ❑ Clear wall area – the components of the wall thickness that can be expected to be found in any opaque area other than noted below.
- ❑ Wall intersections – there are three different intersections that may apply -- an inside (e.g., the corner created in an L-shaped design where the two rectangles meet) and outside corner (e.g., common to the four corners of a rectangle), and the intersection of a interior partition wall at the exterior wall.
- ❑ Wall openings – details at the top, sides, and bottom of wall openings.
- ❑ Wall to support – this covers the connection of the wall to a subfloor, a foundation stem wall, a slab-on-grade, or any other construction that a proponent may develop for a design.
- ❑ Roof to wall – this covers the typical eave connection of the roof to the top of the wall and defines the seal and insulation of the connection.
- ❑ Intermediate floor to wall – details the connection of a loft or second floor to the log wall.

For log wall technology, the thickness of the wall is the element that can be compared to other log walls. When structural elements vary, 2006 IECC Table 402.1.3, Equivalent U-Factors, should be used instead of the prescriptive insulation requirements published in Table 402.1.1.

## **Thermal Mass Effect**

The thermal 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 outside air temperature drops to 50°F and indoor temperature may be 75°F, 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.*

## **Mass-Enhanced R-Values in the Energy Codes**

The concept of mass-enhanced R-values was developed at ORNL in the 1980's and became recognized by the building codes. Originally adopted in 1989, thermal mass was introduced in the 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. The MEC gave way to the International Energy Conservation Code (IECC), but the prescriptive requirements' table remained intact (reproduced below).

**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)**

HEATING DEGREE DAYS	$U_w$ REQUIRED FOR WALLS WITH A HEAT CAPACITY LESS THAN 6 Btu/ft <sup>2</sup> · °F AS DETERMINED BY USING EQUATION 5-1 AND FIGURE 502.2(1)										
	0.24	0.22	0.20	0.18	0.16	0.14	0.12	0.10	0.08	0.06	0.04
0-2,000	0.33	0.31	0.28	0.25	0.23	0.20	0.17	0.15	0.12	0.09	0.07
2,001-4,000	0.32	0.30	0.27	0.24	0.22	0.19	0.17	0.14	0.11	0.09	0.06
4,001-5,500	0.30	0.28	0.26	0.23	0.21	0.18	0.16	0.13	0.11	0.08	0.06
5,501-6,500	0.28	0.26	0.24	0.21	0.19	0.17	0.14	0.12	0.10	0.08	0.05
6,501-8,000	0.26	0.24	0.22	0.20	0.18	0.15	0.13	0.11	0.09	0.07	0.05
> 8,001	0.24	0.22	0.20	0.18	0.16	0.14	0.12	0.10	0.08	0.06	0.04

For SI: °C = [(°F)-32]/1.8, 1 Btu/ft<sup>2</sup> · °F = 0.176 kJ/(m<sup>2</sup> · K).

**Figure 5 - IECC 2003 Table 502.2.1.1.2(3)**

In the 2006 IECC, the tables have been revised with the intention of simplifying the code compliance process. Section 402.2.3 of the 2006 IECC defines mass walls to include solid timber/logs, regardless of density when 50% or more of the insulating component of the wall is integral or to the outside. The goal of simplification is achieved as shown in Figure 6 - IECC 2006 Tables 402.1.1 and 402.1.3. The prescriptive minimum R-value for a log wall can now be found under “Mass Wall R-Value” and matches up to a given climate zone in the left most column. When all of these prescriptive values are met, the building design complies with the code. If, for example, the log wall is going into Climate Zone 5, but it does not meet an R-13 by calculation, then the code provides for analysis using the trade-off approach. This means that the overall “UA” (the product of the u-factors for all assemblies times the areas of those assemblies) must be less than or equal to the UA that would be obtained using the U-Factors found in Table 402.1.3.

**TABLE 402.1.1  
INSULATION AND FENESTRATION REQUIREMENTS BY COMPONENT<sup>a</sup>**

CLIMATE ZONE	FENESTRATION U-FACTOR	SKYLIGHT <sup>b</sup> U-FACTOR	GLAZED FENESTRATION SHGC	CEILING R-VALUE	WOOD FRAME WALL R-VALUE	MASS WALL R-VALUE	FLOOR R-VALUE	BASEMENT <sup>c</sup> WALL R-VALUE	SLAB <sup>d</sup> R-VALUE & DEPTH	CRAWL SPACE <sup>e</sup> WALL R-VALUE
1	1.20	0.75	0.40	30	13	3	13	0	0	0
2	0.75	0.75	0.40	30	13	4	13	0	0	0
3	0.65	0.65	0.40 <sup>f</sup>	30	13	5	19	0	0	5 / 13
4 except Marine	0.40	0.60	NR	38	13	5	19	10 / 13	10, 2 ft	10 / 13
5 and Marine 4	0.35	0.60	NR	38	19 or 13+5 <sup>g</sup>	13	30 <sup>f</sup>	10 / 13	10, 2 ft	10 / 13
6	0.35	0.60	NR	49	19 or 13+5 <sup>g</sup>	15	30 <sup>f</sup>	10 / 13	10, 4 ft	10 / 13
7 and 8	0.35	0.60	NR	49	21	19	30 <sup>f</sup>	10 / 13	10, 4 ft	10 / 13

**TABLE 402.1.3  
EQUIVALENT U-FACTORS<sup>a</sup>**

CLIMATE ZONE	FENESTRATION U-FACTOR	SKYLIGHT U-FACTOR	CEILING U-FACTOR	FRAME WALL U-FACTOR	MASS WALL U-FACTOR	FLOOR U-FACTOR	BASEMENT WALL U-FACTOR	CRAWL SPACE WALL U-FACTOR
1	1.2	0.75	0.035	0.082	0.197	0.064	0.360	0.477
2	0.75	0.75	0.035	0.082	0.165	0.064	0.360	0.477
3	0.65	0.65	0.035	0.082	0.141	0.047	0.360	0.136
4 except Marine	0.40	0.60	0.030	0.082	0.141	0.047	0.059	0.065
5 and Marine 4	0.35	0.60	0.030	0.060	0.082	0.033	0.059	0.065
6	0.35	0.60	0.026	0.060	0.06	0.033	0.059	0.065
7 and 8	0.35	0.60	0.026	0.057	0.057	0.033	0.059	0.065

a. Nonfenestration U-factors shall be obtained from measurement, calculation or an approved source.

**Figure 6 - IECC 2006 Tables 402.1.1 and 402.1.3**

The difference between the two tables is that 402.1.1 lists the rated R-value of insulation that needs to be installed whereas 402.1.3 represents the weighted average of the areas of insulation, structure, skin (sheathing, roofing, etc.), and the inside and outside air films. This is an important concept and is described in IECC 402.1.4 as “The UA calculation shall be done using a method consistent with the ASHRAE *Handbook of Fundamentals* and shall include the thermal bridging effects of framing materials.” For comparison of alternative wall technologies, it is only appropriate to compare to these u-factors, not the 402.1.1 requirements.

## Updating the REScheck® Comparative

The 2001 edition of this article used a representative log home design to generate code compliance. Using the *MECcheck* program, three (3) climate zones (Greenville, SC; Boone, NC; Minneapolis, MN) and three different exterior wall types were examined. It is important to acknowledge that *MECcheck* (now *REScheck*) was developed for compliance with the energy codes and is not a simulation of actual energy use in a building. For a more detailed analysis of how building elements perform, whole building energy simulation programs (e.g., *BLAST*, *DOE-2*, and *ENERGY PLUS*) are used.

The exercise was repeated using the latest version of *REScheck*® (Release 4.1.3), maintaining the same areas for roof, wall, floor, windows and doors. To isolate the exterior walls, the prescriptive minimum requirements from Table 402.1.1 were entered except for doors (u-0.40 in all zones). The Total UA with Exterior Wall 2A shows the prescriptive UA for each climate zone for the house that was entered. The Total UA is then calculated when the two example log walls replace Exterior Wall 2A.

Assembly Type	Gross Area or Perimeter	2006 IECC Insulation R-value or Glazing U-factor			UA		
		SC	NC	MN	SC	NC	MN
Location: 2006 IECC Climate Zone Heating Degree Days (HDD)		3 3272	4 6003	6 7981			
Ceiling: Flat Ceiling or Scissor Truss	1280	30	38	49	45	38	33
Exterior Wall 1: Wood frame, 16" o.c.	420	13	13	19	34	34	25
Window 1: Wood frame, Double Pane w/Low-E	232	0.65	0.4	0.35	151	93	81
Door 1: Solid	80	0.4	0.4	0.4	32	32	32
Floor 1: All-Wood Joist/Truss, Over Unconditioned Space	1280	19	19	30	60	60	42
<b>Exterior Wall 2A: Wood Frame, 16" o/c w/batt insulation in cavity</b>	1348	13	13	19	85	85	62
<b>TOTAL UA with Exterior Wall 2A</b>					<b>407</b>	<b>342</b>	<b>275</b>
<b>2006 IECC Mass Walls:</b>		<b>R-value</b>	<b>U-Factor</b>				
		5	5	15	230	230	85
		0.141	0.141	0.06	190	190	81
<b>Exterior Wall 2B: 8" Southern Pine logs with round face inside and outside</b>	1348	Nominal 8" log wall thickness = R-7.9 (7-in. avg. width)			132	132	132
<b>TOTAL UA with Exterior Wall 2B</b>					<b>454</b>	<b>389</b>	<b>345</b>
<b>Exterior Wall 2C: Log: 6" Eastern White Pine rectangular logs</b>	1348	Nominal 6" log wall thickness = R-8.85 (6-in. avg. width)			117	117	117
<b>TOTAL UA with Exterior Wall 2C</b>					<b>439</b>	<b>374</b>	<b>330</b>

Figure 7 - Thermal Envelope Definition with Exterior Wall Options

The table illustrates another major issue when comparing wall systems. When the UA calculations (all from *REScheck*) for Exterior Wall 2A is reversed to determine the effective whole wall R-value in this analysis, the results are an R-15.86, 15.86 and 21.74 respectively. How can this be? The ORNL hot-box test data determined that Exterior Wall 2A would be only R-9.65 not R-15.86 (or R-13.5 vs. R-21.74). To take another perspective, compare the *REScheck*-generated UAs for Exterior Walls 2B and 2C compared to the 2006 IECC requirements. Wall 2B results in an effective R-value of 10.21 (2C = R-11.52) compared to the 2x4, R-13 frame wall.

The use of *REScheck* to provide some comparison is interesting, but only amplifies the need for correction in the IECC tables and the corresponding calculations in *REScheck*. It appears that the difference between the tabulated results in Figure 7 and the ORNL testing may well be the modification of the framing factor. By modifying the computer simulations to the fact that 25% of the wall area (according to the ASHRAE 2002 and CEC 2002 studies for average US houses) consists of conventional wood framing members and not insulation, the proper relationships may be generated. In light of the results of the ASHRAE 2002 study focused on framing in average US residential construction and corresponding work at ORNL, an interesting relationship was identified. Within the range of framing percentages examined in the research, it appears that for each 1% increase in wall area of wood framing there is a corresponding (1%) reduction in the nominal wall R-value in typical 2x4 wood stud walls.

These facts show that the log home industry still has a long way to go to insure that the IECC code would correctly represent log wall thermal performance against other competitive technologies.

## ***Building with Solid Wood Walls***

Up to this point, the discussion has been about R-values and the various factors that affect a comparison of different wall technologies. The concept of thermal mass was incorporated into that discussion relative to recognition in and compliance with the building energy codes. The research team at ORNL proposed a different way of thinking,

“What wall R-value should a house with wood frame walls have to obtain the same space heating and cooling loads as a similar house containing massive walls?”

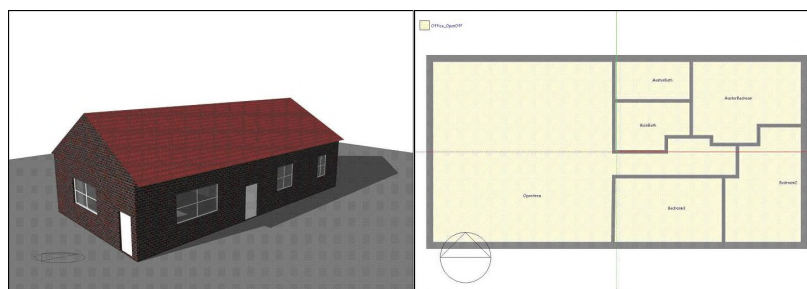
From the perspective of thermal performance, there are absolute energy benefits to building with solid wood walls versus insulated frame. Beyond the mass effect on R-value, benefits of log wall construction include:

- Consistent performance throughout the wall, with little to no variation due to architectural details.  
The 14 details outlined in the Whole Wall R-Value discussion are the key. Log walls are consistent in performance, whereas the ORNL hot-box test data and whole wall analysis for wood stud houses is showing that that a base case for 2x4 walls insulated with R-13 cavity insulation has an actual overall performance of only R-9.65. This 30% difference is caused by architectural details.
- 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 may diminish the performance of many insulation products.

Only airtightness remains an uncertainty relative to the thermal performance of solid wood walls. Qualifying log construction for air infiltration may be a large task, but it will ultimately be required to make it possible for log homes to be rated as Zero-Net or Low Energy Houses.

The codes and standards do not match tested reality when defining solid wood walls. To be considered a Massive System in the 2003 IECC, the wall needs to have a minimum heat capacity of 6-Btu/ft<sup>2</sup> (or weigh 20 pounds per square foot). The Commentary of the 2003 IECC (page 5-17), states that solid wood walls of at least 7 inches (178mm) thick are generally candidates for the mass wall credit as are solid concrete walls of at least 3 inches, common brick of 4 inches, or 8-inch concrete masonry. The 2003 IECC mass wall threshold is also used in REScheck, which explains the dramatic improvement in the UA comparison when the wall dimension is changed from 6" to 7" in colder climates. The 2003 IECC Commentary also includes a table of heat capacities of common building materials (502.2.1.1.2(4)) that further illustrates how thermal mass walls can be achieved.

In the 2006 IECC, the Prescriptive R-value requirements for massive walls are R-3 in Zone 1, R-4 in Zone 2, and R-5 Zones 3 and 4. This means that a 4" nominal rectangular softwood wall-log would meet the prescriptive-R for Zones 1 and 2, while a 6" nominal "D"-shaped softwood wall-log would meet the prescriptive-R for Zones 1-4. It would appear that, since section 402.2.3 Mass Walls includes "solid timber/logs" without qualification, the code is recognizing the benefit of the integral insulating and mass effects of solid wood. Why the change?



**Figure 8 - The base house design used for building energy code modeling, such as ASHRAE 90.2**

The change to the 2006 IECC is due to a focus in code development on concrete and masonry, allowing solid wood walls to follow suite. With the changes in place, it can be seen that several wood species, like oak or yellow pine, would be excluded from 4-in wall applications (since their R-value is less than R-1 per inch). Similarly, after application of thickness correction factors (see *Size & Shape*, above) many nominal 6-in thick log wall profiles will not be applicable in climatic zones 3 and 4. Rather than follow the lead of the concrete industry, the need for true performance of solid wood leads the list of arguments that generated the interest in the ORNL testing and the opportunity to use those results to propose future changes in IECC code requirements.

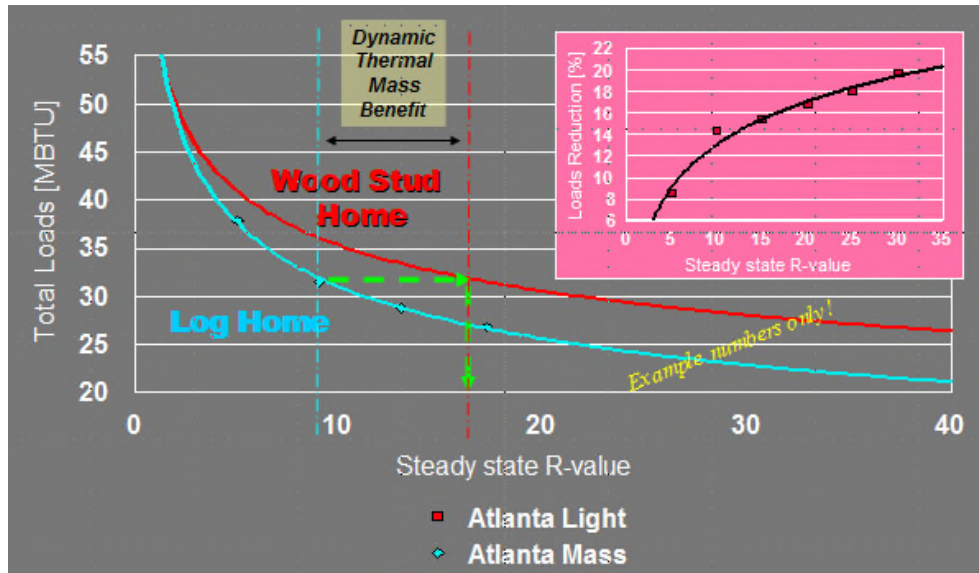
One can say that the use of whole building computer energy simulations have made a difference. Years ago, the single-story, ranch-style home pictured below was developed as the common prototype home for energy code development, but the research for thermal mass considerations was primarily completed for concrete and masonry. While log walls also benefited from the code efforts, it was not specifically analyzed, until now. The Thermal Mass



Calculator for Log Homes Council members is in its final stages of development.

This model home is also used in the ORNL Thermal Mass Calculator that can be downloaded from the ORNL website. By establishing the whole wall R-value for a given mass wall technology (concrete, brick, CMU, etc.), the Thermal Mass Calculator will generate the whole-house HVAC annual energy consumption and then compares that to frame wall criteria. When the LHC Calculator is available, LHC members will be able to demonstrate similar benefits to their wall systems. The calculators for each particular company and log wall type are based on detailed modeling of fourteen basic system details (see Whole Wall R-Value discussion above), accurately represent the log geometry, and use test data for thermal conductivity that was calibrated against hot-box test results.

The Thermal Mass Calculator produces comparative results for the selected mass wall technology and the comparable wood frame home. It demonstrates the “dynamic thermal mass benefit” by comparing the total HVAC load for each to the steady state R-value. When the whole wall R-value for the mass wall is established on the mass wall performance curve, a point on the frame wall curve can be identified. The difference in steady state R-value on these two curves is the dynamic thermal mass benefit.



**Figure 9 - An Illustration of Dynamic Thermal Mass Benefit**

For log wall construction in northern climates (zones 5-8), the mass wall benefit is not as beneficial due to the length of the heating season. Figure 9 illustrates relationship between wall R-value and total building HVAC loads for the house design illustrated in Figure 8. It shows that thermal mass energy benefits and wall R-value are good "friends." For walls with higher R-values, energy saving (loads reductions showed on the pink chart) generated by massive walls are higher. For low-R-value walls these savings negligible, since the log wall and stud wall curves are merging together. The several options for code compliance that have been used for many years are still appropriate:

- For companies that offer multiple log profiles, selecting one with a greater, appropriate average width.
- When the log wall is not going to meet the prescribed R-value for the climate zone:
  - Increase other aspects of the thermal envelope to offset the discrepancy of the wall area.
  - Use the performance option of REScheck by orienting the design for solar benefit and increasing the mechanical efficiency to the more common types of appliances used in those climates rather than using the minimum allowable efficiency (the REScheck default).
  - Reduce the log wall area by using SIPs or frame walls for gable ends and dormers.
  - Reduce the area of fenestration.
  - Increase the R-value of the wall assembly by adding insulation to the interior of the log wall or by sandwiching insulation between to log walls.

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*Many thanks to Dr. Jan Kosny of Oak Ridge National Laboratories, who provided many of the graphics as well as access to the extensive knowledge base that he has developed.*