

**Determining UA**  
**Step I: The Building Envelope** (conductive heat transfer)

$$Q = UA_{\text{envelope}} \times \Delta T$$

Q = Heat loss or gain (Btu/h)  
U = conductance (Btu/h sf °F)  
A = area (sf)  
 $\Delta T = T_{\text{outside}} - T_{\text{inside}} (°F)$

**U ~ C (conductance)**  
**C = 1/R (resistance)**

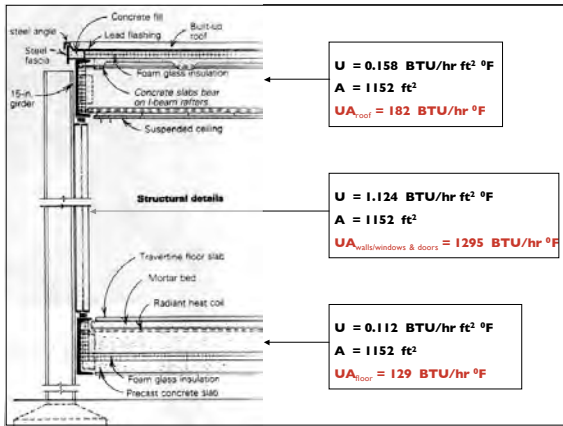
*Finding UA is a process of finding the R-values of each layer of the building envelope*

Table E.1, MEEB 10th

TABLE E.1 Thermal Properties of Conventional Building and Insulating Materials\* (Continued)

Description	Density lb/ft <sup>3</sup> (kg/m <sup>3</sup> )	Conductivity <sup>b</sup> Btu-in h ft <sup>2</sup> °F (W/m K)	Conductance ft <sup>2</sup> Btu-h (m <sup>2</sup> K/W)	IP Resistance (R)		SI Resistance (R)	
				Per Inch Thickness (1x) ft <sup>2</sup> °F Btu-in	For Thickness Listed (1/2) ft <sup>2</sup> °F Btu-in	Specific Heat Btu lb-°F (kJ/kg K)	Per Meter Thickness (1x) K-m W
plywood or wood panels	0.75 in. 19.0 mm	0.14 2.0	1.07 0.1	0.93 0.1	0.26 0.19	—	—
Vegetable fiber board	—	—	—	—	—	—	—
Sheathing, regular density <sup>c</sup>	0.5 in. 12.7 mm	0.18 2.5	0.76 0.3	—	1.22 1.3	0.31 —	0.23 —
—	0.78125 in. 19.8 mm	0.18 2.5	0.49 0.2	—	2.06 —	—	0.36 —
Sheathing, intermediate density <sup>c</sup>	0.5 in. 12.7 mm	0.22 3.0	0.92 0.4	—	1.09 1.30	0.31 —	0.19 —
Nail-base sheathing <sup>d</sup>	0.5 in. 12.7 mm	0.25 3.5	0.94 0.4	—	1.06 1.30	0.31 —	0.19 —
Shingle backer	0.375 in. 9.5 mm	0.18 2.5	1.06 0.5	—	0.94 1.30	0.31 —	0.17 —
Shingle backer	0.3125 in. 7.9 mm	0.18 2.5	1.28 0.6	—	0.78 —	—	0.14 —
Sound deadening board	0.5 in. 12.7 mm	0.15 2.0	0.74 0.4	—	1.35 1.70	0.30 —	0.24 —
Tile and lay-in panels, plain or acoustic	0.5 in. 12.7 mm	0.18 2.5	0.40 0.058	—	2.50 17.0	0.14 —	17.0 —
—	0.5 in. 12.7 mm	0.18 2.5	0.80 0.4	—	1.25 —	0.59 —	— 0.22





**Building Envelope Summary**

Before Design Changes				After Design Changes*			
Building Element	Description	U value (BTU/hr ft <sup>2</sup> °F)	Area (ft <sup>2</sup> )	U x A (BTU/hr °F)	U value (BTU/hr ft <sup>2</sup> °F)	Area (ft <sup>2</sup> )	Description
Roof	metal deck with foam-glass insulation	0.158	1152	182	152	1152	no changes
Walls	Walls	1.124	1152	1295	605	576	existing glass
					34	576	insulated wood frame
Windows	(same as walls)						(same as walls)
Doors	(same as walls)						(same as walls)
Floor	travertine + concrete over metal deck w/foam-glass insulation	0.112	1152	129	129	1152	no changes
		<b>UA envelope</b>		<b>1606</b>	<b>950</b>	<b>UA envelope</b>	

\*The "After Design Changes" portion of this chart shows what would happen to the conductive heat loss (UA<sub>envelope</sub>) if 1/2 of the glass walls were replaced with the wood frame walls developed earlier in this lecture.

**Determining UA**  
**Step 2: Infiltration** (convective heat transfer)

$$Q = .018 \times V_{\text{air}} \times \text{ACH} \times \Delta T$$

$Q$  = heat loss or gain  
 $.018$  = volumetric heat capacity of air (BTU/ft<sup>3</sup> °F)  
 $\text{ACH}$  = air changes per hour  
 $V_{\text{air}}$  = volume of air (ft<sup>3</sup>)  
 $\Delta T$  =  $T_{\text{inside}} - T_{\text{outside}}$

**MEEB Table E.27**  
**Estimated Infiltration Rates for Small Buildings**

Part A. Construction Types	
Type	Description
Tight	Good multifamily residential construction with close-fitting doors, windows, and framing is considered tight. New houses with full vapor retarder, no fireplace, well-fitted windows, weather-stripped doors, one-story, and less than 1500 ft <sup>2</sup> (140 m <sup>2</sup> ) floor area fall into this category.
Medium	Medium structures include new two-story frame houses or one-story houses more than 10 years old with average maintenance, a floor area greater than 1500 ft <sup>2</sup> (140 m <sup>2</sup> ), average-fit windows and doors, and a fireplace with damper and glass closure. Below-average multifamily construction falls in this category.
Loose	Loose structures are poorly constructed single and multifamily residences with poorly fitted windows and doors. Examples include houses more than 20 years old, of average maintenance, having a fireplace without damper or glass closure, or having more than an average number of vented appliances. Average manufactured homes are in this category.

**Part B. Design Infiltration Rate (ACH) for Winter: Indoors 68°F (20°C); Wind Speed = 15 mph (6.7 m/s)**

Construction Type	Winter Outdoor Design Temperature									
	°F: 50	40	30	20	10	0	-10	-20	-30	-40
Tight	0.41	0.43	0.45	0.47	0.49	0.51	0.53	0.55	0.57	0.59
Medium	0.69	0.73	0.77	0.81	0.85	0.89	0.93	0.97	1.00	1.05
Loose	1.11	1.15	1.20	1.23	1.27	1.30	1.35	1.40	1.43	1.47

**TABLE E.27 Estimated Overall Infiltration Rates for Small Buildings**

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**Determining UA**  
**Step 2: Infiltration** (convective heat transfer)

$$Q = .018 \times V_{\text{air}} \times \text{ACH} \times \Delta T$$

$Q = .018 \times 9216 \text{ ft}^3 \times 1.30 \times \Delta T$   
 $Q = 216 \text{ BTU/hr} \cdot \text{ }^\circ\text{F} \times \Delta T$   
**"UA" infiltration = 216 BTU/hr · °F**

**Farnsworth House Results**

$$Q = UA_{ref} \times \Delta T$$

Step 1:  $UA_{envelope} = 1521 \text{ BTU/hr} \cdot ^\circ\text{F}$

Step 2:  $UA_{infiltration} = 216 \text{ BTU/hr} \cdot ^\circ\text{F}$

**Total:  $UA_{reference} = 1737 \text{ BTU/hr} \cdot ^\circ\text{F}$**

Note:

Step 3:  $UA_{perimeter}$  is not applicable since the Farnsworth House is not built with the floor in **contact with the earth.**