Whole Building Design- Site Selection

- Building orientation to take advantage of solar effects
  - Thermal mass of building for passive solar
- Daylighting
- Landscaping - use of deciduous trees
- Site drainage
**WHOLE BUILDING DESIGN - Building Envelope**

- **Heat energy fundamentals**
  1st Law of Thermodynamics - “Heat energy flows from hot to cold”
  - Conduction
  - Convection
  - Radiation

- **Units of heat energy**
  - **BTU** - British Thermal Unit
    
  *Amount of heat required to raise 1 lb of water 1 degree F*
  
  - **THERM** = 100,000 BTU
  - **WATT** = 3.41 BTU/HR
WHOLE BUILDING DESIGN - Building Envelope

- **Conduction**
  - Heat transfer due to materials in contact and temp difference

- **Convection**
  - Heat transfer due to air motion and temp difference
WHOLE BUILDING DESIGN - Building Envelope

- **Convection:**
  - Forced convection - use of fans to assist airflow
  - Natural Convection - Stack effect - “passive convection”

*Figure 15.9: Ventilation principle #7 — The "stack effect" results when air in the building warms, becomes more buoyant than outside air, and rises to escape out of openings high in the building.*
WHOLE BUILDING DESIGN - Building Envelope

- Radiation heat transfer:
  - Heat transfer due to temp difference and material properties
Building Envelope - Heat Transfer Calculations

- **Building Heat Transfer:**
  - $R$ - “resistance value” of building materials to heat flow
  - $R_T = R_{\text{inside film}} + R_1 + R_2 + \ldots + R_{\text{outside film}}$
  - **U-value:** “overall heat transfer co-efficient”
    (NOTE: includes allowance for BOTH convection and conduction heat transfer.)
    \[
    U = \frac{1}{R_T}
    \]
TABLE 4.1 Thermal Properties of Typical Building and Insulating Materials (design values)*

= The customary units for conductivity (k), (condutance (C), and resistance (R), either per inch (1/in.) or for thickness stated (1/1), are given in Table 4.1. Values are for a mean temperature of 75°F unless noted by an asterisk (*), which indicates that such a value has been reported at 45°F. The SI units for resistance (last two columns) were calculated by taking the values from the two resistance columns under Customary Unit, multiplying by the factor 1/144 (in²) and 1/0.12 (in²) for the appropriate conversion factor. Author's note: Actual (on-site) resistance values frequently are lower than the test-ool-determined "design" values listed in this table.

<table>
<thead>
<tr>
<th>Description</th>
<th>Density (lb/ft³)</th>
<th>Conductivity (k)</th>
<th>Conductance (C)</th>
<th>Resistance (R) for 1 in.</th>
<th>Specific Heat (Btu/lb°F)</th>
<th>Resistence (R) for 1 in²</th>
<th>W</th>
<th>W²</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>BUILDING BOARD</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Board, Pressed, unbonded, sheathing</td>
<td>12.0</td>
<td>0.05</td>
<td>0.05</td>
<td>0.24</td>
<td>1.73</td>
<td>0.05</td>
<td>0.05</td>
<td></td>
</tr>
<tr>
<td>Building board, closed-cell polyurethane</td>
<td>25.5</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
<td></td>
</tr>
<tr>
<td><strong>GLASS FIBER BOARD</strong></td>
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<td></td>
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<td></td>
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<td></td>
</tr>
<tr>
<td>Board</td>
<td>30.0</td>
<td>0.05</td>
<td>0.05</td>
<td>0.15</td>
<td>1.00</td>
<td>0.05</td>
<td>0.05</td>
<td></td>
</tr>
<tr>
<td><strong>STEEL SHEET</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>21-ga.</td>
<td>2.50</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
<td></td>
</tr>
<tr>
<td>24-ga.</td>
<td>3.00</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
<td></td>
</tr>
</tbody>
</table>

* (continued)
Building Envelope -
Heat Transfer Calculations

\[ Q = (U) \times (A) \times (\text{delta } T) \]

where:
- **Q**: heat transfer rate in Btu/hour
- **U**: overall heat transfer co-efficient
- **A**: surface area in square feet
- **delta T**: temperature difference across surface; \( T_{\text{inside}} - T_{\text{outside}} \)
**Sample Calculations:**

For sample calculations - 
outside design = 30 F  
inside design = 70 F

- **Walls:** wall area is 300 square feet  
  wall is wood stud with R-11 insulation;  
  approximate $U = 0.08$

$$Q = U \times A \times \Delta T$$
$$= 0.08 \times 300 \times (70 - 30) = 0.08 \times 300 \times 40$$
$$= 960 \text{ Btu/hour}$$
Building Envelope - Heat Transfer Calculations

- **Sample Calculations:**
  - **Windows:** window area is 300 square feet
    window is single pane; appx U = 1.10
    
    \[
    Q = U \times A \times \Delta T
    \]
    
    \[
    = 1.10 \times 300 \times (70 - 30) = 1.10 \times 300 \times 40
    \]
    
    \[
    = 13,200 \text{ Btu/hour}
    \]

NOTE THAT FOR SAME SURFACE AREA, SINGLE PANE GLASS HAS **OVER 13 TIMES** THE HEAT FLOW AS FOR R-11 INSULATED WALL!!
Building Envelope -
Heat Transfer Calculations

- **Radiation heat gain thru windows**

\[ Q = (A) \times (\text{SHGF}) \times (\text{CLF}) \times (\text{SC}) \]

where-

- **Q** = heat transfer in BTU/HR
- **A** = window area in ft²
- **SHGF** = solar heat gain factor (dependent on orientation and globe location)
- **CLF** = cooling load factor (dependent on shading and color of interior surface)
- **SC** = shading coefficient (property of glazing; dependent on clear/tinted/mirror glass surface)

Other ratings - **SHGC** = solar heat gain coefficient = **SC** x 0.86
**Building Envelope - Heat Transfer Calculations**

- **Glazing selection**
  - Single pane vs. dual/triple pane
    - Single pane - “U” = 1.10
    - Dual pane - “U” = 0.35
    - Triple pane - “U” = 0.22
      (NOTE effect of interior “films” at glass surfaces; insulation value increases due to air space and number of surface films)
  - Aluminum/wood/vinyl/fiberglass frames
  - “low E” glass \(\rightarrow\) coating that allows light to get thru but not heat
  - High heat gain in winter vs. no heat gain in summer?
  - Use of different glazing on different exposures?
Building Envelope - Glazing Selection

- **SHGC** - Solar Heat Gain Coefficient
  (% of ALL radiation (UV, visible and IR) that gets thru glass)
- **VT** - Visible Transmittance
  (% of visible light that gets thru glass)

**SOUTH FACING GLAZING:**
- Cold climate: SHGC > 0.6; high VT; low “U”
- Moderate climate: SHGC < 0.6; high VT; low “U”
- Hot climate: SHGC < 0.4; medium VT; low “U”
- East/west facing: SHGC < 0.4; high VT; low “U”