Thermal Performance Data

Heat Flow

Heat flow is defined as the transfer of energy from one area to another due to a temperature difference between the two areas. Heat always flows from the area that has the higher temperature to the area that has the lower temperature. This heat transfer is accomplished by one or more of the following three methods:

- **Conduction** — direct transfer between solids and liquids. A good example: When you touch a hot object, the heat energy is transferred directly from the hot object to your skin.

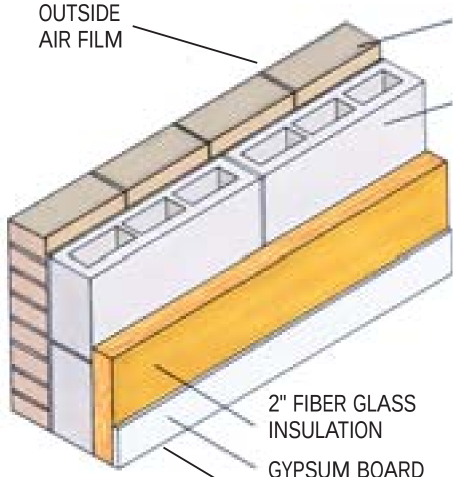
- **Convection** — by air or other fluid movement. Fluids are heated by conduction at the hot surface and are then transported toward the cooler area where they again transfer energy by conduction to the cooler fluids with which they come in contact.

- **Radiation** — by electromagnetic waves. Energy in the form of electromagnetic waves leaves the hot surface and travels directly to another object, where it is absorbed. The sun warms the earth by radiation heat transfer.

Thermal Resistance and Thermal Transmittance

All materials or constructions resist the flow of heat to some extent. This property is called *thermal resistance* and is often designated as "R-value," "R-factor," or simply as "R." (Thermal resistance is designated as RSI in the metric system.)

R-value is a convenient property to use in commercial building construction because R-values of materials in series can be added to determine the thermal resistance of the total construction. The example below shows how the thermal resistance of an insulated masonry wall is determined by adding the individual component R-values:



RESISTANCES	R	RSI
Outside air film	0.17	0.03
4" (102mm) brick	0.98	0.17
4" (102mm) concrete block	0.63	0.11
2" (51mm) fiber glass insulation	8.70	1.53
1/2" (13mm) gypsum board	0.45	0.08
Inside air film	0.68	0.12
Total resistance (R_t)	**11.61**	**2.04**

$$U = \frac{1}{R_t} = \frac{1}{11.61} = 0.09 \text{ Btu/hr} \bullet \text{ft}^2 \bullet {}^\circ\text{F}$$

The thermal transmittance of a material or assembly is a measure of the amount of heat that passes through the construction for each degree temperature difference between one side of the construction and the other side. Thermal transmittance is designated as "U-value" or "U-factor."

Thermal resistance and thermal transmittance are related to each other by the following equation:

$$U = 1/R$$

In the example above:

$$U = 1/R_t = 1/11.61 = 0.09$$

The thermal resistance and transmittance properties of a material can vary depending upon the temperature of the material. For this reason, material thermal properties are normally referenced to a *mean temperature* which, for most energy code requirements, is 75°F (24°C).

Materials that are uniform or homogenous in nature, such as concrete or fiber glass insulation, can also be characterized by their thermal conductivity, or k-value (metric: λ). Thermal conductivity is a measure of the ability of a material to allow heat to pass through itself, independent of its thickness. Thermal conductivity is related to R-value by the following equation:

$$R = t/k, \text{ where t is the material thickness}$$

Materials that are not homogenous in nature, such as cinder blocks, are characterized by their thermal conductance or C-value. Thermal conductance is a measure of the ability of a material to allow heat to pass through its entire thickness and is related to R-value by the following equation:

$$R = 1/C$$

Use of these equations is straightforward as long as the units used to measure the properties are consistent. In the English system the units are: feet (ft), inches (in), degrees Fahrenheit (°F), hour (hr), and British thermal units (Btu). In the metric or SI system the units are: millimeters (mm), meters (m), degrees Celsius (°C), hour (hr), and watts (W).

PROPERTY	ENGLISH UNITS	METRIC (SI) UNITS
Thermal resistance	$R = \frac{(hr \bullet ft^2 \bullet {}^\circ F)}{Btu}$	$RSI = \frac{(m^2 \bullet {}^\circ C)}{W}$
Thermal transmittance	$U = \frac{Btu}{(hr \bullet ft^2 \bullet {}^\circ F)}$	$RSI = \frac{W}{(m^2 \bullet {}^\circ C)}$
Thermal conductivity	$k = \frac{Btu \bullet in}{(hr \bullet ft^2 \bullet {}^\circ F)}$	$RSI = \frac{W}{(m \bullet {}^\circ C)}$
Thermal conductance	$C = \frac{Btu}{(hr \bullet ft^2 \bullet {}^\circ F)}$	$RSI = \frac{W}{(m^2 \bullet {}^\circ C)}$