Basic Heat Flow Fundamentals

Heat is the energy associated with the random motion of molecules, atoms or smaller structural units of matter. Heat always flows from higher to lower temperatures. All materials and matter, including air, contain heat down to a temperature of absolute zero (approx. 460 °F). There is no such thing as cold! Cold is the absence of heat. When we feel cold it is not cold penetrating our clothes or structures, but rather the rapid loss of heat from our bodies. The flow of heat cannot be stopped but only slowed by the use of insulation, trapped air or heat-reflective surfaces.

Heat flows by means of conduction, convection or radiation or a combination of any or all of these.

- *Conduction* – The transfer of heat in a material due to the molecule-to-molecule transfer of kinetic energy. An example is when the handle on a skillet gets hot when the bottom of the pan is heated on the stove. With most materials, the denser the material, the higher the rate of heat flow due to conduction.
- *Convection* – The transfer of heat by physically moving the molecules from one place to another through fluid flow either in air or liquid. An example would be a forced-air heating system in a building or the heat rising from a steam or hot-water-heated pipe.
- *Radiation* – The transfer of heat through space from a very hot object through electromagnetic energy. An example would be when you feel the heat from a fireplace while standing many feet away. Another example is the heating from the sun during the day. Radiant heat is not affected by air. In a roofing system, radiation is seldom a cause of concern in heat lost.

Radiation from the sun during the day impacts the roof-top surface of a dark-colored roof membrane. In these situations, insulation is typically used to block the heat flow into the building. Another method to minimize heat flow from radiation on a roof surface is to use a reflective roof membrane or a “cool roof”. Contact the membrane manufacturer for additional “cool roof” information.

Heat Flow Terminology

Heat is measured in terms of BTUs, or British Thermal Units. A BTU is the amount of heat required to change the temperature of one pound of water by one degree Fahrenheit at sea level. An example of 1 BTU would be the energy released by a typical wood match that is allowed to burn end to end.

Thermal Conductivity, k-Value (BTU•inch/hr•ft²•°F)

Thermal conductivity, or k-Value, is the measure of the amount of heat that will be transmitted through a 1" piece of a homogenous material, per hour, per square foot, per degree Fahrenheit temperature difference. The smaller the k-Value, the better the insulator. This is the basic physical property of a material measured in the laboratory.

Thermal Resistance, R-Value (hr•ft²•°F)/BTU

Thermal resistance, or R-Value, is a material’s resistance to heat flow. The higher the R-Value, the higher the insulating value of the insulation. All materials that have the same R-Value, regardless of thickness, weight or appearance, are equal in insulating value.

Thermal Conductance, C-Value = BTU/(hr•ft²•°F)

Thermal conductance or C-Value is the measure of heat flow for any given thickness of material and is calculated as:

$$C = k/\text{Thickness}$$

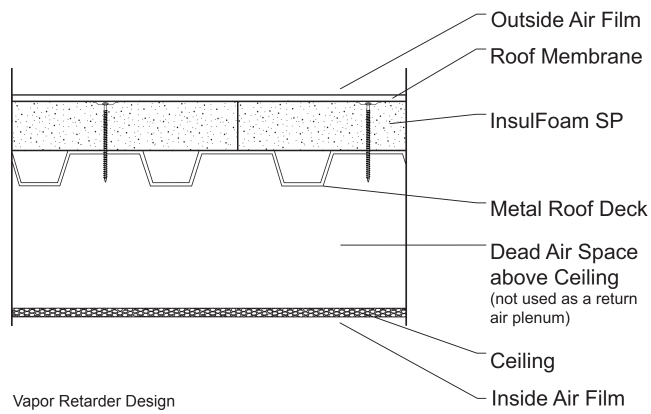
The C-Value is also equal to the reciprocal of the R-Value (C = 1/R).

Overall Coefficient of Thermal Transmission, U-Value

The overall coefficient of thermal transmission, or U-Value, is determined by adding all of the R-Values of the ceiling and roof components in the system, and taking the reciprocal value. The formula for this coefficient is:

$$U = 1/(R1 + R2 + R3\ldots)$$

The following is an example of the use of the various heat flow terms:



Vapor Retarder Design

Remember that R-Values are cumulative. The above installation consists of a TPO membrane installed over 4 inches of InsulFoam SP that is installed directly to a metal deck. Take all of the R-Values of each component and list them in order from outside to inside. See chart on following page.

Component	R-Values
Outside Air Film	0.17
Single Ply Membrane	negligible
4" InsulFoam SP (R = 4.25/in. @ 40 °F)	17.00
Steel Deck	negligible
Dead Air Space	0.94
1/2" Ceiling Tile	1.40
Inside Air Film	0.61
R-Value of the Assembly = R_t=	**20.12**

The k-Value (thermal conductivity) of the InsulFoam SP is:

k = 1/4.25 or 0.236

The C-Value (thermal conductance) of the InsulFoam SP is:

C = k/Thickness = .236/4.0 or .059

The U-Value (overall transmission coefficient) of the assembly is:

$U = 1/R_t = 1/20.12$ or .050

Fastener Load Study

InsulFoam insulations have been used in single ply, mechanically attached systems since their inception. Questions have been raised regarding InsulFoam's ability to resist membrane fastener loads. To address these questions, Insulfoam embarked on a study of fasteners typically used for membrane attachment and their effect on various insulation systems. Samples of the insulation systems were placed in a Dillon Compression Test Apparatus and covered with a single ply membrane. The membrane was attached to the insulation to duplicate a typical field application. Once the membrane and insulation systems were in place, a 2" membrane fastener plate was placed through the membrane. The force of the test apparatus was channeled through a 2" column onto the plate. A load was applied to the plate at a rate of 0.2 inches per minute until 120 pounds was reached. The load was recorded for a period of 72 hours.

A review of the final data showed that there was not a significant difference for the insulation systems tested. The following chart gives the insulation system tested and the average load retained for each system after the monitoring period.

Insulation System	Fastener Load
InsulFoam I	49.4 lbs.
InsulFoam I w/ SecurePly	55.5 lbs.
InsulFoam VIII	56.5 lbs.
InsulFoam SP	60.3 lbs.
InsulFoam VIII w/ SecurePly	62.1 lbs.
InsulFoam II	62.1 lbs.
InsulFoam IX	67.5 lbs.
Polyisocyanurate	50.6 lbs.

Test Conclusions

- Increased InsulFoam density improves fastener load retention.
- The addition of SecurePly to lower density InsulFoam products improves fastener load retention by 10-15%.
- Products exhibiting clamping pressures equal to or greater than those of polyisocyanurate would also be acceptable in mechanically fastened roof applications.
- InsulFoam SP or InsulFoam VIII overlaid with SecurePly are viable UL approved insulation systems. Other InsulFoam brand insulations may also be suitable under SecurePly.

For additional information, please contact the Insulfoam Technical Center or your local Insulfoam representative.