The primary feature of a thermal insulation material is its ability to reduce heat exchange between a surface and the environment, or between one surface and another surface. This is known as having a low value for thermal conductivity. Generally, the lower a material's thermal conductivity, the greater its ability to insulate for a given material thickness and set of conditions.

Architects, contractors and builders use various "factors" to express the insulation value of a material or a composite structure including factors such as U, C and R. The most common of these is the **R-value**, which is used in the building industry to rate the insulation properties of construction materials and building assemblies. Material suppliers most often specify the product’s k-value.

Thermal conductivity (k or λ)

The physical property that measures the effectiveness of a material to conduct heat is called thermal conductivity. It is expressed in Watt per meter Kelvin (W/mK). Very often, you will see that number given on insulation material specifications. The smaller the number, the better the material is regarding thermal insulation.

k-value is thermal conductivity. The ASTM Standard C168, on Terminology, defines the term as : “Thermal conductivity, n: the time rate of steady state heat flow through a unit area of a homogeneous material induced by a unit temperature gradient in a direction perpendicular to that unit area.”

Thermal conductivity is independent of material thickness. In theory, each slice of insulation is the same as its neighbouring slice. The slices should be of some standard thickness measured in meters. So we need to think in terms of Watts of heat flow, for a meter of material thickness, per hour, per square meter of area, per degree C of temperature difference

Thermal resistance (R-value)

Thermal conductivity allows comparing materials and their ability to conduct heat. In practice, that alone is not enough to judge the quality of a given thermal insulation solution. The thickness of the material applied has to be taken into account.

That is the reason we use another measure called thermal resistance or R-value. It is simply the thickness of the material divided by the thermal conductivity of that material:

Equation 1: $R = \text{thickness } (d) / k$

Where d is the thickness in meters. Its unit is m^2K/W.

R-values both in the US and elsewhere in the world are often cited without their units, e.g., R-35. Usually, however, the correct units can be inferred from the context and from the magnitudes of the values. It has been found that architects and builders when quoting the R-Value are actually referring to the American standard which is in the imperial system of measurement of Foot, Pound, Second and its units are ft^2 °F hr/Btu. In SI units R-Value is measured as m^2K/W (or equally, m^2 °C/W).

To convert US/FPS R-values to metric R-values, multiply by 0.1761

Thermal conductance (C)

In term of thermal insulation, thermal resistance gives a counterpoint of thermal conductivity: bigger thermal resistance = better while smaller thermal conductivity = better. For that reason, another measure, called thermal conductance is also used. Thermal conductance is simply the inverse of thermal resistance: C = 1/R. Its unit is W/m^2K.

According to ASTM C168; Conductance, thermal, n: the time rate of steady state heat flow through a unit area of a material or construction induced by a unit temperature difference between the body surfaces

Equation 2: C-value = k-value / thickness (d)

Equation 3: C-Value = 1/R

Where d is the thickness in meters.

Very often, you will see the thermal conductance assimilated to the U-value defined below. It is not exact as U-value is a more subtle and complex parameter.

Thermal conductance is also called Heat Transfer Coefficient.

Total thermal resistance (R_T)

As we mentioned above, when evaluating a thermal insulation solution, all components of the solution have to be taken into account. For instance, for a wall made of inner surface + clay block + mineral wool + air space + brick + outer surface, the R-value of each component has to be considered. In addition, because the exchange of heat between the wall and the ambient air occurs via convection and radiation, the heat transfer coefficient of the wall surface indoor and outdoor have also to be taken into account.

The total thermal resistance does just that. It represents the sum of all thermal resistances for each component of the building section, including the surface thermal resistance of both sides of the section. Its unit is m^2K/W.

The surface thermal resistance of a building section represents the resistance to heat transfer via convection and radiation between the ambient air and the surface of that building section. It is the inverse of the surface conductance (h) for that surface.

Equation 4: $R_T = R_1+R_2+R_3+\ldots+R_N$

Total Thermal transmittance (U -value)

The total thermal transmittance or U_T -value represents the amount of heat, transferred through a building section, between the indoor and outdoor climate, for a unit of surface and temperature. Its unit is W/m²K. It is also called the overall coefficient of heat transmission.

U -value is simply equal to the inverse of the total thermal resistance.

Equation 5: $U = 1 / R_T$

Simply put, U-value rates the energy efficiency of the combined materials in a building component or section. The smaller the U-value, the better the solution is in term of thermal insulation and energy saving.

Total thermal resistance and thermal transmittance are used to rate and compare building solutions. They are also used in various construction norms around the world to set the acceptable standards for new constructions.

Relationship and Conversion factors

Convert to	Convert From		
	k-value	R-value	C-value
K-value	-	=Thickness/R-Value	=Thickness x C-Value
R-value	=Thickness/k-value	-	=1/C-value
C-Value	=k-value/Thickness	=1/R-value	-
Units (SI)	W/mK	M^2K/W	W/m^2K
Units (FPS)	Btu/ ft °F hr	ft^2 °F hr/Btu	Btu/ft^2 °F hr
SI to FPS multiplier	X 0.5782	X 5.6783	X 0.1761
FPS to SI multiplier	X 1.7296	X 0.1761	X 5.6783