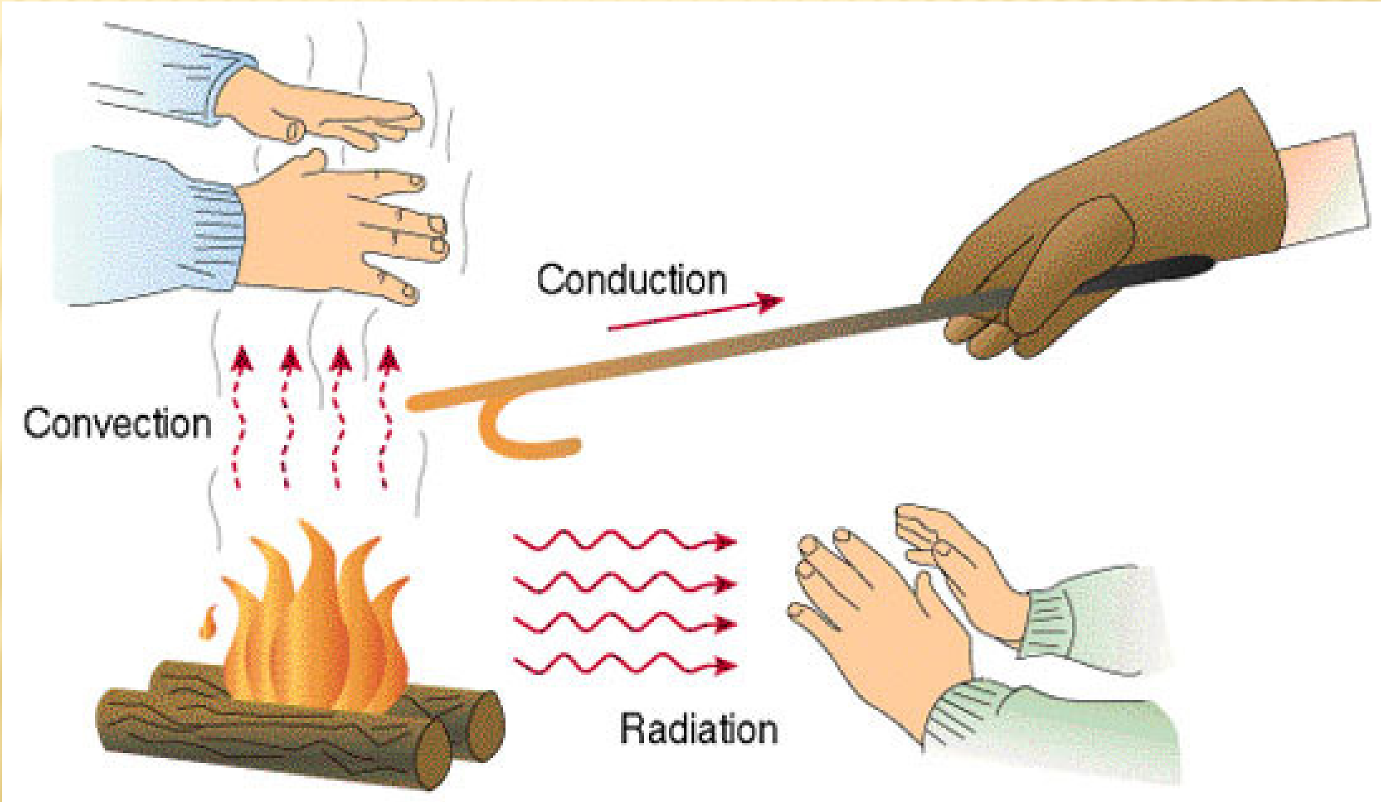
TRANSFERÊNCIA DE CALOR

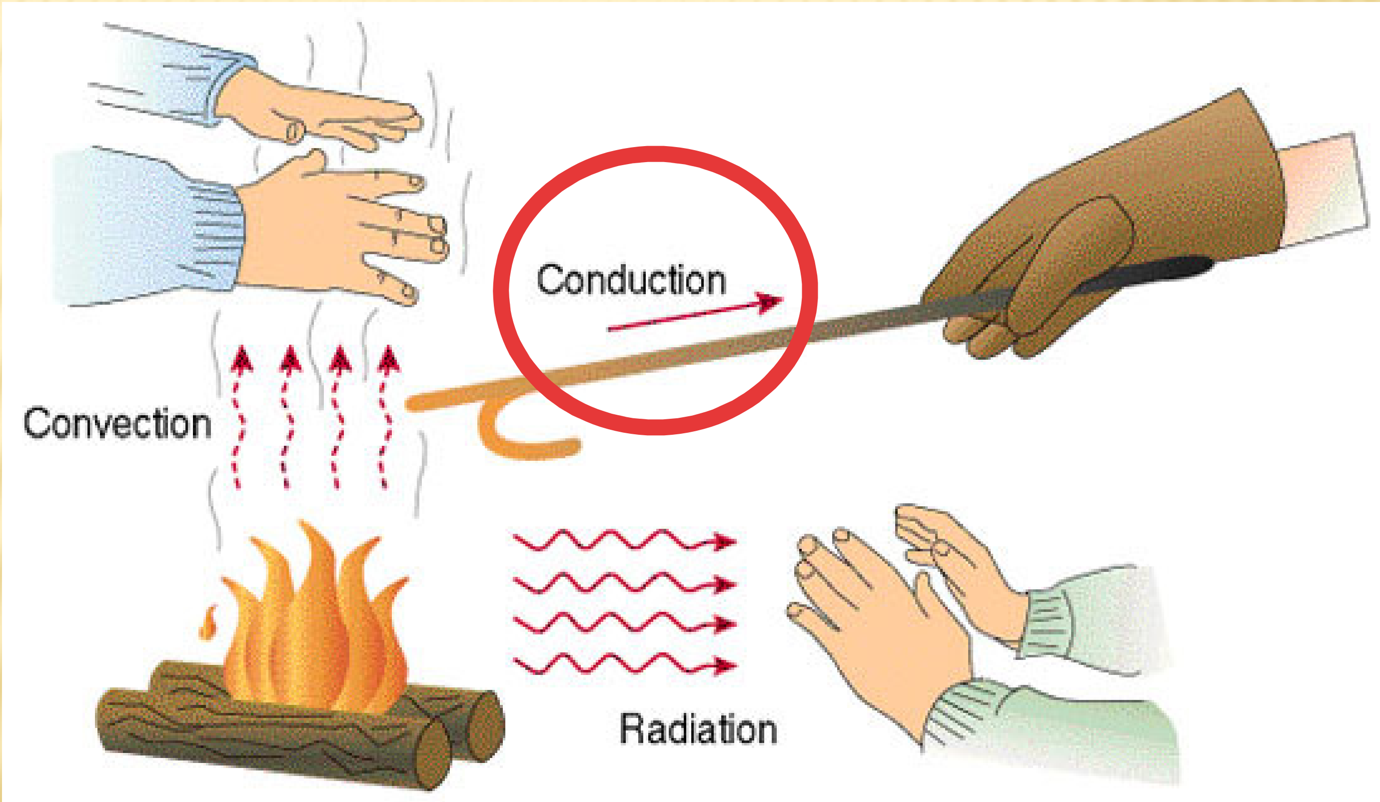
Transferência de Calor

Let's review the three methods of transferring energy between two bodies at different temperatures:

convection, conduction, and radiation.



CONDUÇÃO



Transferência de Calor por Condução

Conduction is the transfer of heat through a solid medium. The energy transfer depends on:

-Temperature differences in the solid body
-The material's thickness → *(espessura)*
-The material's thermal conductivity
-The material's cross-sectional area

The basic heat conduction equation is also known as the **Fourier law** of heat conduction. Below is the conduction equation for a one-dimensional system, i.e., considering heat conduction in **only one direction**

$$q = kA\frac{(T_1 - T_2)}{x}$$

Transferência de Calor por Condução

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Note:
q <> Q <> q''

Where: q = heat flow over time, kW → *rate*
k = thermal conductivity, kW/m°C
A = area, m^2
T_1 = Temperature on cold side, °C
T_2 = Temperature on hot side, °C
x = Thickness, m → *(espessura)*

Transferência de Calor por Condução

Embora a tabela esteja em Kelvin, não é necessário converter. Pois a equação usa delta T, logo Celsius e Kelvin equivalem

$$q = kA\frac{(T_1 - T_2)}{x}$$

kW = kW m2 K
m K m

$$kW = \frac{kW}{m\,K} \; m2 \; \frac{K}{m}$$

Ver tabela slide seguinte.

Where: q = heat flow over time, kW
k = thermal conductivity, kW/m°C
A = area, m

Table 1-2 Thermal Properties of Some Common Materials[a]

Material	Conductivity k (W/m°K)	Specific heat, c_p, (J/kg°K)	Density, ρ (kg/m^3)	Thermal diffusivity, $\frac{k}{\rho c_p}$ α (m^2/s)	Thermal inertia, $k\rho c_p$ (W^2.s/m^{4}K^2)
Copper	387	380	8940	1.14×10^{-4}	1.3×10^{9}
Steel (mild)	45.8	460	7850	1.26×10^{-5}	1.6×10^{8}
Brick (common)	0.69	840	1600	5.2×10^{-7}	9.3×10^{5}
Concrete	0.8-1.4	880	1900-2300	5.7×10^{-7}	2×10^{6}
Glass (plate)	0.76	840	2700	3.3×10^{-7}	1.7×10^{6}
Gypsum plaster	0.48	840	1440	4.1×10^{-7}	5.8×10^{5}
PMMA[b]	0.19	1420	1190	1.1×10^{-7}	3.2×10^{5}
Oak[c]	0.17	2380	800	8.9×10^{-8}	3.2×10^{5}
Yellow pine[c]	0.14	2850	640	8.3×10^{-8}	2.5×10^{5}
Asbestos	0.15	1050	577	2.5×10^{-7}	9.1×10^{4}
Fibre insulating board	0.041	2090	229	8.6×10^{-8}	2.0×10^{4}
Polyurethane foam[d]	0.034	1400	20	1.2×10^{-6}	9.5×10^{2}
Air	0.026	1040	1.1	2.2×10^{-5}	—

Drysdale, D. D. *An Introduction to Fire Dynamics*. New York: John Wiley & Sons, 1985, p. 36. Reproduced by permission of John Wiley and Sons Limited.)

a From Pitts and Sissom (1977) and others. Most values for 0 or 20°C. Figures have been rounded off.

b Polymethylmethacrylate. Values of k, c_p and for other plastics are given in Table 1.2.

c Properties measured perpendicular to the grain.

d Typical values only.

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Muito condutor!

Pouco condutor

Drysdale, D. D. *An Introduction to Fire Dynamics*. New York: John Wiley & Sons, 1985, p. 36. Reproduced by permission of John Wiley and Sons Limited.)

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[b] Polymethylmethacrylate. Values of k, c_p and for other plastics are given in Table 1.2.

[c] Properties measured perpendicular to the grain.

[d] Typical values only.

Transferência de Calor por Condução

$$q = kA\frac{(T_1 - T_2)}{x}$$

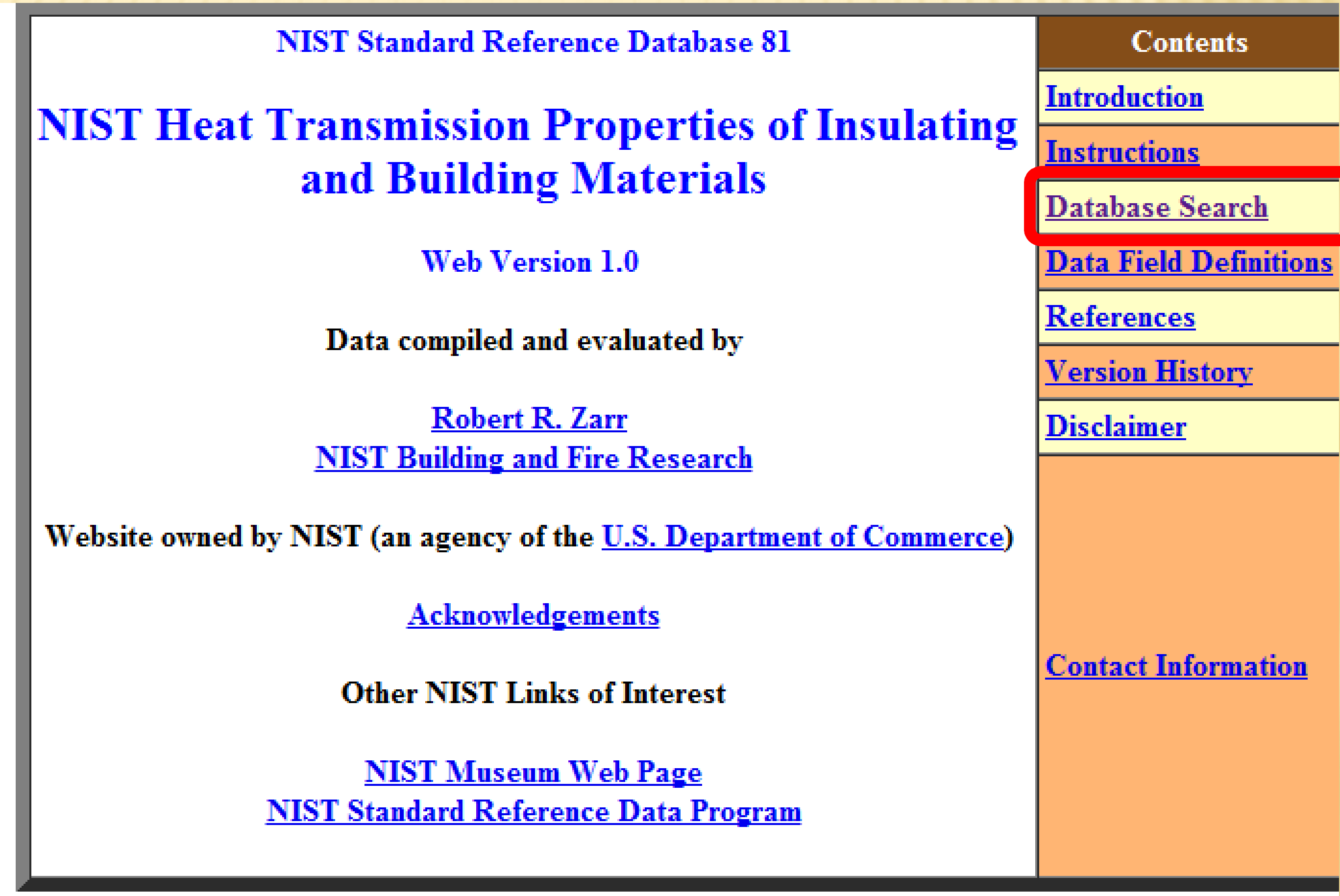
Equation applies only after the system has reached **steady state**.

This means the temperature on the cold side is not going to increase as long as the temperature on the hot side doesn't change.

If a steady state is assumed, then the temperature gradient is constant. By temperature gradient we mean the temperature across a body. Generally, in conduction problems, we'll assume steady state has been achieved.

Banco de Dados NIST

http://srdata.nist.gov/insulation/



NIST Standard Reference Database 81

NIST Heat Transmission Properties of Insulating and Building Materials

Web Version 1.0

Data compiled and evaluated by

Robert R. Zarr
NIST Building and Fire Research

Website owned by NIST (an agency of the U.S. Department of Commerce)

Acknowledgements

Other NIST Links of Interest

NIST Museum Web Page
NIST Standard Reference Data Program

Contents

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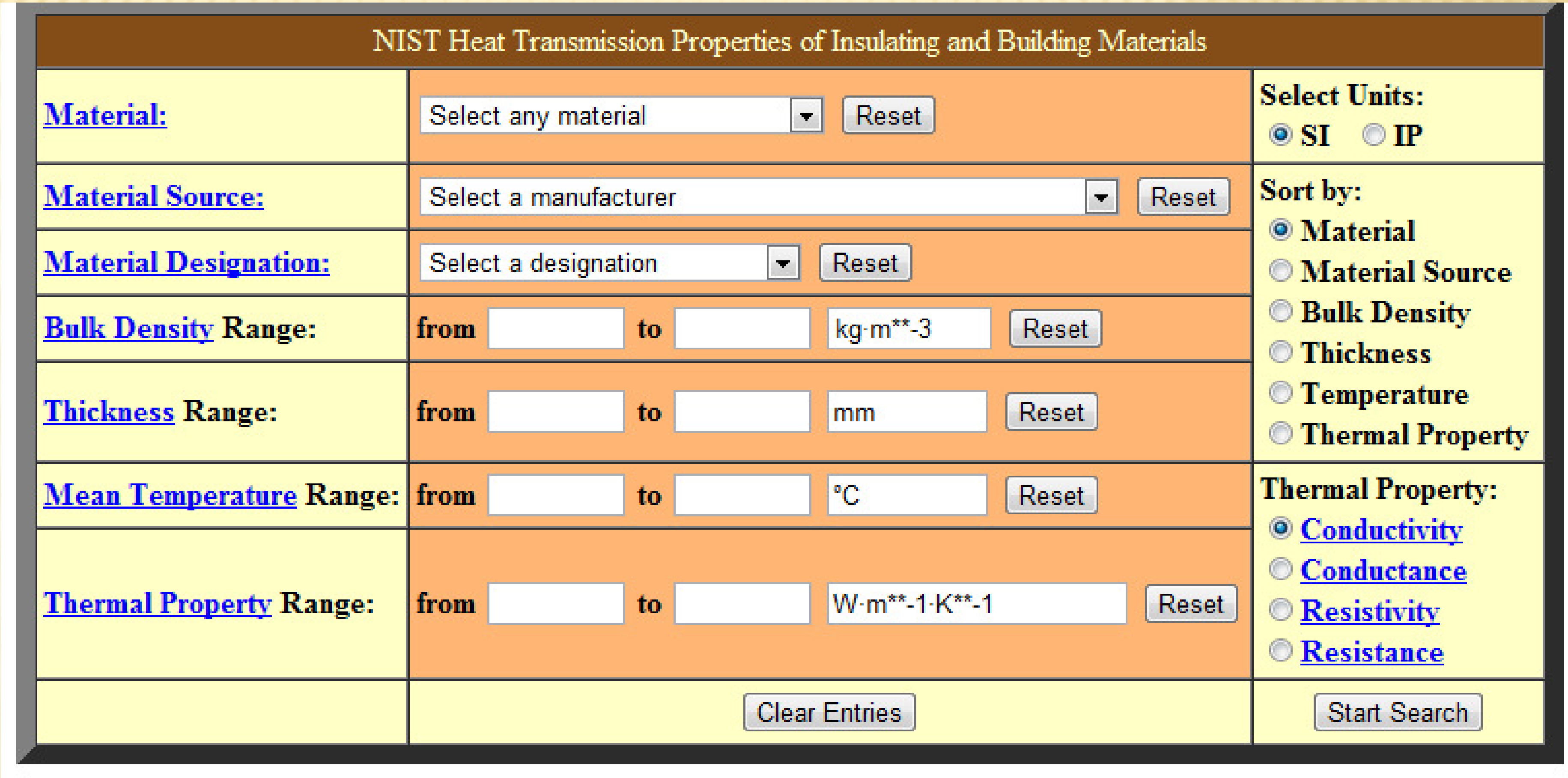
- Contact Information

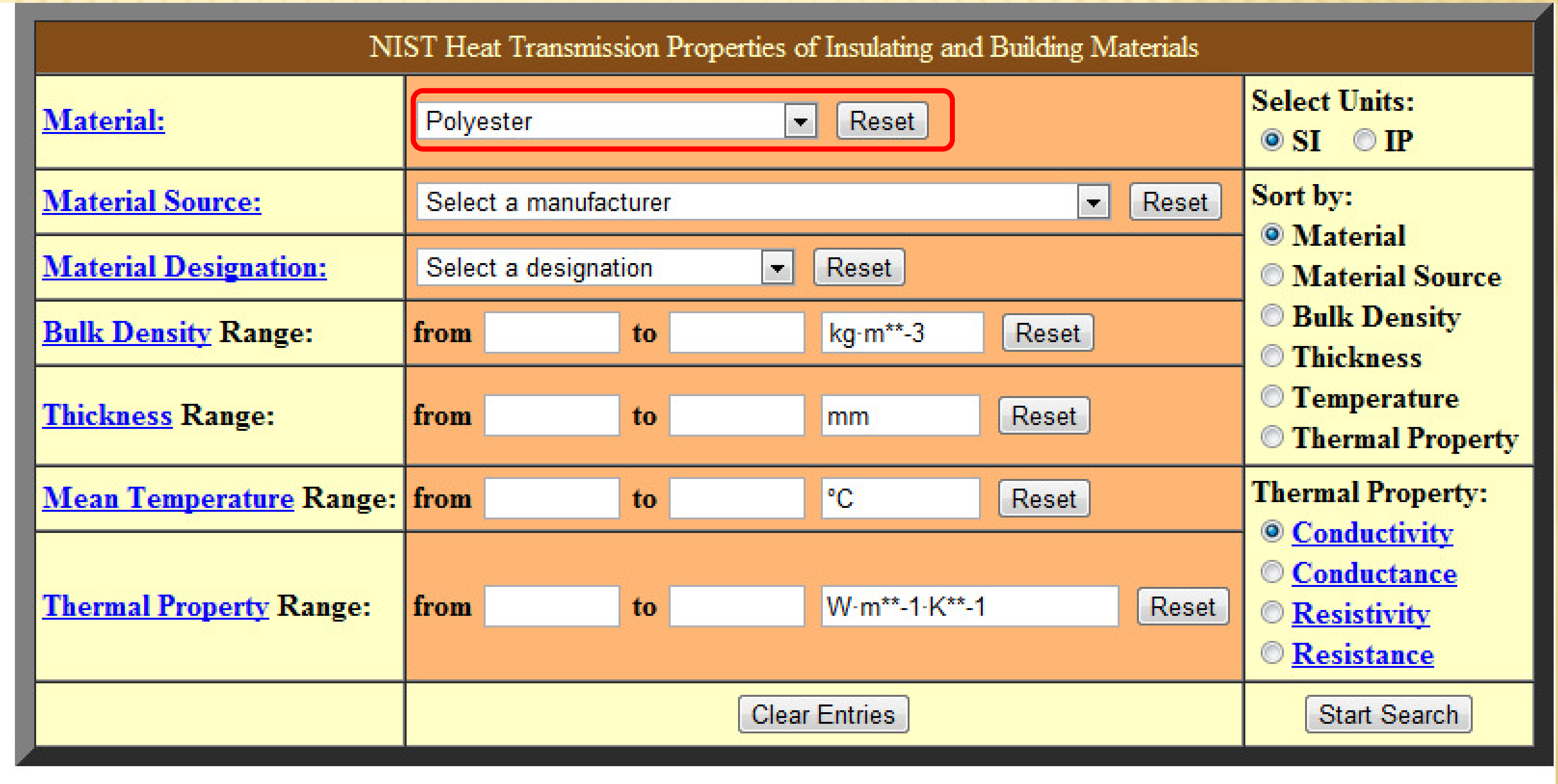
Banco de Dados NIST

http://srdata.nist.gov/insulation/insul_search_menu_12.asp



Banco de Dados NIST

Exemplo:



Banco de Dados NIST

Exemplo:

Results from NIST Heat Transmission Properties of Insulating and Building Materials Database

Plot Data

Total Number of Records: 2

You are searching for the following fields:

* **Density Range:** 4.19 to 2991 kg· m^{-3} (Default values)
* **Thickness Range:** 0.71 to 51.95 mm (Default values)
* **Temperature Range:** -19.02 to 58.6 °C (Default values)
* **Thermal Conductivity Range:** 0.016 to 2.3 W· m^{-1}· K^{-1} (Default values)
* **Material:** Polyester

Material	Date	Bulk Density kg· m^{-3}	Thickness mm	Mean Temperature °C	Delta T K	Thermal Conductivity W· m^{-1}· K^{-1}	Material Source	ID
Polyester	6/21/1949	163	24.65	21.8	13.3	0.0487	NBS	680
Polyester	7/20/1949	153	25.08	21.9	13.4	0.053	Monsanto Chemical Co.	683

Total Number of Records: 2

Go Back

Banco de Dados NIST

Exemplo:

Results from NIST Heat Transmission Properties of Insulating and Building Materials Database
Detail Summary for ID 680

ID	680
Material	Polyester
Form	Block
Material Source	NBS
Specimen Number	1
Bulk Density ($kg \cdot m^{-3}$)	163
Thickness (mm)	24.65
Mean Temperature (°C)	21.8
Delta T (K)	13.3
Thermal Conductivity ($W \cdot m^{-1} \cdot K^{-1}$)	0.0487
Initial Moisture Content (%)	0
Final Moisture Content (%)	0.1
Description	Specimen pair unlike
Comment	Density, dry as tested. Density of pair (#1, 9.3 lb/ft^3; #2, 10.9 lb/ft^3).
Date	6/21/1949
Apparatus	200 mm guarded hot plate
Mode of Operation	2

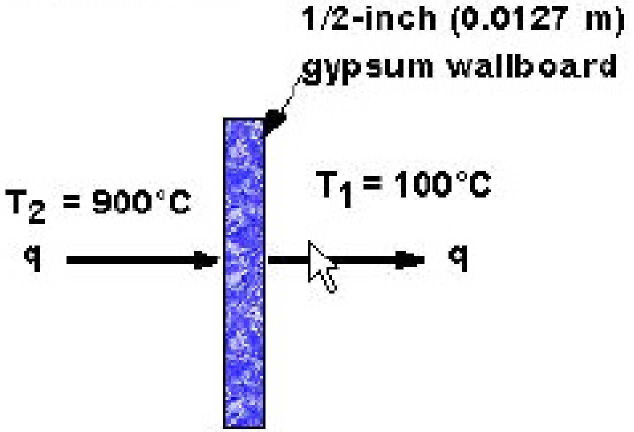
Transferência de Calor por Condução

Exemplo:

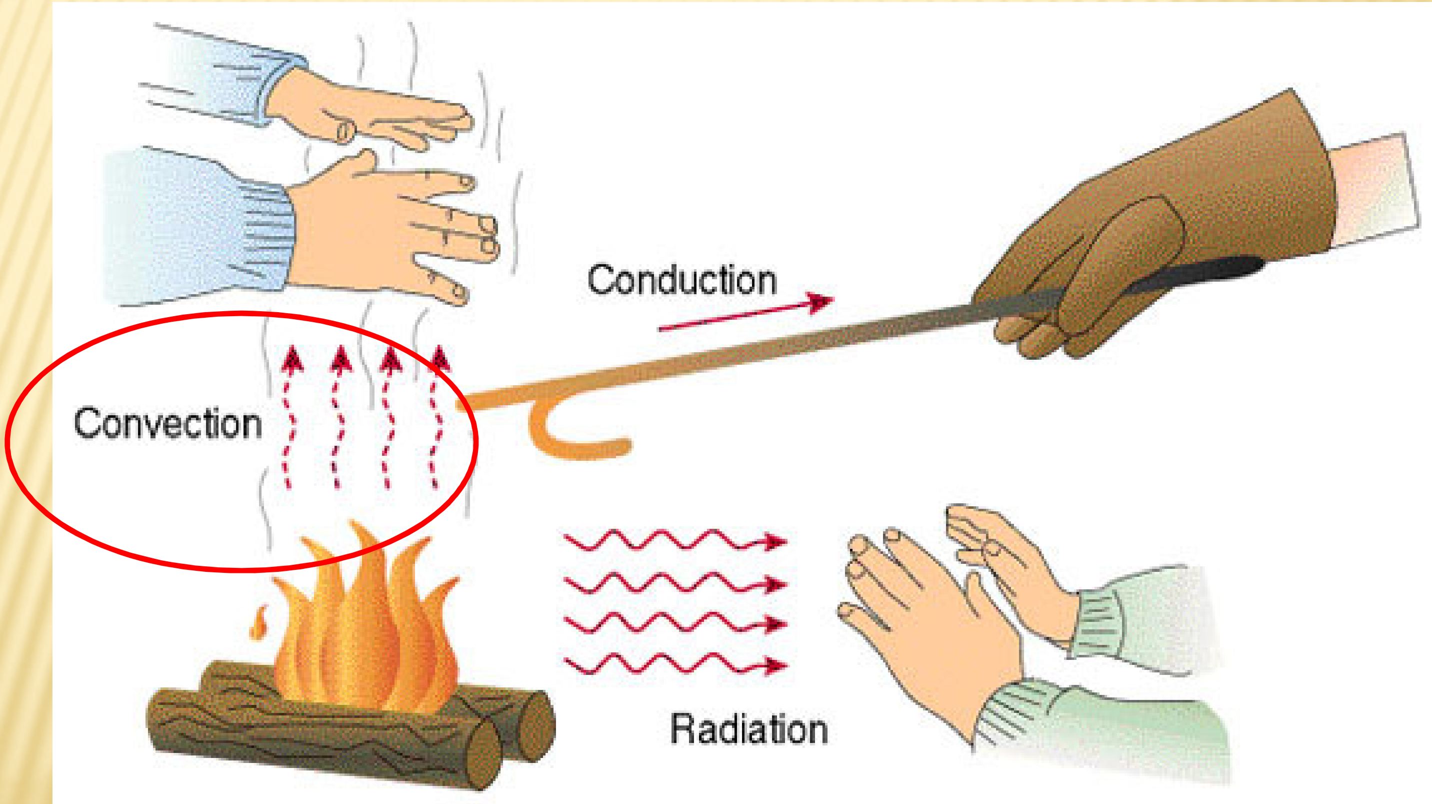
Example 1-1 After investigating a fire and in preparation for a trial you want to determine the heat transfer through a sheet of gypsum wallboard at a given stage of the fire. (See **Figure 1-13**.) You determined that the temperature on the hot side, T2, was 900°C and the temperature on the cold side was 100°C. The conductivity of gypsum wallboard is 4.8 x 10-4 kW/m°C (**Table 1-2**) and the thickness was ½-inch (0.0127 m.) To simplify calculations, assume the area is 1 m^2.

$$q = kA\frac{(T_1 - T_2)}{x} = \left(4.8 \cdot 10^{-4}\right)(1)\frac{(900-100)}{0.0127} = 30\ kW$$

Figure 1-3



CONVECÇÃO



Transferência de Calor por Convecção

$$q = hA\left(T_f - T_s\right)$$

Note:
q <> Q <> q”

rate

Where: q = heat transfer to a solid (kW, kJ/s or Btu/s)

h = convective heat transfer coefficient (kW/m^2°C)

A = solid surface area (m^2) or (ft^2)

T_f = temperature of fluid (°C or °K) (°F or °R)

T_s = temperature of a solid (°C or °K) (°F or °R).

Transferência de Calor por Convecção

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T_f = temperature of fluid

T_s = temperature of a so

To solve convection problems we must know the convective heat transfer coefficient. In general, it is a complex function of the geometry, fluid properties, fluid velocity, and film and surface temperatures.

Typical heat transfer coefficient from flames is 0.005 … 0.01 kW/m2℃.

Transferência de Calor por Convecção

$$q = hA(T_f - T_s)$$

Where: q = heat transfer to a solid (kW, kJ/s or Btu/s)

h = convective heat transfer coefficient ($kW/m^2°C$)

A = solid surface area (m^2) or (ft^2)

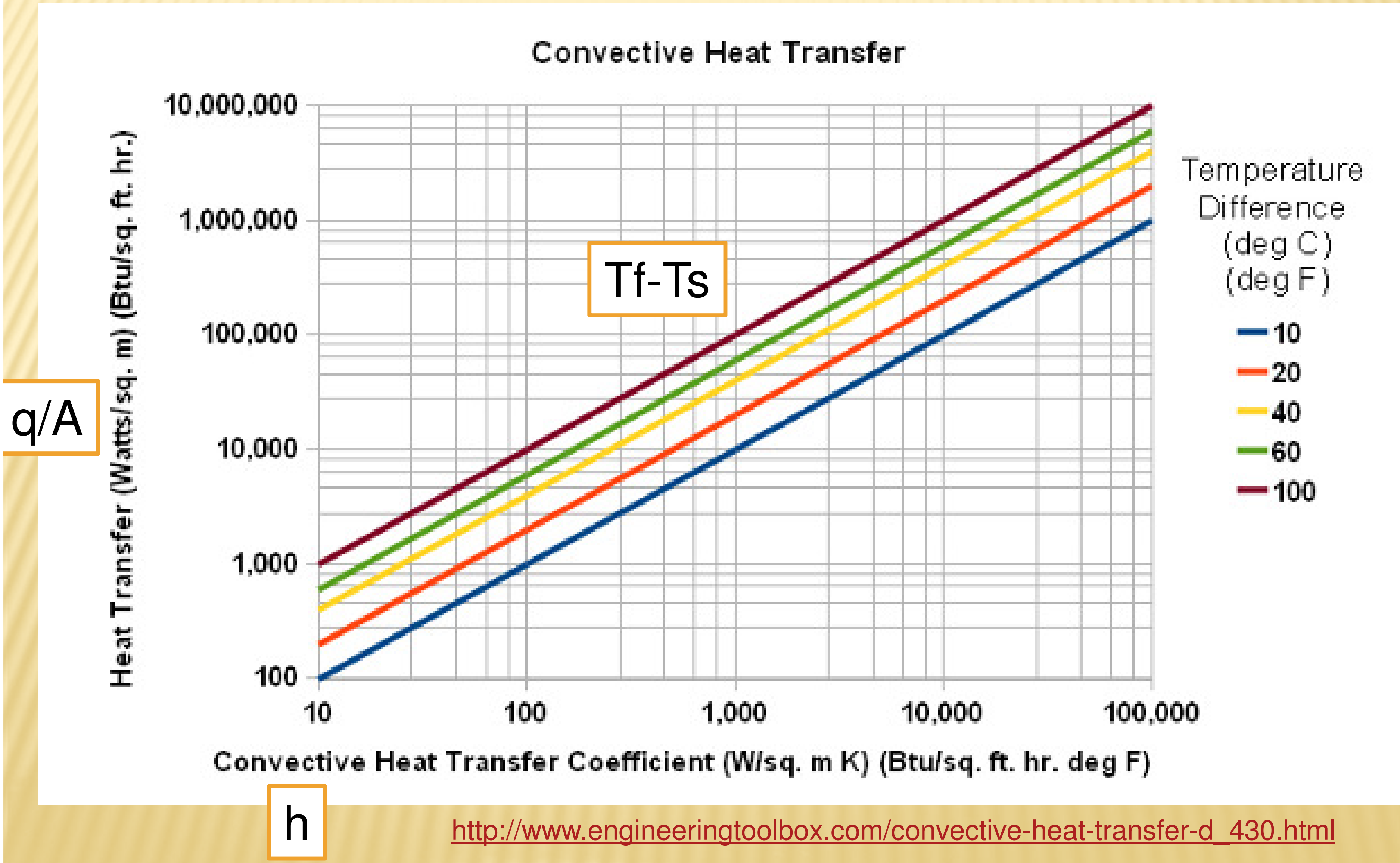
T_f = temperature of fluid (°C or °K) (°F or °R)

T_s = temperature of a solid (°C or °K) (°F or °R).

Free Convection - Air : 5 - 25 (W/m^2K)
Forced Convection - Air: 10 - 200 (W/m^2K)

http://www.engineeringtoolbox.com/convective-heat-transfer-d_430.html

Transferência de Calor por Convecção



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Transferência de Calor por Convecção

$$q = hA\left(T_f - T_s\right)$$

kW = kW m2 C
m2 C

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