# Thermal Conductivity: Measurement, Standards & Things to look out for!

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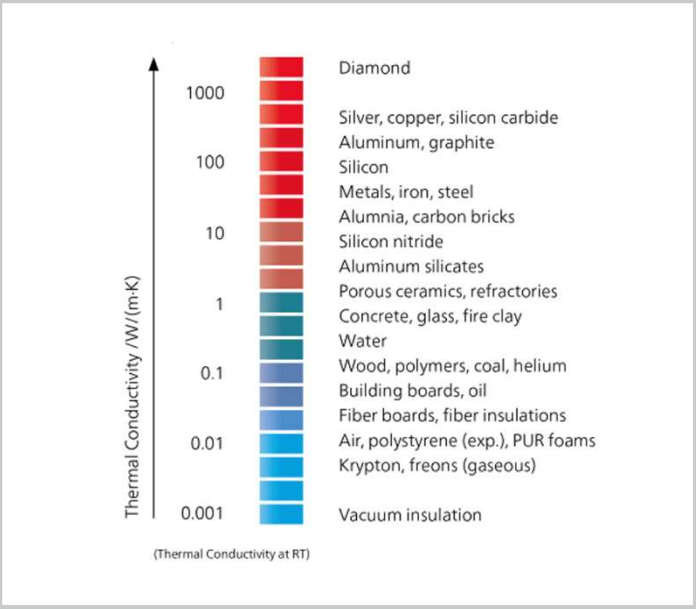
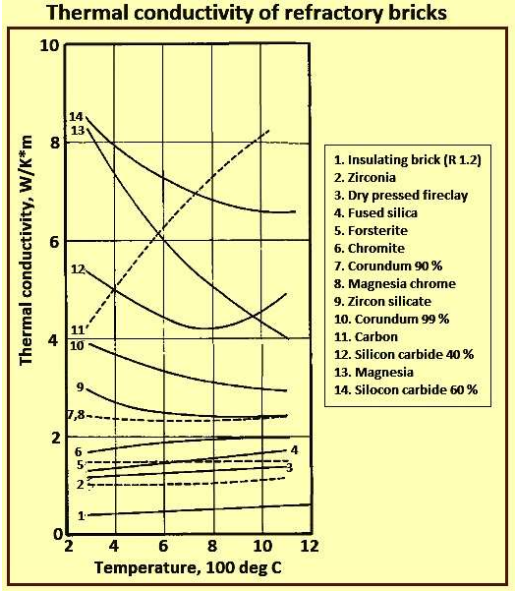
## Thermal Conductivity

- Diamond 2000 W/m/°C
- Steel 50 W/m/°C
- Air 0.01 W/m/°C
- Vacuum 0.001 W/m/°C



# Thermal Conductivity

- 60% SiC brick 8 W/m/°C
- 90% Alumina 2.3 W/m/°C
- Insulating brick 0.4 W/m/°C
- Aerogel 0.03 W/m/°C






# Thermal Conductivity

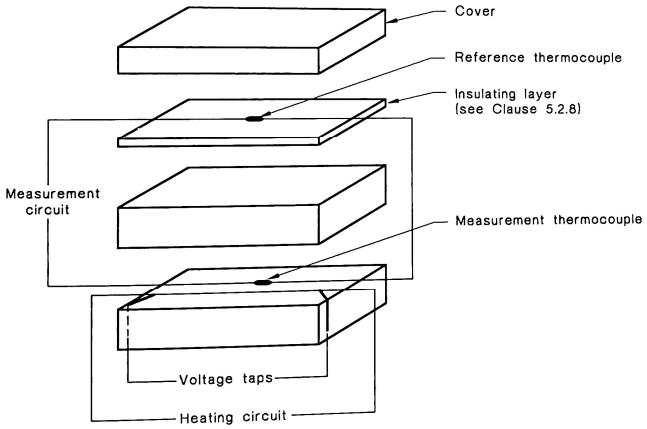
What you need to consider when measuring

- Heat losses: can increase the apparent value of thermal conductivity by 5–10%
- Humidity: can increase the thermal conductivity by 15–25% in a porous material
- Heterogeneity and anisotropy: can vary the thermal conductivity by 10–15%.

# Determination of thermal conductivity. Hot-wire methods

BS EN ISO 8894-2:2007
Parallel wire

BS EN ISO 8894-1:2010
Cross-array and resistance thermometer





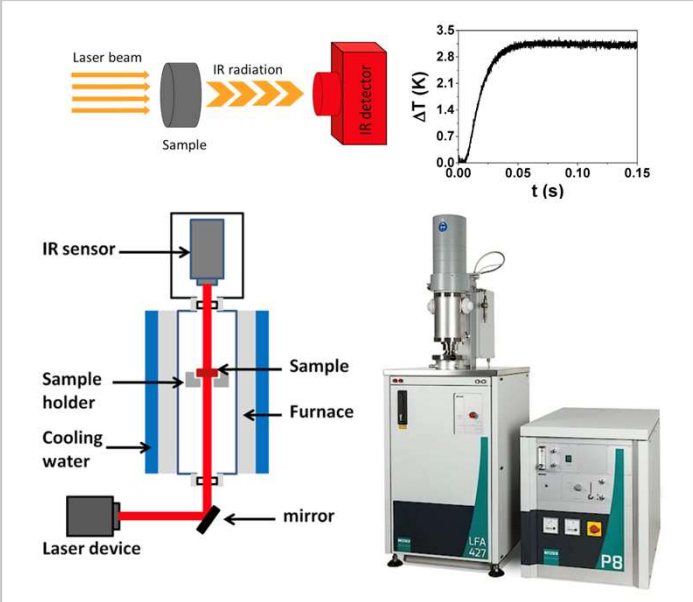

# Laser Flash Method

- Laser pulse technique
- Sample up to 4 mm thick.
- Ø25 mm diameter

$$\lambda(T) = \rho(T) \cdot c_p(T) \cdot a(T)$$

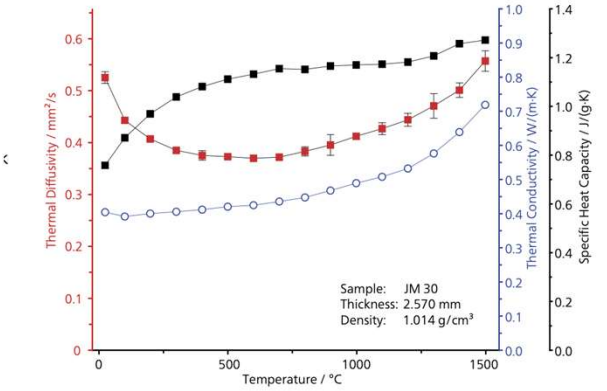
Where

$a$: Thermal diffusivity
$c_p$: Specific heat capacity
$\rho$: Density



# Laser Flash Method

- Firebrick example
- Thermal diffusivity (T)
- Specific heat capacity (T)
- Thermal conductivity is calculated from these.
- Density also changed with Temperature.

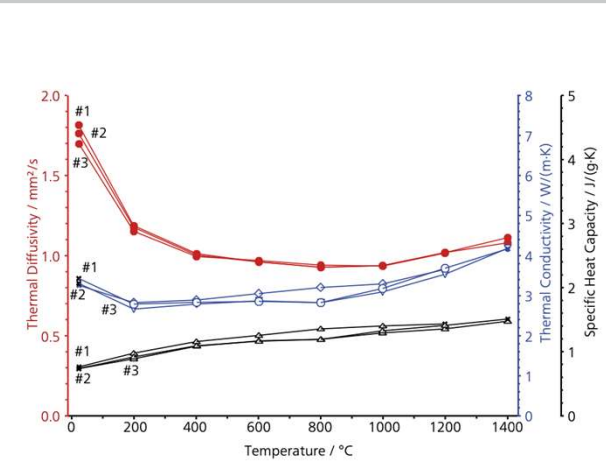



Comprehensive characterization of a firebrick containing 69.9% $Al_2O_3$, 28.1% $SiO_2$, 1.2% $TiO_2$ and some minor amounts of $Fe_2O_3$, CaO, MgO, $Na_2O$ and $K_2O$.



# Laser Flash Method

- 25% SiC Alumino-silicate Brick
- Note: Thermal conductivity scale compared to the firebrick.




Thermal diffusivity, thermal conductivity and specific heat capacity of a brick containing 45% $Al_2O_3$, 29% $SiO_2$ and 25% SiC; three specimens cut from the same brick.

# Thermo-Physical Properties

- RUL and Creep
- Ø50 x 50 mm high

- HT MOR
- 25 x 25 x 150 mm bars.

International Standards for Testing Refractory Materials

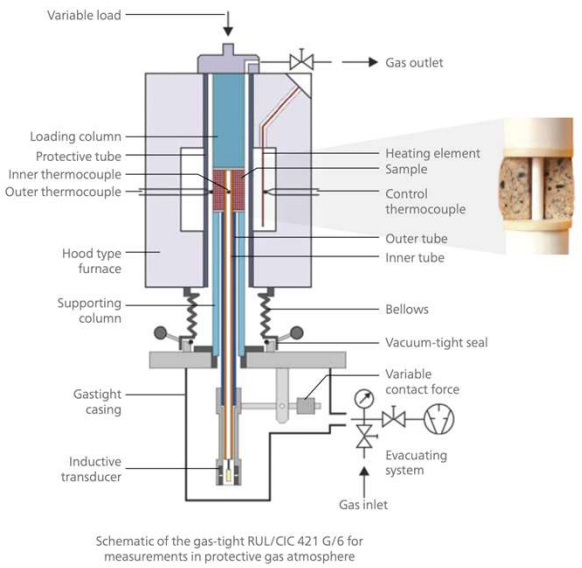
| Standard | ISO | DIN EN | ASTM |
|---|---|---|---|
| Determination of Refractoriness under Load (Differential—with Rising Temperature) | 1893 | 993-8 | |
| Determination of Creep in Compression (CIC) | 3187, 16835 | 993-9 | C832-00 |
| Determination of Modulus of Rupture at Elevated Temperature | 5013 | 993-7 | C583-00 |



# Refractoriness Under Load

&

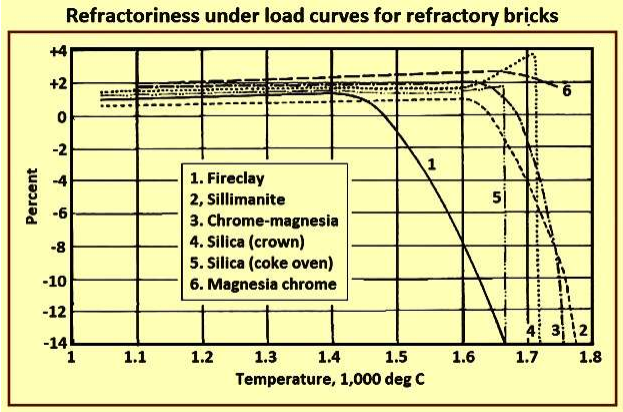
# Creep in Compression




Schematic of the gas-tight RUL/CIC 421 G/6 for measurements in protective gas atmosphere

# Refractoriness Under Load

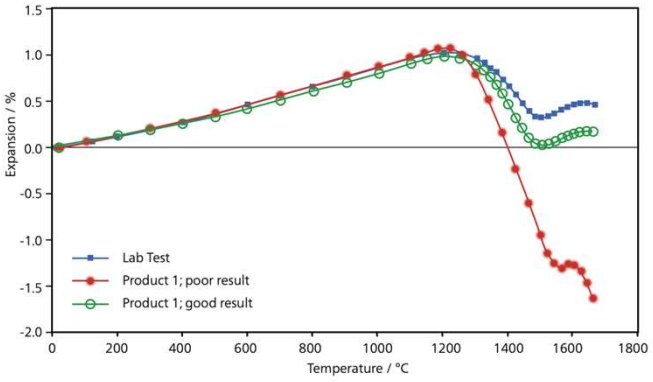
- Shrinkage can effect the thermal conductivity.
- Porosity decreases





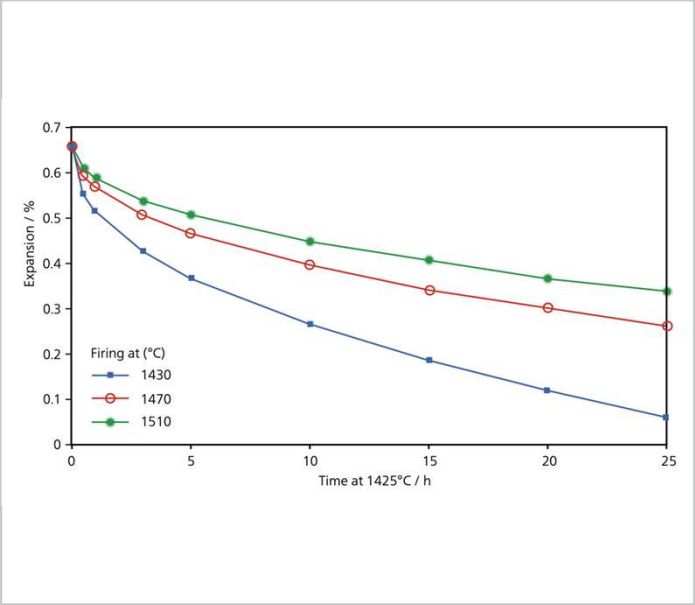

# Refractoriness Under Load

- Shrinkage can effect the thermal conductivity.
- Porosity decreases
- Used for Quality Control



# Creep in Compression

- Load is applied once at the test temperature
- If your material 'creeps' must consider the effect of this on thermal conductivity






# Take home points – Thermal conductivity

- Need to consider Thermal conductivity changes with temperature.
- Many factors effect thermal conductivity
  - Humidity
  - Homogeneity of material
  - Heat losses during measurement.
  - Creep of material can increase density / reduce porosity
- Laser flash systems measure a wide range of thermal conductivities