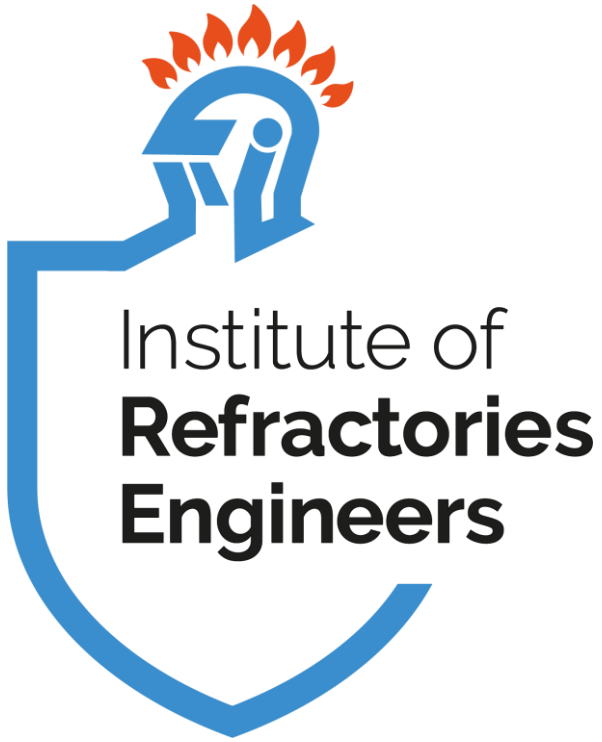


Online Training Event 2020

Heat Flow and Thermal Expansion

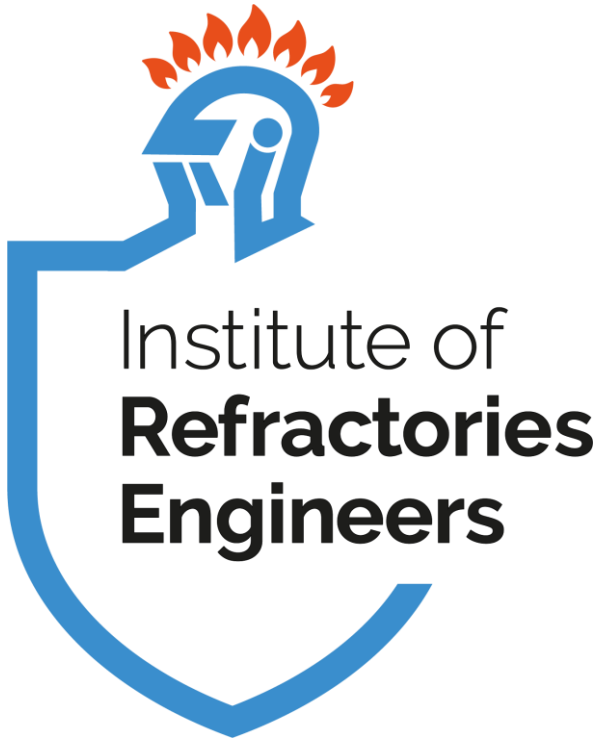
Course Aim

- To give an appreciation of how heat flows through a lining and how thermal gradients are calculated and used
- To give an appreciation of thermal expansion and how thermal expansion allowances can be made.

Contents

Institute of Refractories Engineers

Day 1		
• Welcome	Katy Moss	10.00
• Introduction - Thermal conductivity	Sam Franklin	10.10
• Thermal Gradient Calculations	Sam Franklin	11.10
• Exercise		11.40
• Exercise Feedback		12.20
Day2		
• Thermal Expansion	Martyn Frith	10.00
• Exercise		10.45
• Exercise Feedback		11.25
• Transient Conditions	Sam Franklin	11.35



Online Training Event 2020

Introduction

Contents

1. Introduction
2. Why heat flow is important
3. How Heat flows
4. What is Thermal Conductivity
5. Thermal Conductivity of Refractories

Introduction – Why Consider Heat Flow

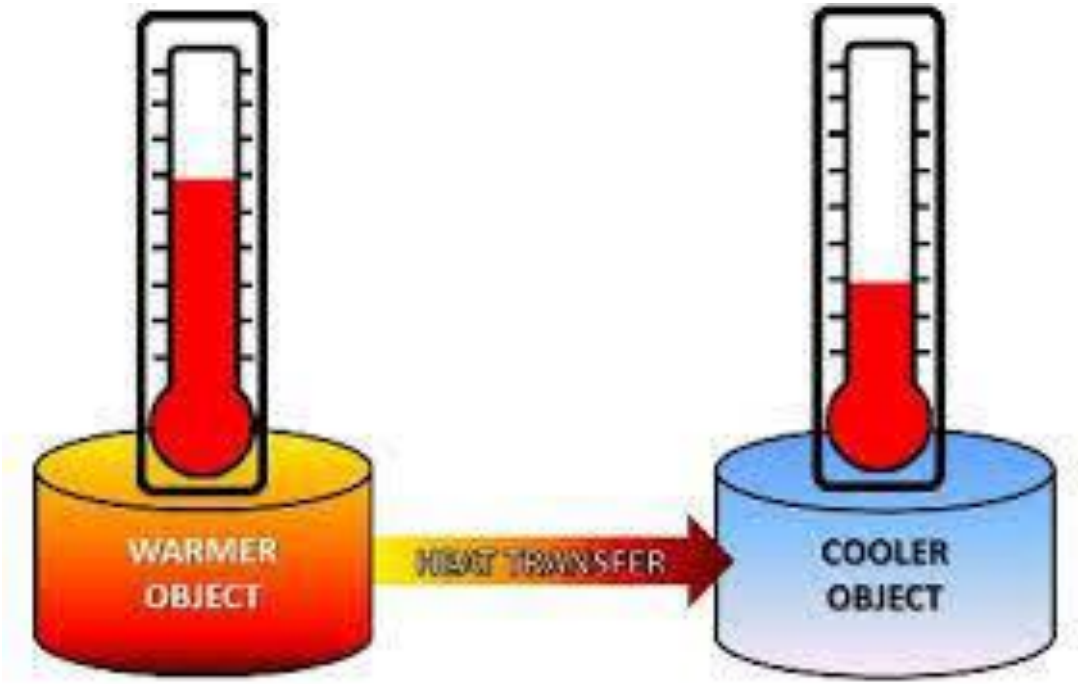
Temperature Gradient

- Shell temperature
  - Max design temperature
  - Acid dewpoint
  - Hand safe
- Refractory Service
  - Material melting
  - Slag Penetration
  - Maximum Service Temperature
  - THERMAL EXPANSION
- Heat Flow
  - Skull stability
  - Energy loss
  - Heating and cooling rates
    - Turnaround time

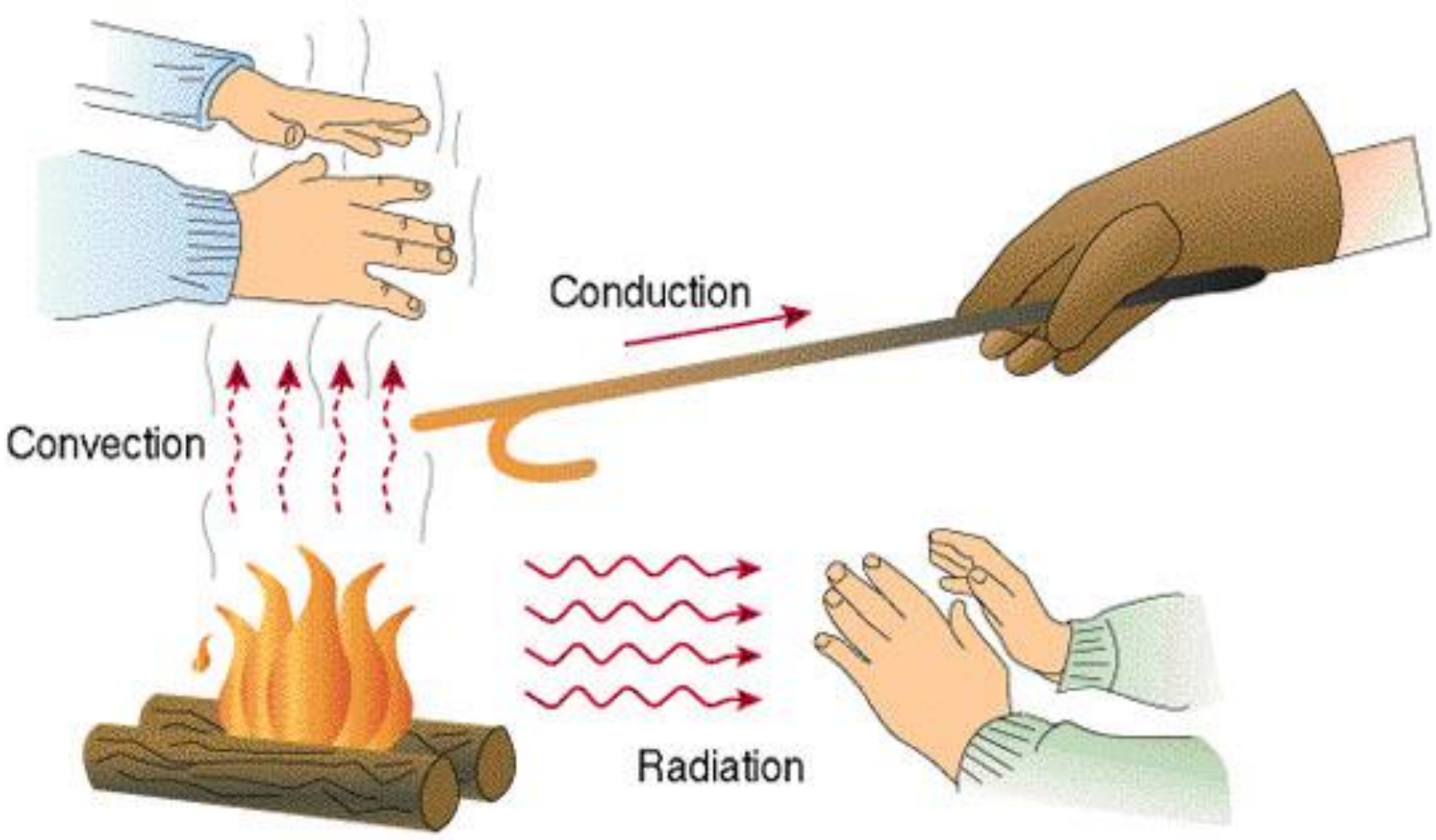
What is Heat

Heat is a form of ENERGY

- Temperature is a measure of thermal state
  - As a material cools it looses heat (thermal energy)
- Heat Energy flows in one direction



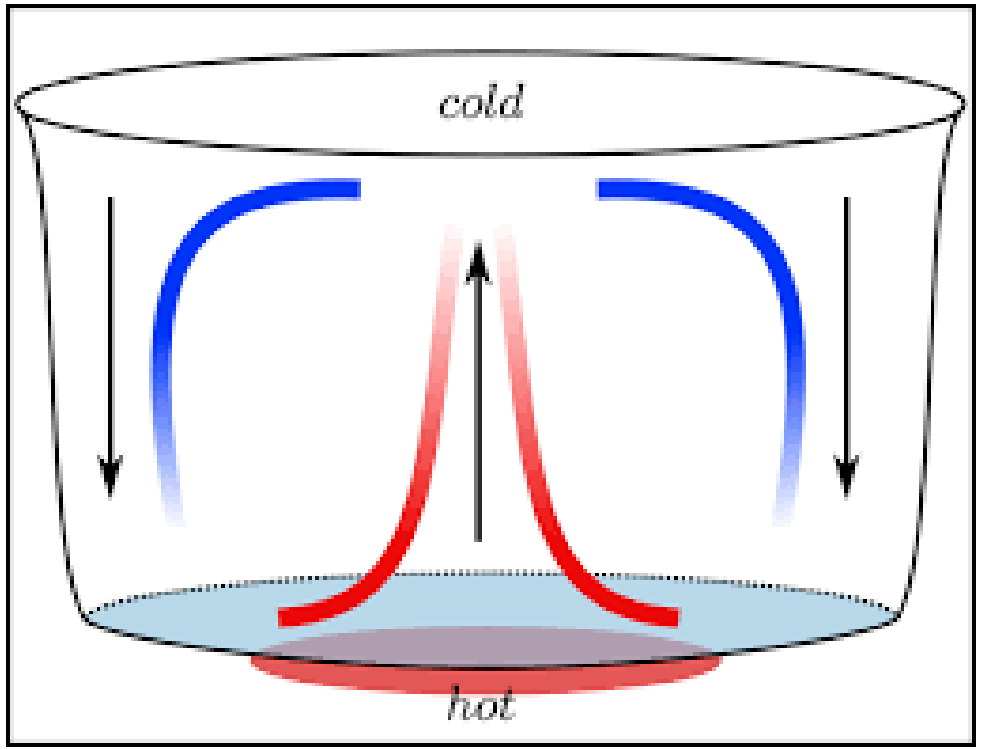
How Does Heat Flow?



Convection

Convection is when heat energy is moved by a movement of a fluid (mass flow)

- Natural Convection
- Fluid near hot object is heated
- Thermal expansion of heated fluid
- Decrease in density
- Low density fluid rises,
- High density fluid sinks
- Cool fluid into contact with heat source
- Cycle continues

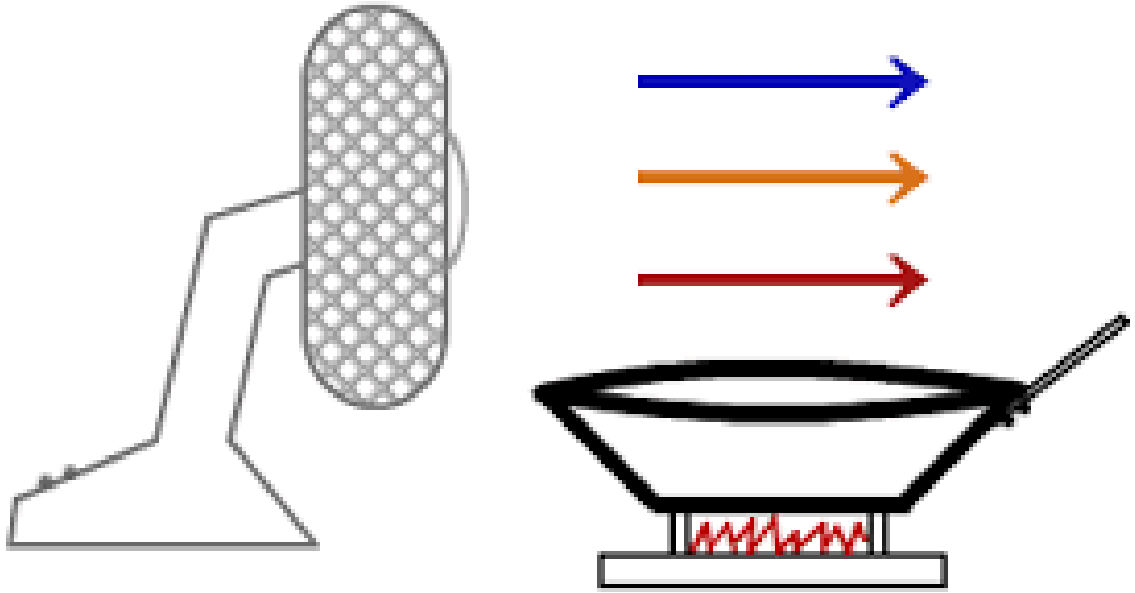


Forced Convection

Heat (energy) transfer caused by mass transfer

Mass transfer caused by externally driven fluid flow

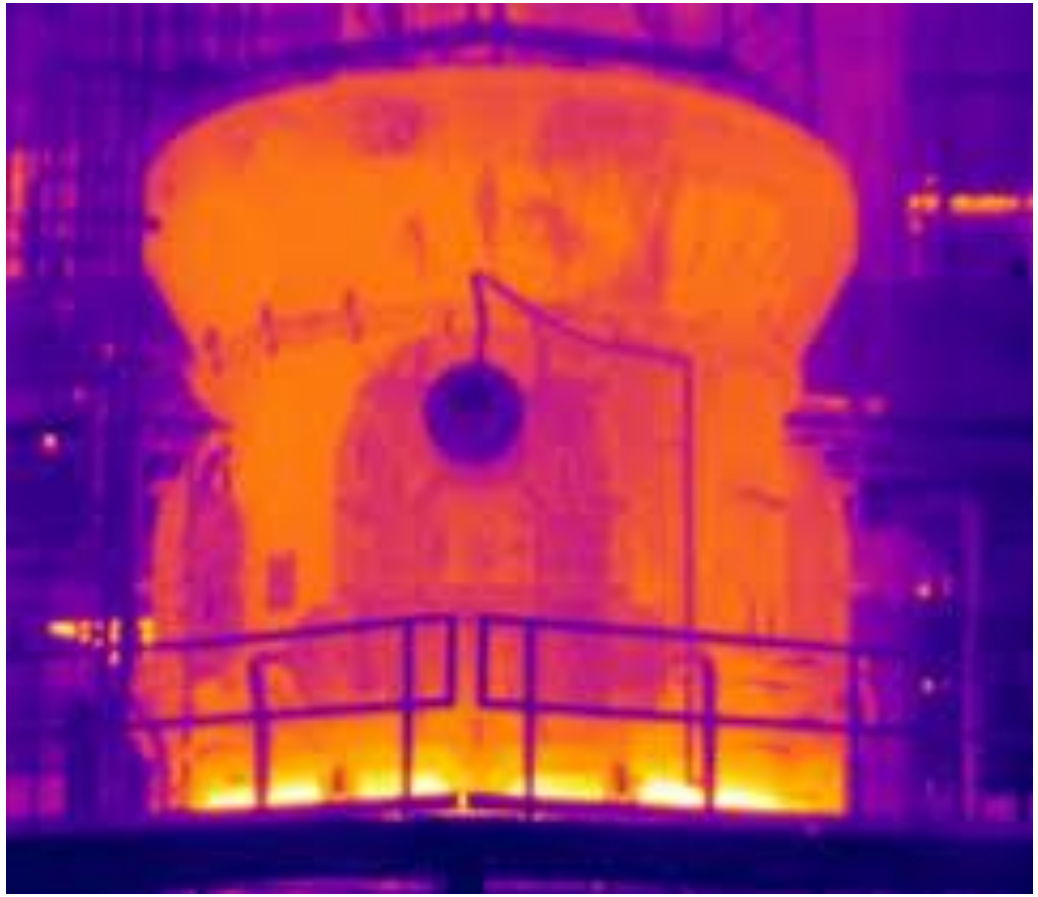
- Cooling fans
- Water cooling circuits
  - Car engine cooling
  - Blast furnace cooling
  - Domestic boiler



Radiation

Heat Transfer by Electromagnetic Radiation,

- IR wavelengths
- Can pass through transparent materials and space
- Stopped by opaque materials
- Amount of energy transfer depends strongly on temperature



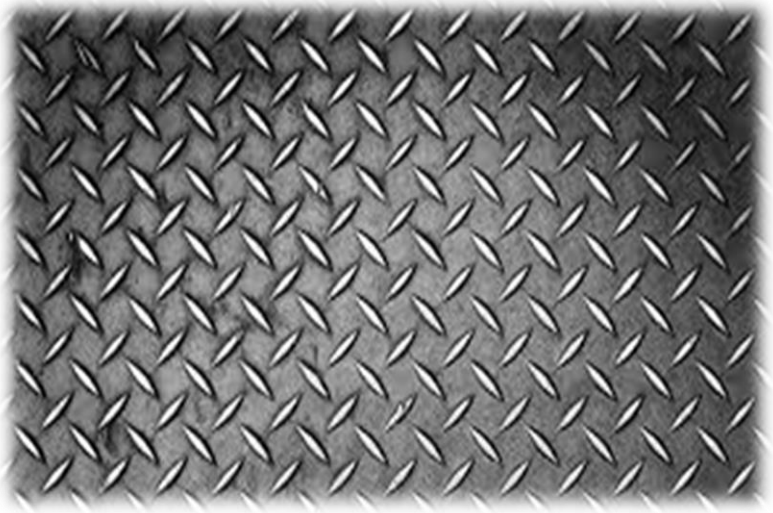
Thermal Expansion

- Refractories expand when heated up
- The steel shell constrains the expansion and leads to stresses
- The stresses can be very high
  - Damage to lining
  - Damage to shell
  - Loss of containment
- Correct understanding of expansion and how to allow for it is essential

Thermal Conductivity

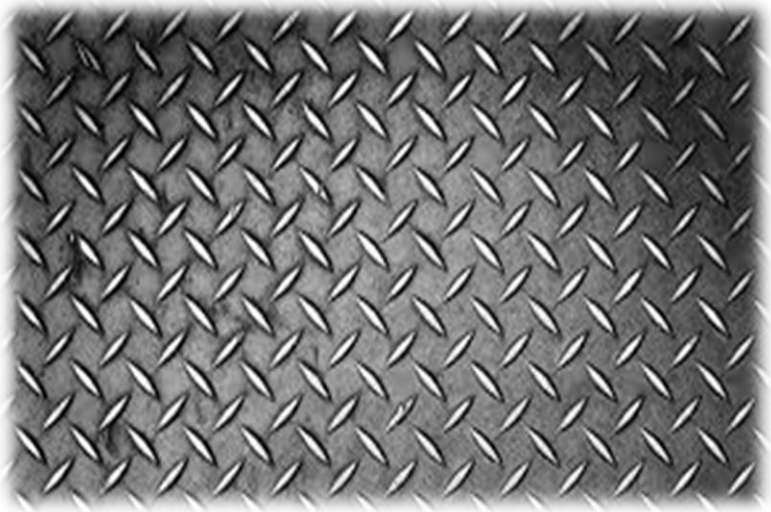
Which is colder?

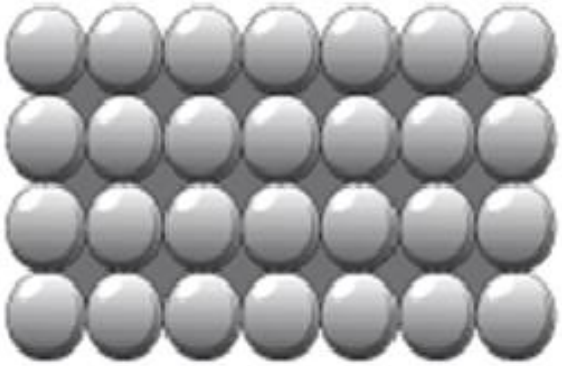
Both materials have been sat in the room for the same time, theoretically they should be the same temperature. But do they feel that way?



Or

Which is Colder





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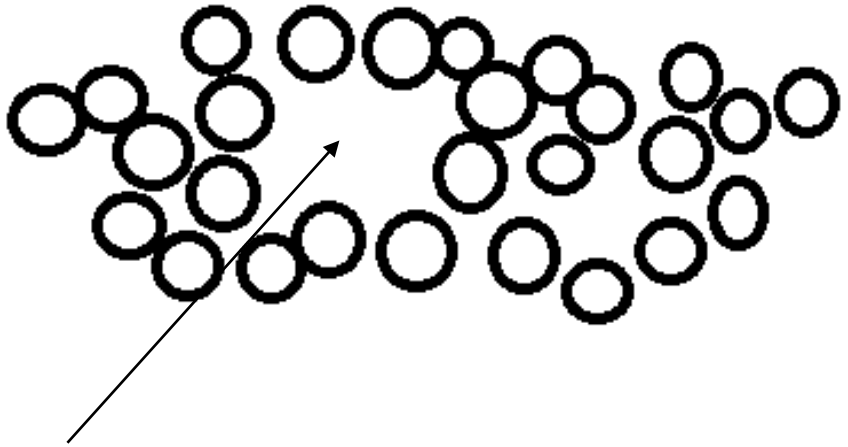


What is thermal conduction?

Thermal conduction is "*the process by which heat flows from the hotter regions of a substance, to the colder regions without there being any net movement of the substance itself*" – Roger Muncaster

- The transfer of heat through physical contact
- The mechanism of heat transfer depends upon the nature of the material itself

Thermal Conductivity is a measure of how much heat flows through a material

Thermal conductivity

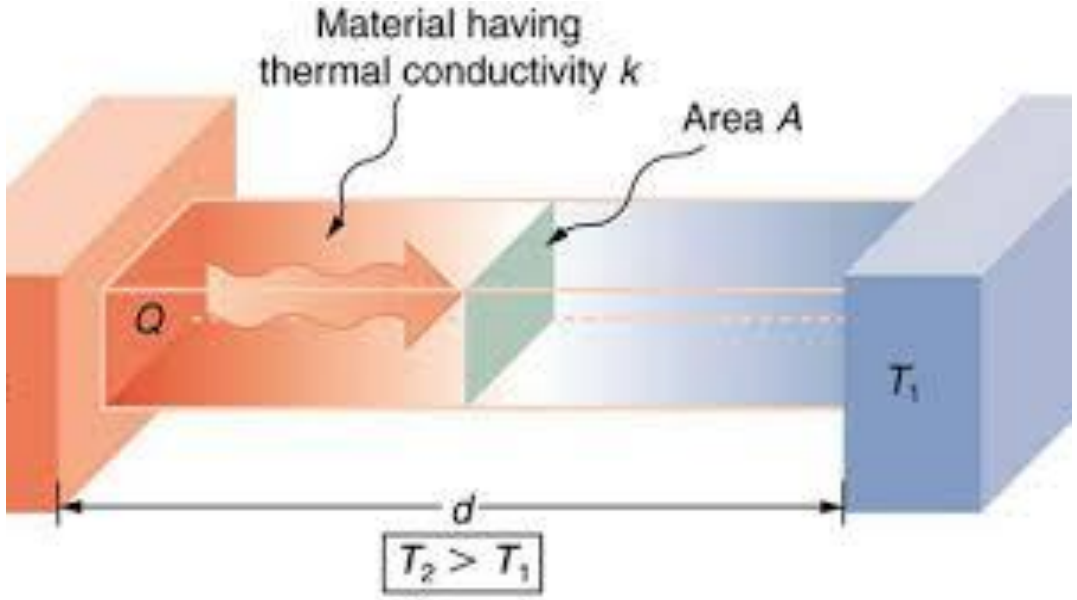
Thermal conductivity, k, is defined by the equation

$$P = k \cdot \frac{d}{A} \cdot \Delta T$$

Where P is rate of heat flow, d is the length of the material, A is its area and ΔT is the temperature difference

k is a material property but

- it can vary with test temperature
- direction through the material (anisotropic)



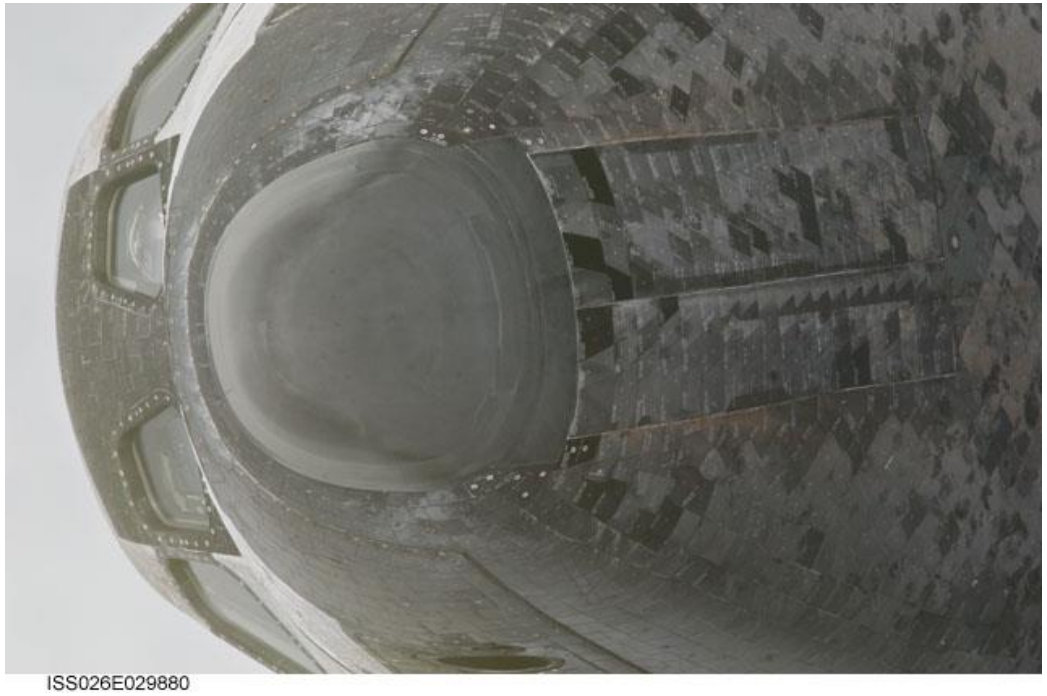
What affects how heat is transferred?

Rate of heat transfer and affecting factors;

-Temperature gradient
-Cross – section & path
-Material properties

-Coefficient of thermal conductivity of a material is a measure of the rate of heat flow per unit area, per unit temperature gradient

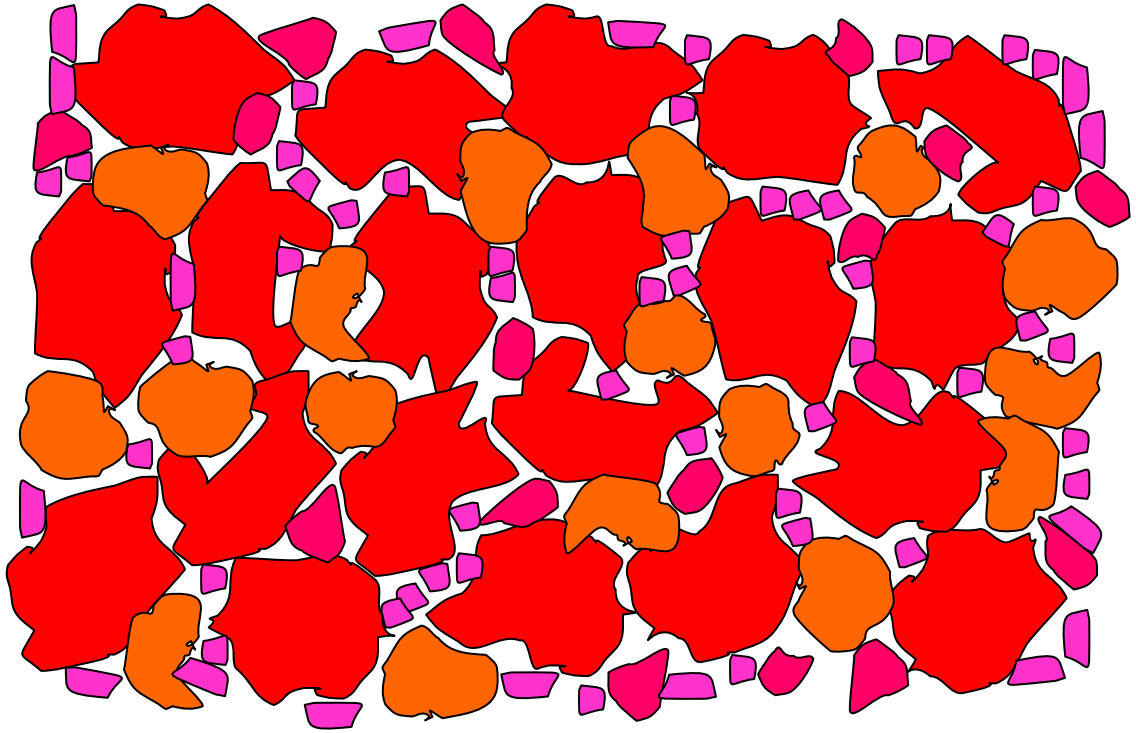
-Units: W/mK



Source: NASA. Heat resistant carbon-composite tiles on the nose of space shuttle Discovery

Porosity and Conductivity

- Refractories contain pores
  - They contain air or furnace atmosphere
  - Gases are more insulting than solids
  - Higher porosity tends to lower conductivity
    - Not a simple relationship, other factors
  - Materials with a low conductivity are referred to as insulating materials or isnulation



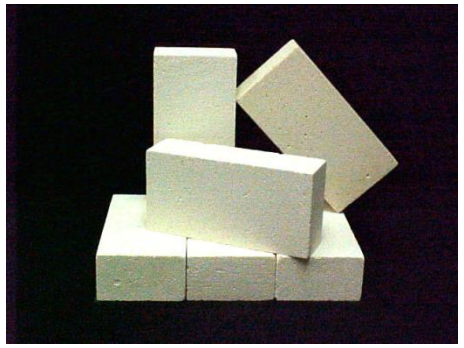
High or Low Conductivity

- Low conductivity (insulation)
  - Conserves energy
  - Reduces shell temperature

  - High porosity
- High conductivity
  - High heat flow – eg heat exchangers
  - Thermal shock resistance

  - Low Porosity

Types of Insulating Refractories



Insulating Firebrick

Fibre Insulation

Microporous insulation

Insulating castable/ gunmix

Thermal Conductivity Values

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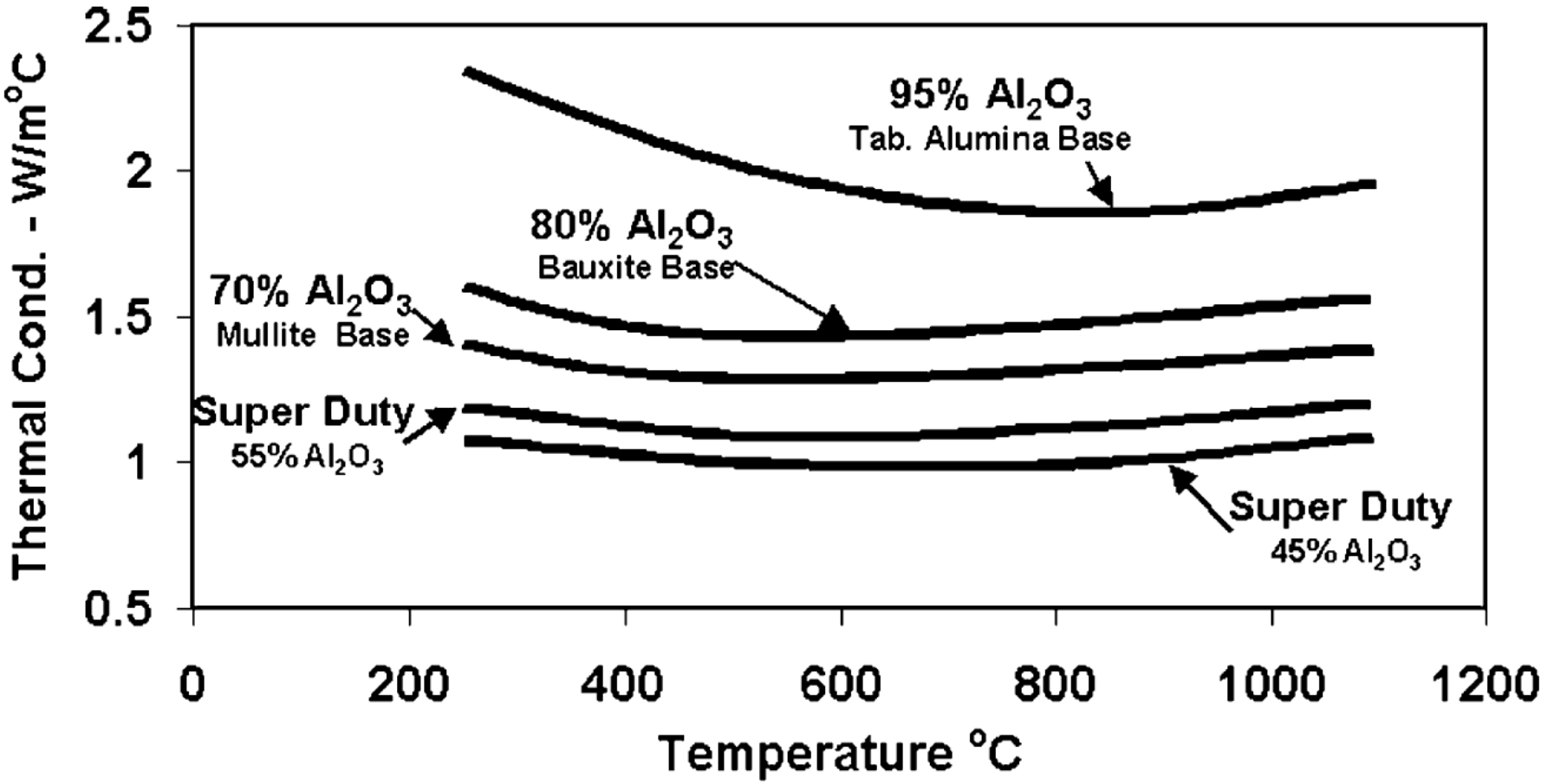
Material	W/mK
Air, atmosphere (gas)	0.024
Rubber, natural	0.13
Timber, ash	0.16
Insulating Firebrick	0.25
House Brick	0.9
Glass, window	0.96
Granite	1.9
80% Alumina brick	1.9
Fired Magnesia Brick	3.6
Magnesia Carbon	7
Blast furnace Carbon	18
Carbon Steel	54
Aluminum	205
Gold	310
Copper	401
Values at ambient temp	

Thermal Conductivity of Insulating Castables



Thermal Conductivity of Carbon Refractories

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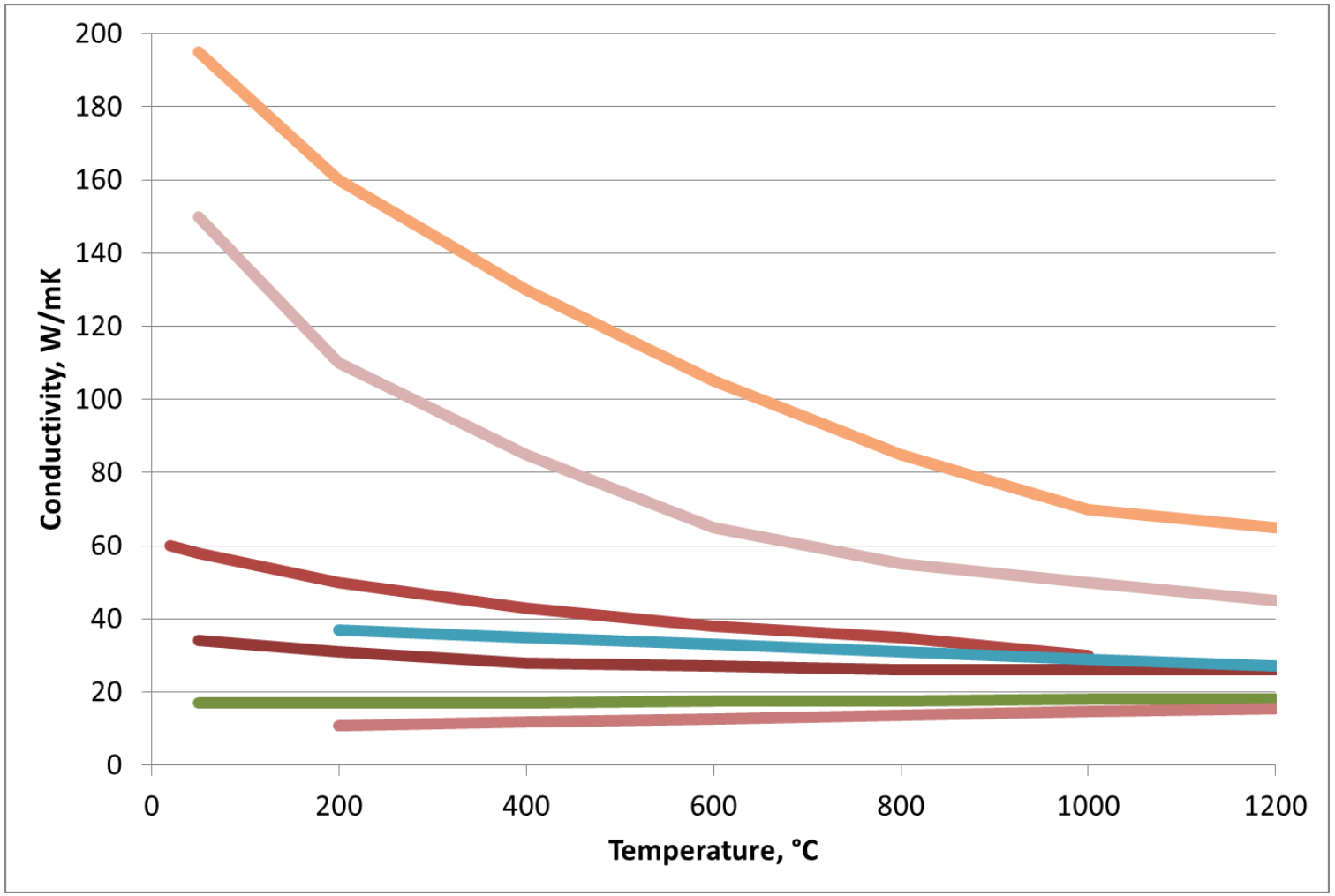
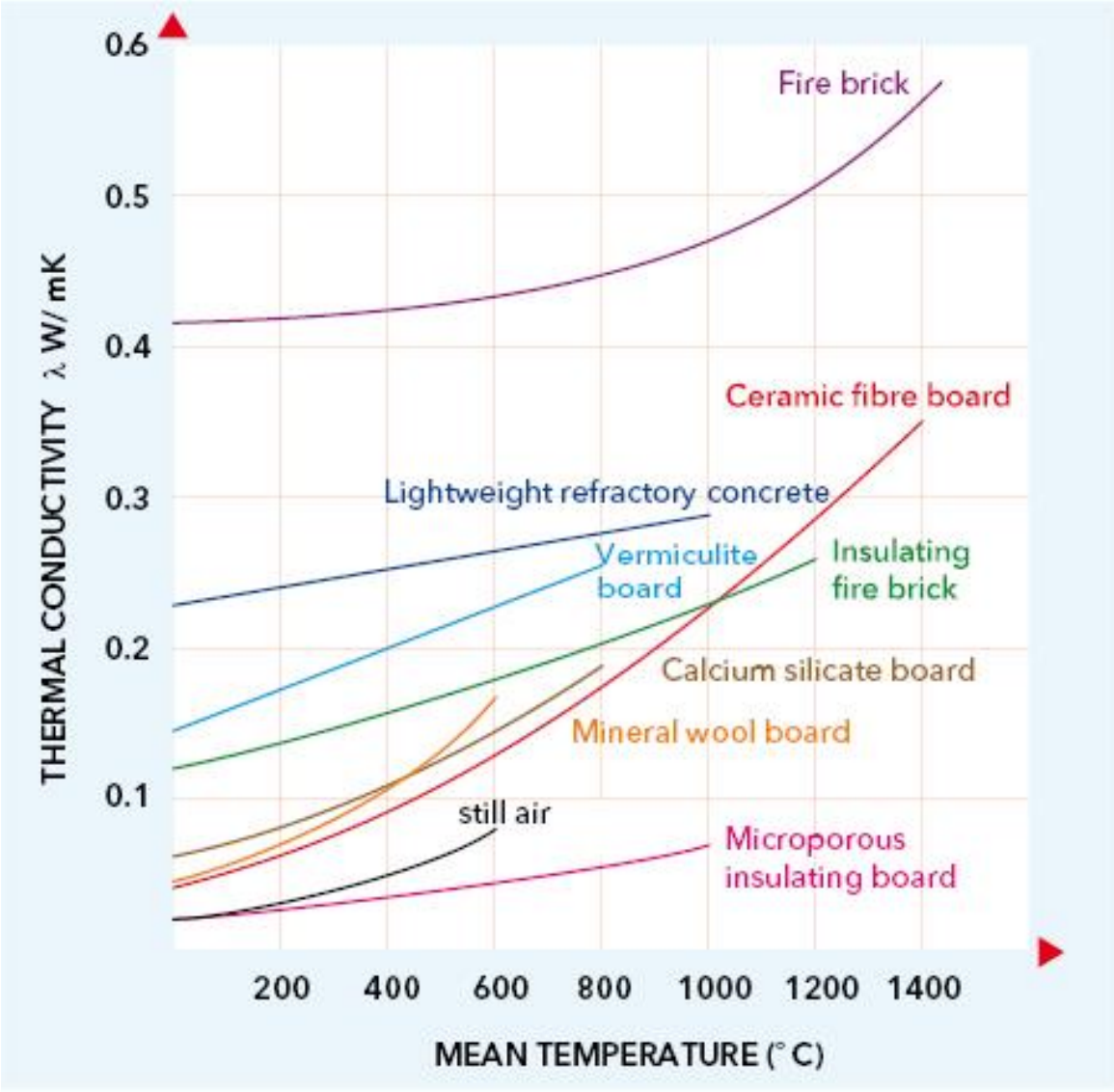


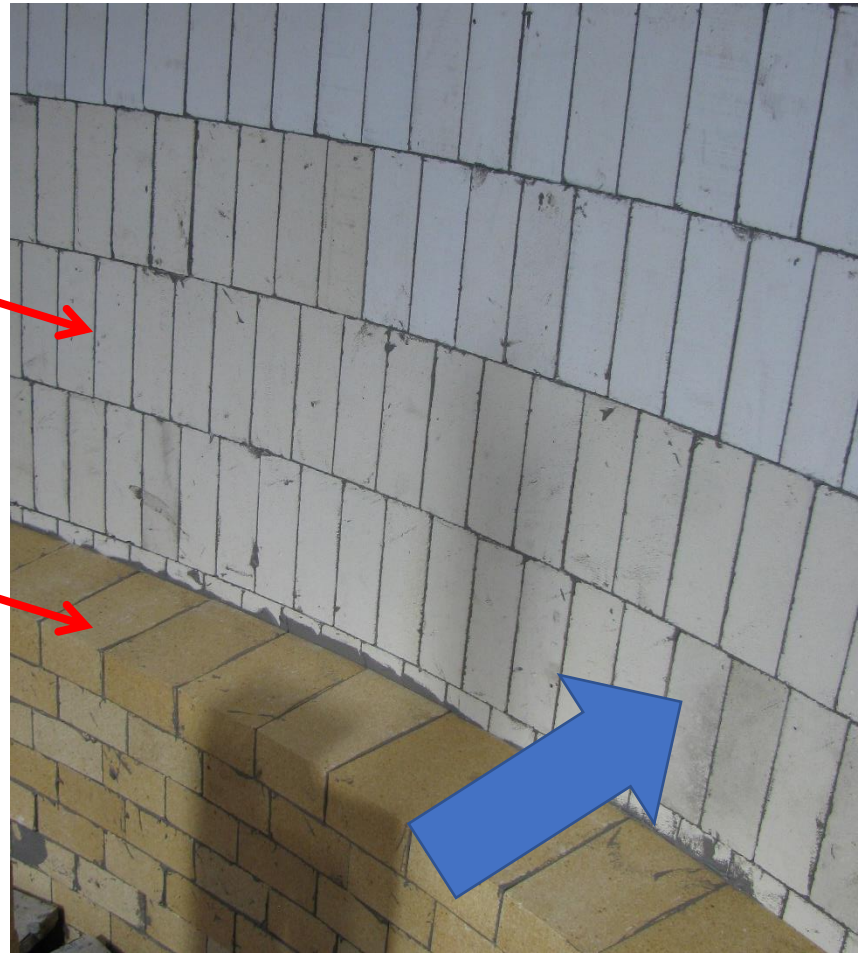
Thermal Conductivity – Insulation Refractories

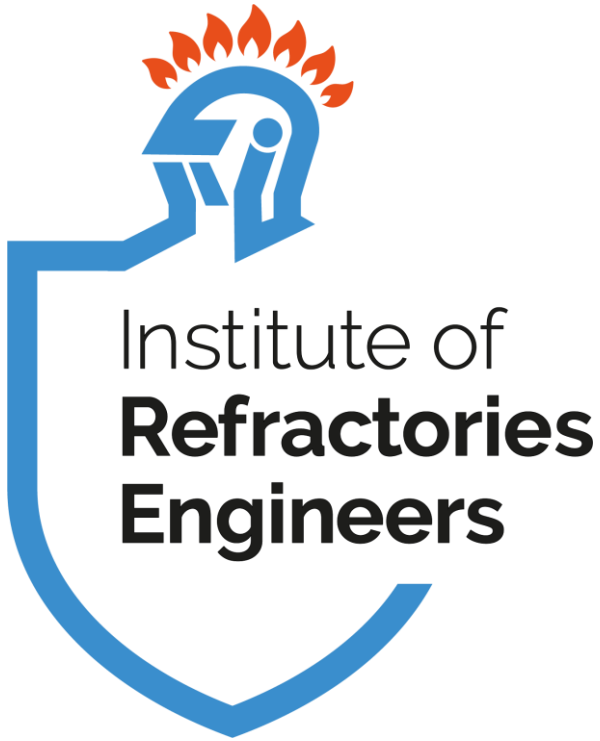


Thermal Conductivity – Key points

- Very wide range of values available from <0.1 to >200 W/mK
- Strong variation with temperature
- Design lining to have required properties

Thermal Conduction in a Refractory Structure





Thank you

Any Questions?

https://irengineers.co.uk/