Institute Of Refractories Engineers

Introduction To Thermal Shock and Thermal Stress in Refractories

14 November 2019

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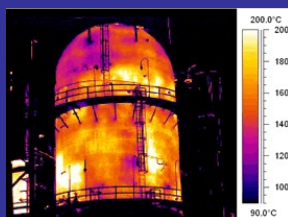# Refractory Applications and their effect on refractories

Glass

Aluminium

Iron & Steel

Petrochemical

Cement/ lime

Waste incineration

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What is thermal shock?

Thermal shock refers to the damage that occurs if a component (not material) is subjected to rapid temperature changes (heating/cooling) that causes thermal stress or thermal strain higher than what the material can accommodate.

It could result in cracking or fracture (often called thermal spalling) or deterioration of the component.

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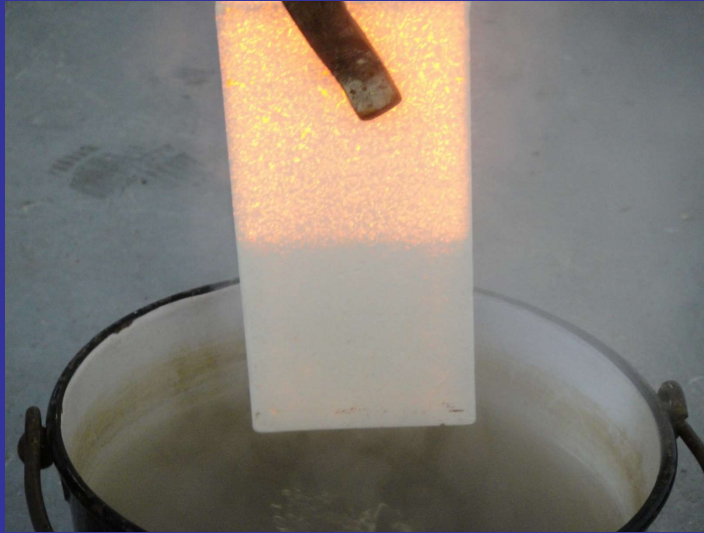# What is thermal shock?

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Heated brick water quenched

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Water cooling half the brick

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Large temperature difference
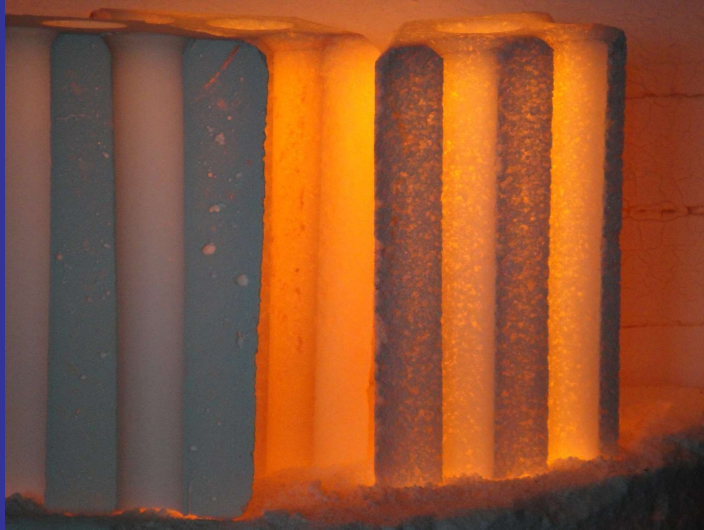

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Testing the component

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Testing the component

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Testing component - Water quenching

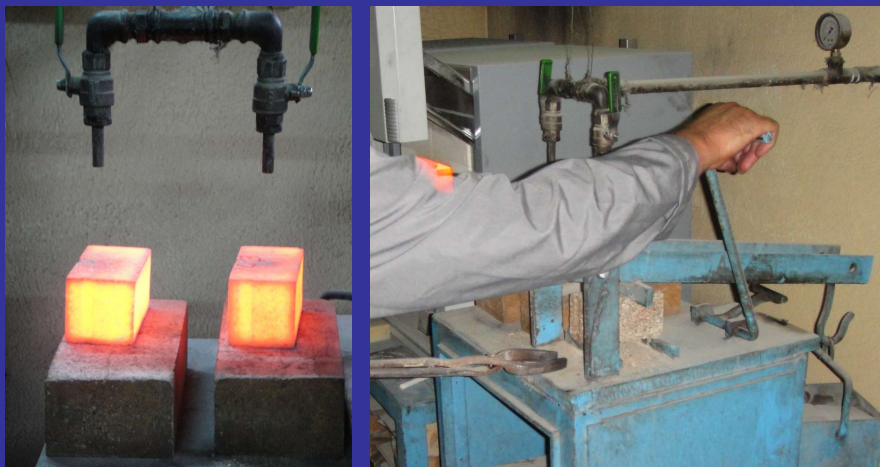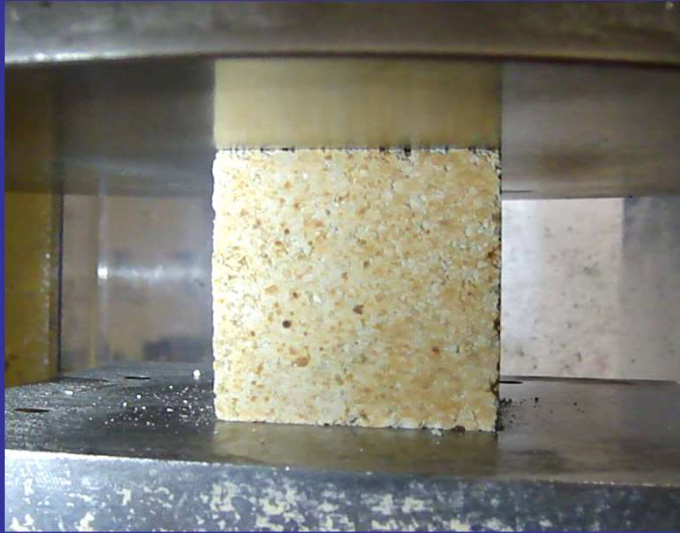10

From furnace to air blowing

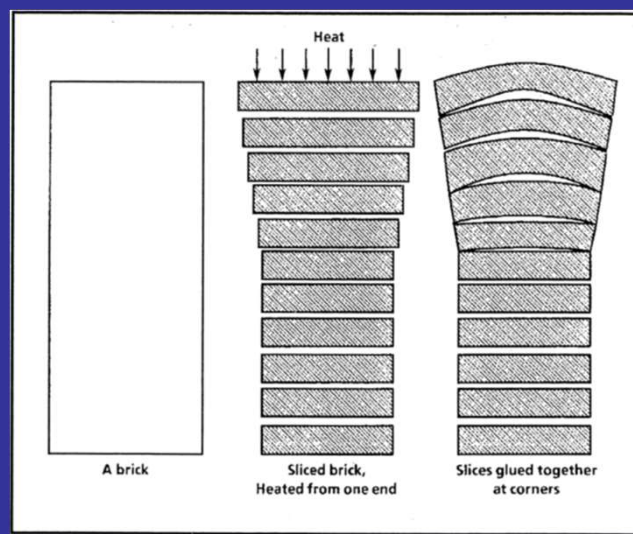11

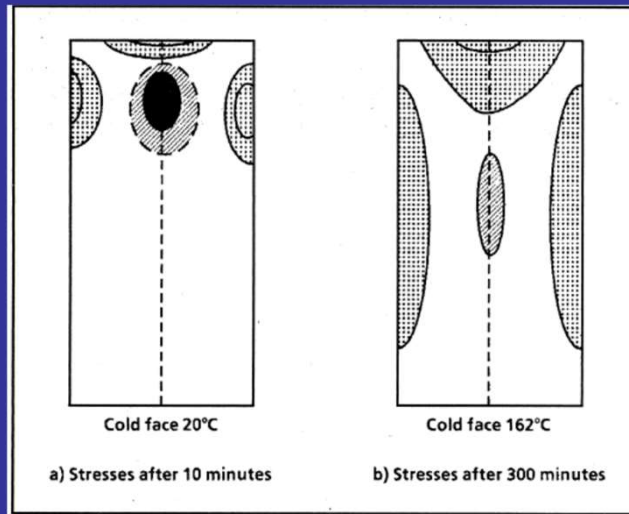Air Cooling followed by MOR

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Failure due to excessive stress

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Deformation of Sliced brick heated from one end
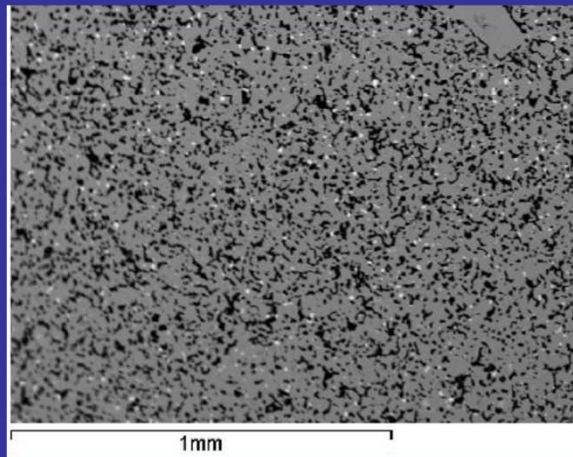

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Stresses in brick heated from one end

Cold face 20°C Cold face 162°C

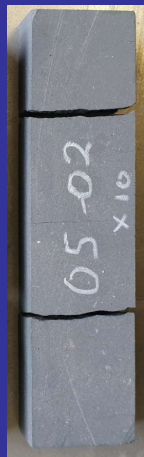a) Stresses after 10 minutes b) Stresses after 300 minutes

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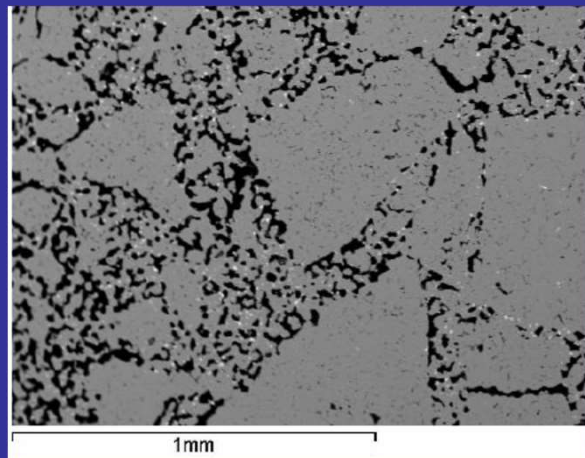Long rectangular specimens, cracks appear during cool down
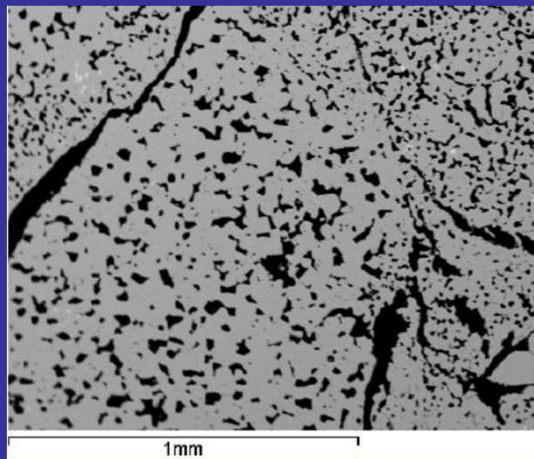
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Chromic oxide - Very fine structure

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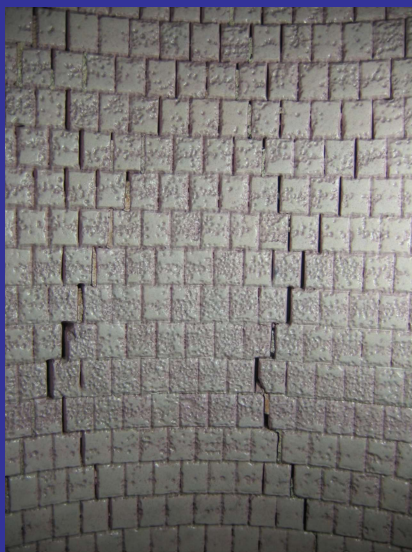Chromic oxide – course grains

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Chromic oxide – internal gaps

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Thermal stress by design

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Thermal stress equation: R

Thermal shock fracture resistance parameter or also known as the critical quench temperature difference

$$R = \sigma_f \, (1 - \nu)/(\alpha E)$$

σ_f = MOR (flexural strength)

ν = Poisson's ratio

α = Thermal expansion coefficient

E = Elastic modulus (Young's Modulus)

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Thermal stress equation: R" "

Thermal shock fracture resistance parameter for catastrophic (extreme rapid) fracture

$$R'''' = (E\gamma_{WOF})/[\sigma_f^2(1 - \nu)]$$

σ_f = MOR (flexural strength)

ν = Poisson's ratio

γ_{wof} = Work-of-Fracture

α = Thermal expansion coefficient

E = Elastic modulus (Young's Modulus)

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Thermal stress equation: R_{st}

Thermal shock fracture resistance parameter for quasi-stable crack propagation

$$R_{st} = [\gamma_{WOF}/(\alpha^2 E)]^{0.5}$$

γ_{wof} = Work-of-Fracture

α = Thermal expansion coefficient

E = Elastic modulus (Young's Modulus)

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Final Comment

Most damage on refractory linings occur during cool downs rather than heat-ups

Enjoy the rest of your day.

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