Institute of Refractories Engineers

PROPERTIES OF REFRACTORIES

IRE Training Day
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Sheffield

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Properties of Refractories

- Reminder about Refractories
- What are ‘Properties’
- Why are ‘Properties’ important?
- Why some measurements are important?

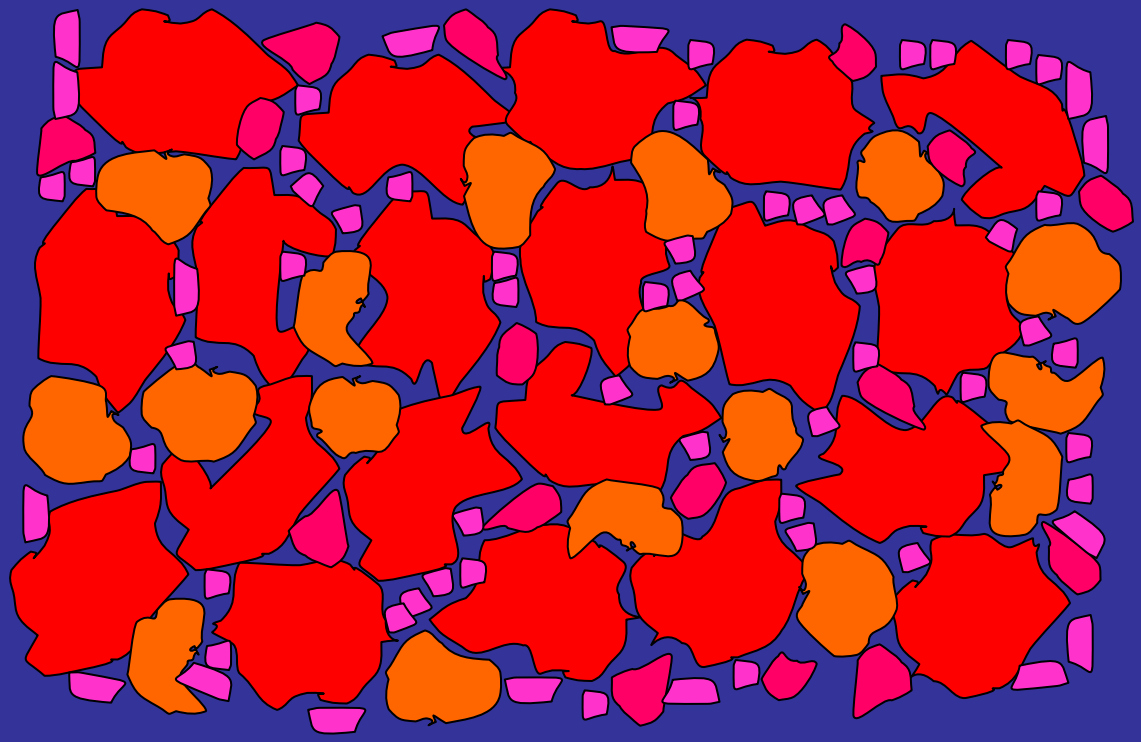
What Are Refractories

Mostly made from metal oxides.

Acid	**Neutral**	**Basic**
Silica	Alumina	Magnesia
Mulite	Bauxite	Doloma
Fireclay	Zirconia	Magnesia-Chrome
Andalusite	(Carbon)	Magnesia-Carbon

What Are Refractories

Made by mixing grains of different sizes.



What Are Refractories

Customers want a product which will give a consistent performance in service

Manufacturers must produce a consistent product which will meet customer requirements

- Chemical resistance
- Thermal behaviour
- Mechanically suitable

What are Properties

Properties are values we can measure which are characteristic of the material. The should be independent of

- The person doing the test
- When the test is done

If two different laboratories measure a property, we want them to get the same result.

Standard Test Methods

Many property values depend on how the test is carried out.
Factors like

- Sample size
- Heating Rate
- Pre-firing

Can influence the measured values

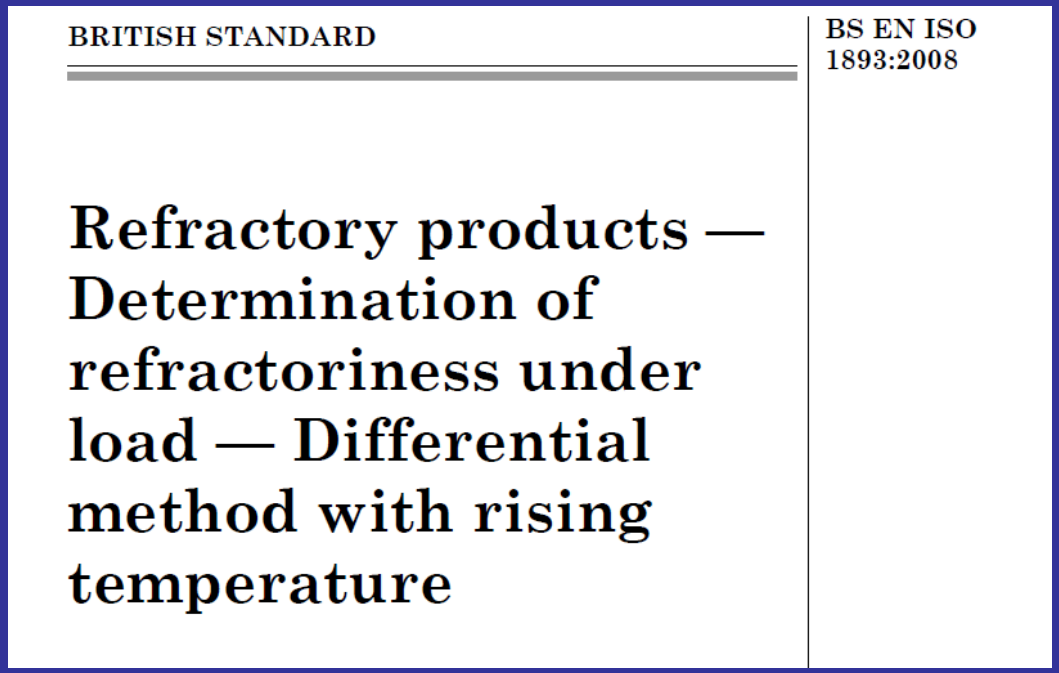
There are standard test methods for refractories agreed at National, European and Global level.

Standard Test Methods

BS = British Standard
EN = European Standard
ISO = International Standard

Dual Numbered Standards

Different standards will give different results.


BRITISH STANDARD

BS EN ISO 1893:2008

Refractory products — Determination of refractoriness under load — Differential method with rising temperature

Standard Test Methods

Scope

This International Standard specifies a method for determining the deformation of dense and insulating shaped refractory products, when subjected to a constant load under conditions of progressively rising temperature (or refractoriness under load), by a differential method. The test may be carried out up to a maximum temperature of 1 700 °C.

What the method does
What type of materials it applies to
Test conditions

Check it is applicable – this standard is not applicable to castables

Standard Test Methods

Principal

A brief summary of what you do

4 Principle

A cylindrical test piece is subjected to a specified constant compressive load and heated at a specified rate of temperature increase until a prescribed deformation or subsidence occurs. The deformation of the test piece is recorded as the temperature increases, and the temperatures corresponding to specified proportional degrees of deformation are determined.

The rest of the standard gives a detailed description of the equipment, sample, method, calculation and results.

If you follow these instructions you will get a reliable result

Why Properties Matter

Producer vs User Requirements

In general, users want tests which indicate how the material will behave at high temperatures and over a long time period. These tests are going to need special equipment and a long time.

This is the opposite of producer requirements.

We may need to measure both types of properties.

Some properties may be of use to both sides.

Why are Properties Important

1 Producer Requirements

Refractories are made from raw materials, many of which are naturally occurring. This leads to variability

- Chemistry changes – impurities
- Size changes, shape changes

Producer must make a consistent product from variable raw material.

Tests needed to ensure the production process is producing what it is supposed to

Quality Control and Quality Assurance

Why are Properties Important

1 Producer Requirements

Producers make MEASUREMENTS of certain aspects of the process to determine if it is in control and to make adjustments if needed, eg

- Chemical analysis of raw materials
- Setting behaviour of castables
- Density of Shaped Products

Why are Properties Important

1 Producer Requirements

Producers do a lot of ROUTINE testing and so want tests which are

- Reliable – no use if different technicians get different results
- Quick – so corrective actions can be taken with minimal wastage
- Cheap – so costs are not excessive
- Meaningful – tests which REFLECT that the production process is doing what it should

Why are Properties Important

2 User Requirements

Where do we use refractories?

- Industries that use high temperatures

What are they for?

- Contain the process – ie keep the heat and ‘charge’ in the process vessel
- Withstand the chemical conditions
- Physical loading – self weight, abrasion, impact…..

Users want to compare different refractories to select the most appropriate for their process

Users want to know that the refractories they are purchasing are ‘fit for purpose’

Why are Properties Important

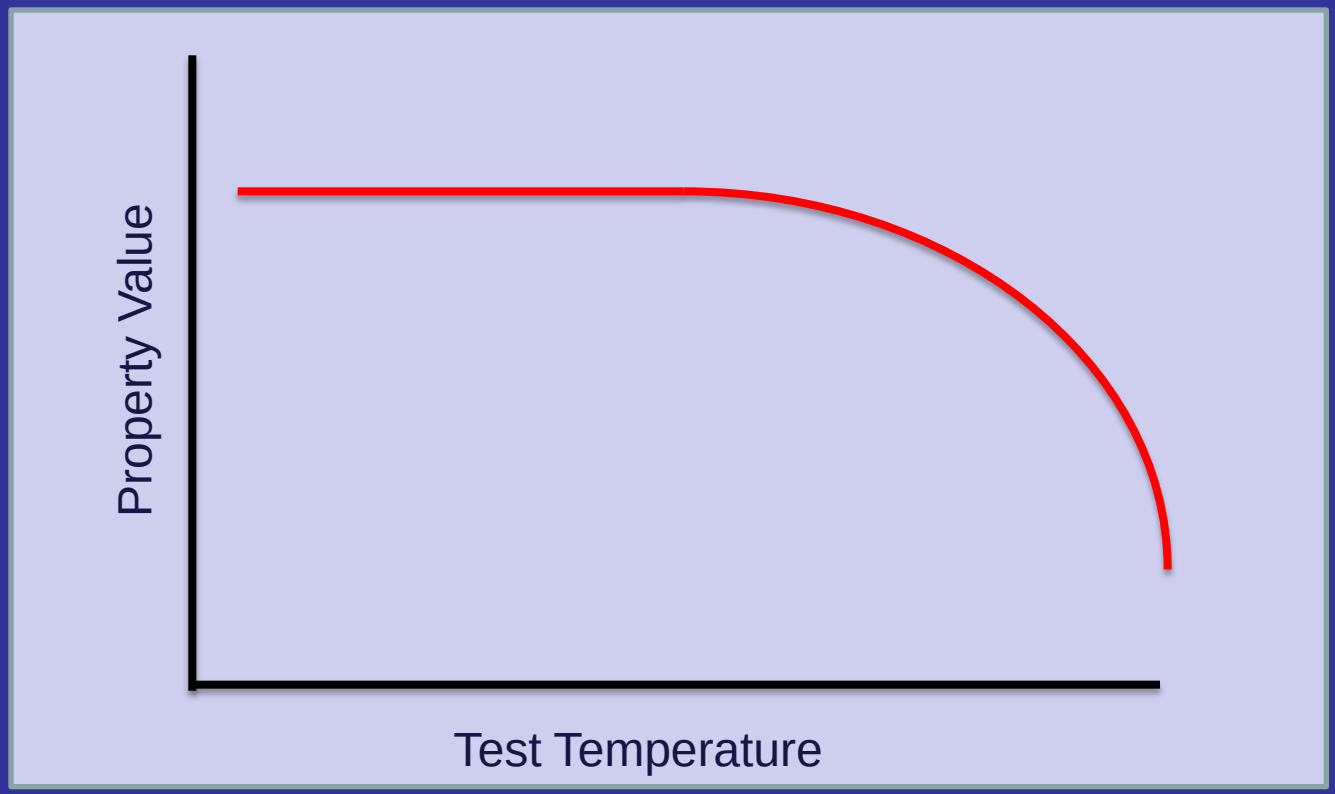
2 User Requirements

Tests which indicate how the material will perform in service

- Resistance to chemical attack
- The material will not fail due to high temperature
- Mechanical strength at temperature

Testing at Temperature

The properties of a material at high temperature are not the same as those at ambient temperature.

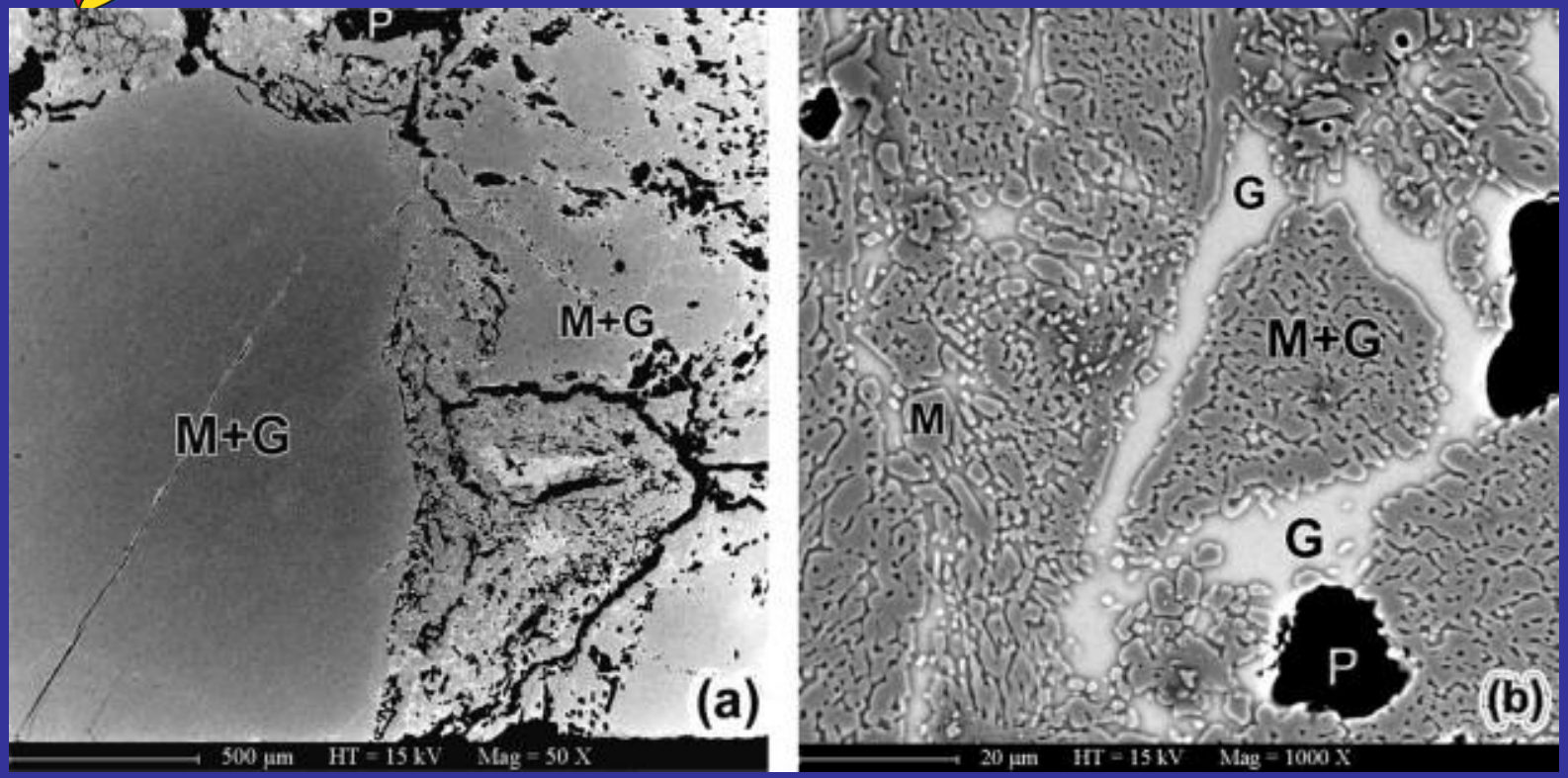


Testing After Heating and Cooling

Changes occur on heating

- Dry-out of castable
- Changes to carbon bond
- Phase Changes
- Sintering
- Partial melting (glass formation)

Alumina Brick Microstructure



G = Glassy Phase formed on sintering
A high temperature glass softens.

Testing After Heating and Cooling

Consider a material with a cold crushing strength as received of 30MPa
After firing at 1500°C, the cold crushing strength is now 90MPa

What does this tell us about the strength at 1500°C ?

What about the TIME at test temperature

- Sintering
- Oxidation
- etc

Why Some Properties Matter

Simulative Tests try to repeat service conditions and indicate directly how a material will perform in service.

- Slag Resistance tests
- Chemical Attack tests (Carbon Monoxide, Alkali, Acid Resistance etc)
- Abrasion Resistance

Generally, test is MORE severe than service conditions to give a result in a short time

Why Some Properties Matter

Commonly Used Tests

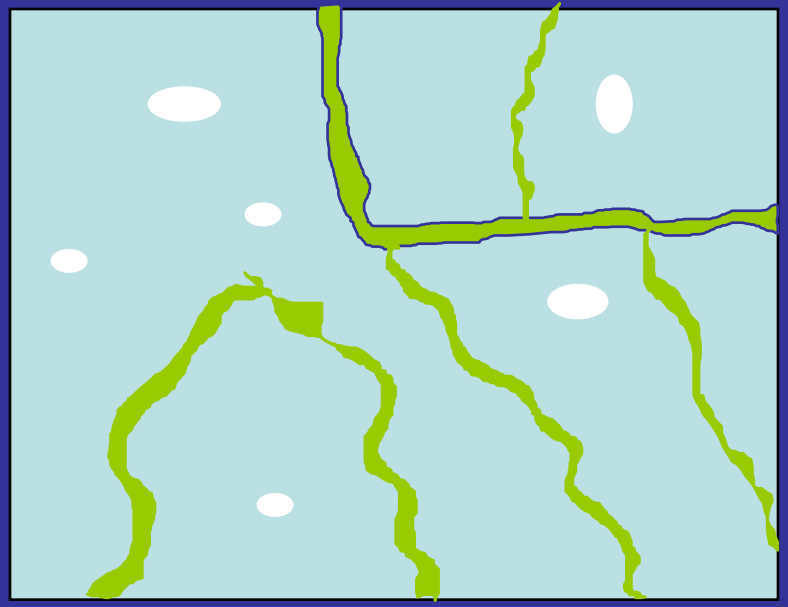
- Density
- Porosity
- Cold Crushing Strength
- Size Analysis
- Permanent Linear Change
- Chemical Analysis

Density

Density is widely measured

- Single operation to measure density and porosity
- Indicates how well material is ‘put together’
- Chemical changes also change density

- Very useful for QA/QC testing
- Some use for assessing service performance



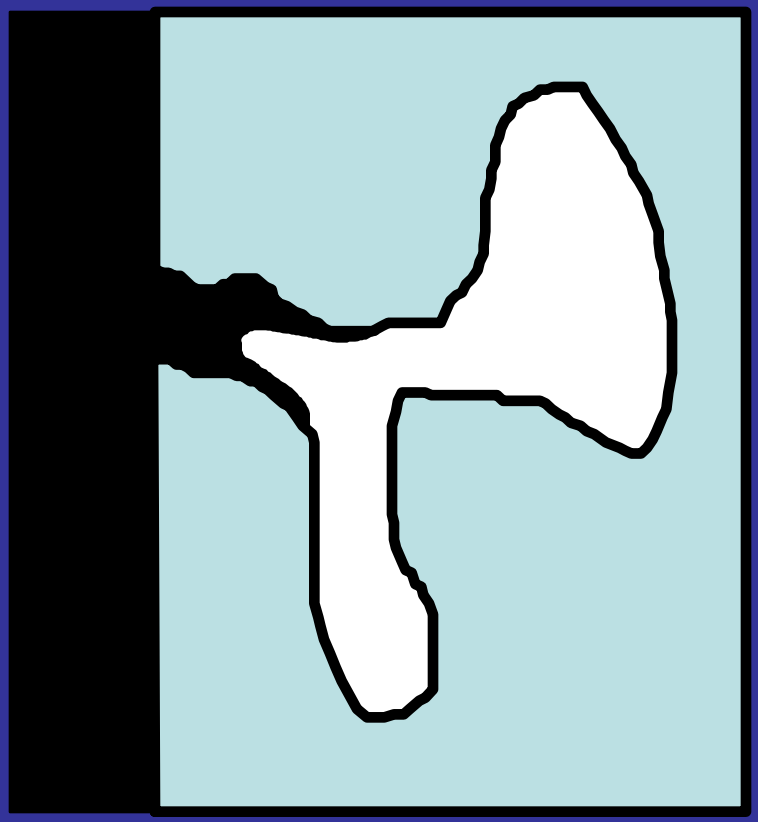
Porosity

Porosity can promote chemical attack, especially slag penetration.

As pores get filled with slag, the corrosion goes on from inside and not only the outside surface.

For hot face materials, porosity is minimised

For insulation materials, a high porosity entrains more air and indicates a high insulation value



Strength Tests

Cold Crushing Strength is the most widely measured property.
Refractories in service do not fail under compressive load at ambient temperatures
Why does every product description use this property?

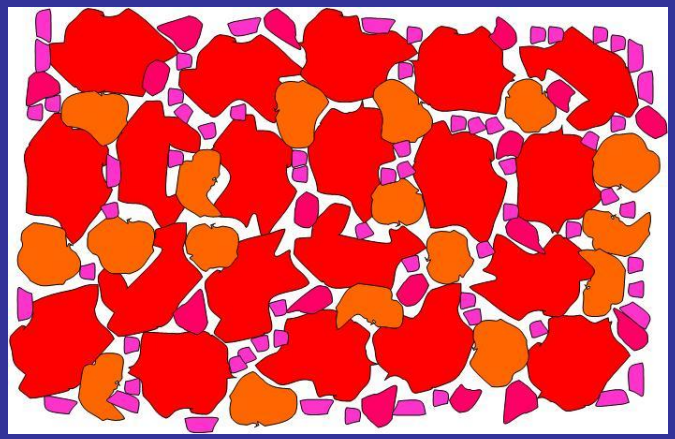
- Easy to measure
- Quick to measure
- Production changes will change the CCS
    - either **increase** or **decrease**
    - change does not say what has changed
- Useful for QA/QC purposes

Size Analysis

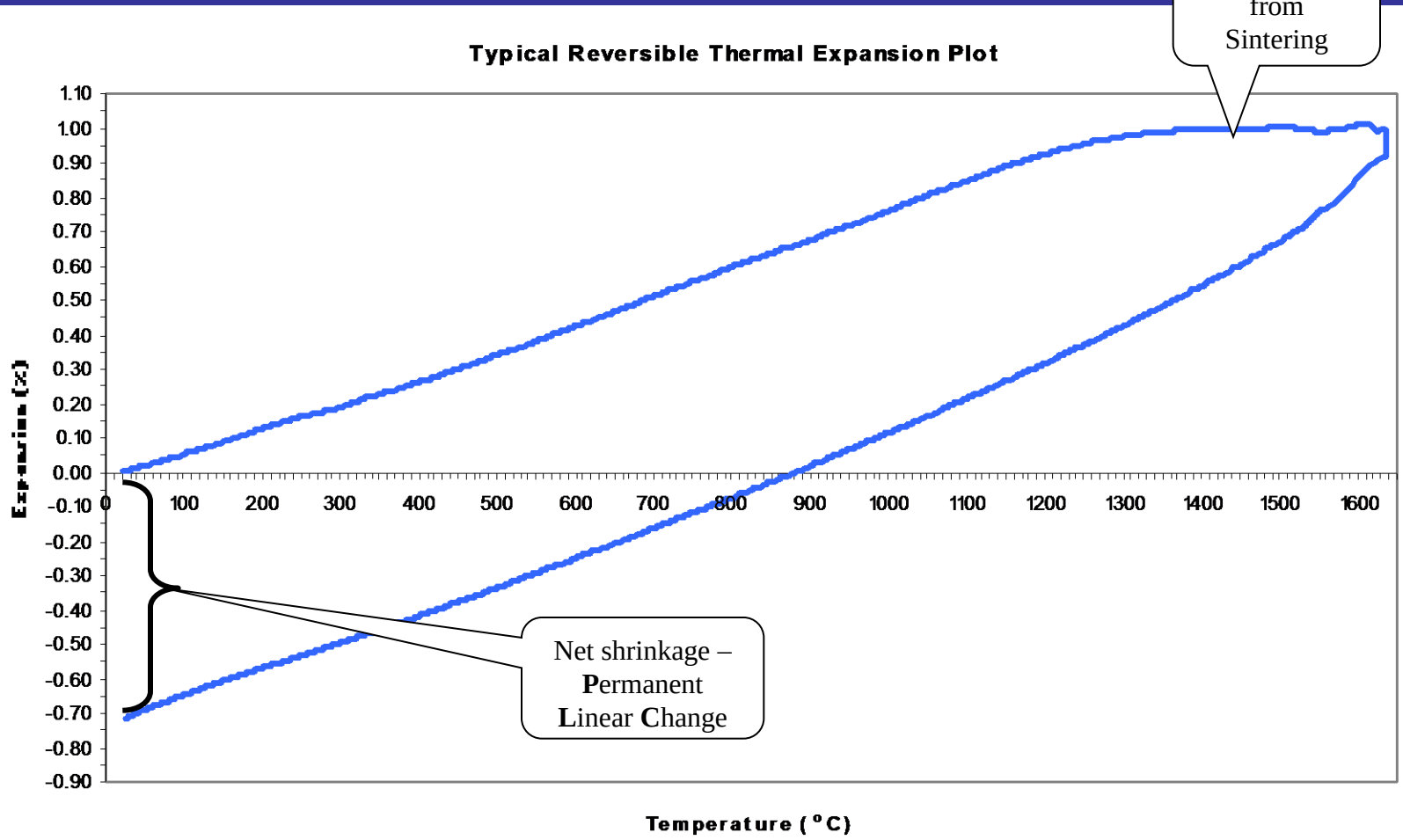
To produce a product with a consistent porosity, manufacturers blend particles of different sizes.

To do this, they must know about the sizing of each delivery of each raw material.

How would density and porosity vary if the size of one material changes?



Permanent Linear Change



Permanent Linear Change

PLC must NOT be confused with thermal expansion.

PLC indicates if material is stable at the test temperature

- Partial Melting
- Phase changes
- Sintering

Will all lead to a non-zero PLC value

Chemical Analysis

High temperature properties depend strongly on chemical analysis

Small levels of certain impurities can destroy the usefulness of a refractory

Chemical analysis is a key to predicting how a material will perform in use

Thank You For Your Attention