Thermal Properties of Refractories

1) Refractoriness

- Refractoriness of refractory materials is the temperature at which is the material softens and hence is the measure of fusibility of the material.

- The refractoriness property of refractories should be higher than the application temperatures.

Addition of an **impurity** to the refractory material lowers its fusion point/refractoriness depending upon the amount of impurity present and the melting point of the lowest fusing constituent.

Refractoriness decreases when refractory is under **load**. Therefore more important is refractoriness under load (RUL) rather than refractoriness.

The refractoriness is indicated by **PCE (Pyrometric cone equivalent).**

The refractory materials do not have sharp fusion/melting point due to their chemical complexity melt progressively over a range of temperature.

Hence refractoriness or fusion point is ideally assessed by the Pyrometric Cone Equivalents (PCE) or cone fusion method.

- PCE is determined by comparing the softening of a test pyramid cone with that of standard pyramid cones of known fusion temperature by heating them under similar conditions.

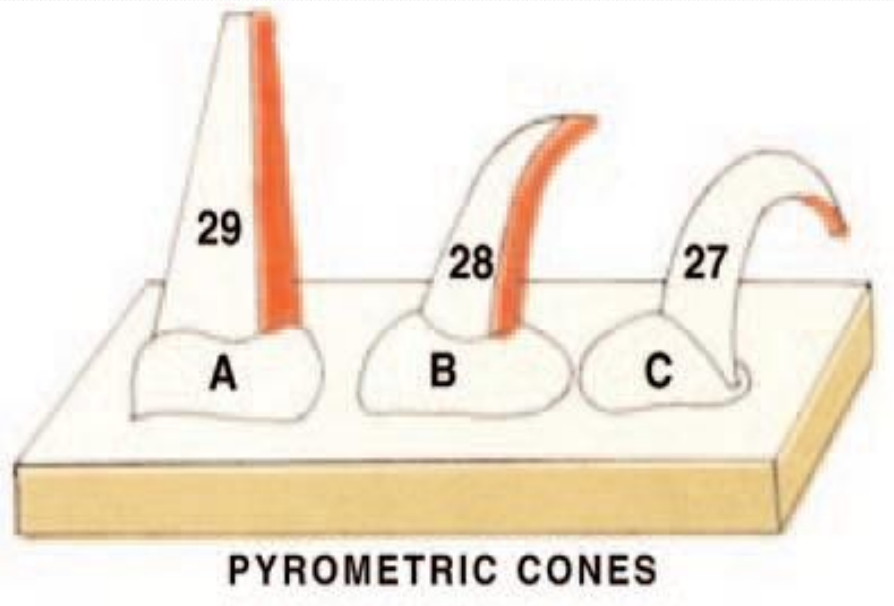

Figure (1)

- In the figure (1), the refractoriness of sample **A** is much higher than **B** and **C**.

The standard cones are called '**Segar Cones**' (as Germany standard) and '**Orton Cones**' (as British standard) and they are numbered according to their refractoriness/fusion points.

End Points of Orton Pyrometric Cones

Cone number	End point (°C)	Cone number	End point (°C)
12	1337	31	1679
13	1349	$31\frac{1}{2}$	1699
14	1398	32	1717
15	1430	$32\frac{1}{2}$	1730
16	1491	33	1741
17	1512	34	1759
18	1522	35	1784
19	1541	36	1796
20	1564	37	1830
23	1590	38	1850
26	1605	39	1865
27	1627	40	1885
28	1638	41	1970
29	1645	42	2015
30	1654		

The pyrometric cone equivalent indicates only the softening temperature. But, in service the refractory is subjected to loads which would deform the refractory at a much lower temperature than that indicated by PCE. With change in the environmental conditions, such as reducing atmosphere, the PCE value changes drastically.

PCE can be useful for quality control purposes to detect variations in batch chemistry that result from changes or errors in the raw material formulation.

2) Refractoriness Under Load (RUL)

- The refractoriness under load test (RUL test) **gives an indication of the temperature at which the bricks will collapse, in service conditions with similar load**.
- RUL of a refractory material is a measure of its failure resistance to the combined action of **heat** and **load**.

A refractory material composed of a **single pure compound** will have a closer value of its refractoriness and refractoriness under load.

But generally, the refractory bricks composed from more than **two constituent compounds**, so the temperature corresponding to the refractoriness under load of a refractory brick is much lower than its refractoriness.

Refractory failure is also influenced by its exposure **time to load and heat**.

Longer exposure time results in failure of refractory under relatively low load and temperature conditions. Similarly refractories will fail at a lower temperature with increased load.

3) Thermal Conductivity

- Thermal conductivity is defined as the quantity of heat that will flow through a unit area in direction normal to the surface area in a defined time with a known temperature gradient under steady state conditions.
- Thermal conductivity (k) is directly proportional to the heat capacity (C), the quantity and velocity of the carrier (v) and the mean free path (λ):

$$k \propto C \, v \, \lambda$$

- Thermal conductivity depends upon the

(1) chemical compositions

(2) the glassy phase contained in the refractory and

(3) the application temperature.

Low thermal conductivity is desirable for conservation of heat by providing adequate insulation.

- After firing process of refractories, the inner structure contents three phases (crystal phase, glass phase and gas phase (pores)).
- **Effect of the structure and the microstructure of refractories on the thermal conductivity**:

1. The **high thermal conductivity** is achieved in structures that consisting of **single elements**, and structure with no extraneous atoms in solid solution. Graphite is a good example of a single element refractory structure having high thermal conductivity.

2. Refractories composed of elements of **similar atomic weight and size**, **having high thermal conductivity**. Good examples of this type of refractory are BeO, SiC and B_4C. While the refractories have large different in atomic weight and size have low thermal conductivity as example UO_2 and ThO_2.

3. Impurities, porosity and microcracks exert the main influence on the effective thermal conductivity. Presence of these defects can **reduced the thermal conductivity** of refractories.