REFRACTORIES:

Any substance that is difficult to fuse is Refractory. A Refractory is a material which does not melt easily, because its fusion temperature is very high. Therefore refractories are inorganic materials which can withstand high temperature as well as abrasive and corrosive action of molten metals, slags and gases, without suffering a deformation in shape.

With increasing use of high temperature processes, the demand for various types of refractories is constantly growing in mechanical engineering as well as in the metallurgical, chemical and power industries. Refractories are widely used for providing high temperature resistant lining for furnaces, kiln, ladles, crucibles, etc., in various industries such as ferrous and non-ferrous, glass, ceramic, power-generation, oil refining and cement. They are also used in the manufacture of rocket nozzles, launch pads and for domestic heating.

CHARACTERISTICS OF A GOOD REFRACTORY MATERIAL

1. A good refractory material should have a softening temperature much higher than the operating temperature.
2. Refractories should be chemically inert under the condition wherein they are employed i.e., they should not react with corrosive agents like acidic or basic molten slags, hot gases etc.
3. The Refractoriness should be high for a good Refractory. Resistance to fusion on increasing the temperature is called the Refractoriness.
4. The refractories should not crack at operating temperatures.
5. They should possess low permeability.
6. They should possess low thermal co-efficient of expansion and should expand and contract uniformly, with increase and decrease of temperature respectively.
7. They should be able to withstand the overlying load of structure, at operating temperatures.
8. They should possess good physical, chemical and mechanical properties.

However no single substance can satisfy all of these requirements and therefore a refractory is usually formulated from a mixture of compounds. If a given refractory material does not have the above mentioned characteristics, it will fail in service.

CLASSIFICATION OF REFRACTORIES:

Refractories are classified on the basis of their chemical properties, constituent substances and fusion temperature into the following categories:

On the basis of fusion temperature ranges, they are classified as:

a) Normal refractory : Fusion temperature = 1580 – 1780°C. Eg: Fire clay
b) High refractory : Fusion temperature = 1780 – 2000°C. Eg: Chromite
c) Super refractory : Fusion temperature = 1780 ≥ 2000°C. Eg: Zircon

On the basis of chemical composition, they are classified as:

1. Acidic Refractories: These refractories are made of acidic materials like alumina (Al₂O₃), silica (SiO₂), etc. They can withstand acidic materials but are easily attacked by basic materials. Eg: Silica, alumina and fire clay refractories.

2. Basic Refractories: These refractories consist of basic materials like lime (CaO), magnesia (MgO), etc. They are resistant to basic materials but easily attacked by acidic materials. Eg: Magnesite, dolomite and chrome-magnesite refractories.
3. **Neutral refractories:** These refractories are made of weakly acidic/basic materials like carbon, chromite and zirconia. They are attacked by either acidic or basic materials. Eg: Carborundum, graphite and chromite.

**CRITERIA OF REFRACTORIES OR PROPERTIES OF REFRACTORIES:**

(i) **Refractoriness:** It is the ability of the refractory to withstand high temperature without appreciable deformation or softening under service conditions. It is generally measured by the softening temperature of the refractory material. The softening temperatures of the refractory material are usually determined by the Pyrometric cones test or Seger cones test.

**Measurement of Refractoriness:** Generally, the Refractoriness is measured in terms of Pyrometric cone equivalent (PCE) by comparing the softening behaviour of the test cone with that of the standard cone. These cones are small pyramid shaped, 38mm high and 19mm long sides with a triangular base. Test cone along with standard cones are heated under standard conditions of 10°C per minute. The PCE value of given Refractory (test cone) is taken as the number of the standard cone, which fuses along with the test cone. The temperature at which the fusion of the test cone occurs is indicated by its apex touching the base. If the test cone softens earlier than one standard cone but later than the next cone, the PCE value of test cone is taken as the average value of the two standard cones. Thus a good Refractory should have high Refractoriness.

Examples:
1. Silica bricks – PCE number 32 and softening temperature 1710°C.
2. Magnesite bricks – PCE number 38 and softening temperature 1850°C.

(ii) **Refractoriness under load (RUL) or strength:** Refractories should have high mechanical strength to withstand the load applied under operating temperatures. Thus a good Refractory should have high load bearing capacity which can be measured by RUL test.

(iii) **Chemical inertness:** The Refractory selected for a specific purpose should be chemically inert and should not react with the slags, furnace gases, etc. A simple guideline in the use of refractories is that, an acidic Refractory should not be used in a basic furnace and vice-versa.

(iv) **Dimensional stability:** The resistance of material to any volume changes, which may occur on its exposure to high temperature over a prolonged period, is called dimensional stability.

(v) **Thermal spalling:** It is the property of breaking, cracking or fracturing of a refractory under high temperature. So, a good refractory should show a high resistance to thermal spalling.

**Control of thermal spalling:** Thermal spalling can be controlled by the following factors:
(a) Low porosity and low coefficient of expansion
(b) By avoiding sudden changes in temperatures
(c) By modification of furnace design.

(vi) **Porosity:** Refractories generally contain pores either due to manufacturing defects or incorporation of saw dust, etc. during manufacture. Porosity is defined as the ratio of its porous volume to the bulk volume

\[
P = \frac{W - D}{W - A} \times 100
\]

Where

- \( P \) = Porosity.
- \( W \) = Weight of saturated specimen (with water) in air.
- \( D \) = Weight of dry specimen.
- \( A \) = Weight of saturated specimen (with water) in water.

(vii) **Thermal expansion:** The refractory tends to expand when temperature increases and contract when temperature decreases. Thermal expansion affects all dimensions of the body. So a good refractory should have less thermal expansion.

(viii) **Thermal conductivity:** It depends upon the chemical composition and degree of porosity of refractory. Most of the furnaces are lined inside with refractory materials of low thermal conductivity in order to reduce heat losses to outside by radiation. However, in muffle furnaces, retorts, etc. high thermal conductivity refractories are employed.

(ix) **Abrasion resistance:** A good refractory should resist the abrasion action of flue gases, flames, slags, etc.

(x) **Electrical conductivity:** Generally, refractories are poor conductors of electricity (except graphite). So, refractories should have low electrical conductivity.

**CAUSES FOR THE FAILURE OF REFRACTORIES:**

The efficiency of the refractory product mainly depends on its constituents, processing and final curing.

(i) The most common cause for failure of refractory is chemical reaction with the environment in which it is operating. For example, an acidic refractory should not be used in furnaces using basic fluxes, slag, etc. and vice-versa.

(ii) The porosity of refractory plays an important role in the chemical reaction. The more porous it is, the greater will be the depth to which the slag will penetrate and destroy the refractory.

(iii) The deposition of carbon from carbon monoxide in fire clay refractories in a blast furnace is an important cause of its failure.

(iv) As the temperature increases, the rate of chemical reaction gradually increases. Sometimes, rise in temperature beyond the safe limit quickly brings about the destruction of the refractory.

(v) The other important cause is spalling. It may be thermal, mechanical or structural. Thermal spalling may be due to unequal expansion or contraction caused by the difference in temperature at different parts. Mechanical spalling is mostly due to carelessness in loading the furnace or in the removal of materials from furnace, thereby damaging the refractory. Structural spalling takes place due to change in composition of the refractory because of reaction with slags, flux, etc. as a result its coefficient of expansion changes. Thus, different parts expand and contract to a different extent.