Overview of Refractories

An Online Continuing Education Course for Engineers

Course Number: M-4027

Credit: 4 Hours / 4 PDH / 4 CPD

Overview of Refractories

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Abstract

Refractories are heat resistant materials used in almost all processes involving high temperatures and/or corrosive environment. These are typically used to insulate and protect industrial furnaces and vessels due to their excellent resistance to heat, chemical attack and mechanical damage. Any failure of refractory could result in a great loss of production time, equipment, and sometimes the product itself. The various types of refractories also influence the safe operation, energy consumption and product quality; therefore, obtaining refractories best suited to each application is of supreme importance.

This course discusses the types, characteristics and properties of various refractories. There is an outline of energy conservation and therefore the cost savings. The course covers 6 sections:

Section -1: Refractory Overview

Section -2: Types of Refractories

Section -3: Insulating Refractories

Section -4: Selection of Refractories

Section -5: Heat Loss and Energy Conservation

Section -6: Refractory Applications in Industry

SECTION - 1: REFRACTORY OVERVIEW

Refractories are inorganic, nonmetallic, porous and heterogeneous materials composed of thermally stable mineral aggregates, a binder phase and additives. The principal raw materials used in the production of refractories are: the oxides of silicon, aluminum, magnesium, calcium and zirconium and some non-oxide refractories like carbides, nitrides, borides, silicates and graphite.

The main types include fire-clay bricks, castables, ceramic fiber and insulating bricks that are made in varying combinations and shapes for diverse applications. The value of refractories is judged not merely by the cost of material itself, but by the nature of the job and/or its performance in a particular situation. Atmosphere, temperature, and the materials in contact are some of the operating factors that determine the composition of refractory materials.

What are Refractories used for?

Refractories are used by the metallurgy industry in the internal linings of furnaces, kilns, reactors and other vessels for holding and transporting metal and slag. In non-metallurgical industries, the refractories are mostly installed on fired heaters, hydrogen reformers, ammonia primary and secondary reformers, cracking furnaces, incinerators, utility boilers, catalytic cracking units, coke calciner, sulfur furnaces, air heaters, ducting, stacks, etc. Majority of these listed equipment operate under high pressure, and operating temperature can vary from very low to very high (approximately 900°F to 2900°F). The refractory materials are therefore needed to withstand temperatures over and above these temperatures. Listed below is the sample melting temperatures of key metallurgical elements where refractory application is critical.

MELTING POINT CHART

KEY MATERIALS	MELTING TEMPERATURES (°F)
Iron	2800 °F
Nickel	2650 °F
Copper	1980 °F
Aluminum	1220 °F
Zinc	780 °F
Lead	620 °F
Tin	450 °F

Due to the extremely high melting point of common metals like iron, nickel and copper, metallurgists have to raise furnace temperatures to over 2800°F. Furnaces are lined with refractory materials such as magnesia, which has a melting point of 5070 degrees.

Requirements of Right Refractory

The general requirements of a refractory material can be summed up as:

1) Its ability to withstand high temperatures and trap heat within a limited area like a furnace;
2) Its ability to withstand action of molten metal , hot gasses and slag erosion etc;
3) Its ability to withstand load at service conditions;
4) Its ability to resist contamination of the material with which it comes into contact;
5) Its ability to maintain sufficient dimensional stability at high temperatures and after/during repeated thermal cycling;
6) Its ability to conserve heat.

Properties of Refractories

Important properties of refractories are: chemical composition, bulk density, apparent porosity, apparent specific gravity and strength at atmospheric temperatures. These properties are often among those which are used as 'control points' in the manufacturing and quality control process. The chemical composition serves as a basic for classification of refractories and the density, porosity and strength is influenced by many other factors. Among these are type and quality of the raw materials, the size and fit of the particles, moisture content at the time of pressing, pressure at mould, temperature, duration of firing and the rate of cooling.

Some of the important characteristics of refractories are:

1) **Melting Point:**

   Melting temperatures (melting points) specify the ability of materials to withstand high temperatures without chemical change and physical destruction. The melting point of few elements that constitute refractory composition in the pure state varies from 3100°–6300°F as indicated in the table below:

MELTING POINT CHART OF PURE COMPOUNDS

REFRACTORY ELEMENT	MELTING TEMPERATURES (°F)
Graphite C Pure	6300 °F
Thoria, ThO_2 Pure Sintered	5430 °F
Magnesia, MgO, Pure Sintered	5070 °F
Zirconia, ZrO_2 , Pure Sintered	4890 °F
Lime, CaO	4660 °F
Beryllia, BeO, Pure Sintered	4620 °F
Silicon Carbide, SiC, Pure	4080 °F

REFRACTORY ELEMENT	MELTING TEMPERATURES (°F)
Magnesia, 90-95%	3980 °F
Chromite, FeO-Cr_2O_3	3960 °F
Chromium Oxide	3880 °F
Alumina, Al_2O_3, Pure Sintered	3720 °F
Chromite, 38%, Cr_2O_3	3580 °F
Alumina Fused Bauxite	3400 °F
Silicon Carbide, 80-90%	3400 °F
Fireclay	3400 °F
Titania, TiO_2	3360 °F
Kaolin, Al_2O_3 -, SiO_2	3300 °F
Silica, SiO_2	3120 °F

The melting point serves as a sufficient basis for considering the thermal stability of refractory mixtures and is an important characteristic indicating the maximum temperature of use.

2) **Size and Dimensional Stability:**

   The size and shape of the refractories is an important feature in design since it affects the stability of any structure. Dimensional accuracy and size is extremely important to enable proper fitting of the refractory shape and to minimize the thickness and joints in construction.

3) **Porosity:**

   Porosity is a measure of the effective open pore space in the refractory into which the molten metal, slag, fluxes, vapors etc can penetrate and thereby contribute to eventual degradation of the structure. The porosity of refractory is expressed as the average percentage of open pore space in the overall refractory volume.

   High porosity materials tend to be highly insulating as a result of high volume of air they trap, because air is a very poor thermal conductor. As a result, low porosity materials are generally used in hotter zones, while the more porous materials are usually used for thermal backup.

   Such materials, however, do not work with higher temperatures and direct flame impingement, and are likely to shrink when subjected to such conditions. Refractory materials with high porosity are usually NOT chosen when they will be in contact with molten slag because they cannot be penetrated as easily.

4) **Bulk Density:**

The bulk density is generally considered in conjunction with apparent porosity. It is a measure of the weight of a given volume of the refractory. For many refractories, the bulk density provides a general indication of the product quality; it is considered that the refractory with higher bulk density (low porosity) will be better in quality.

An increase in bulk density increases the volume stability, the heat capacity, as well as the resistance to abrasion and slag penetration.

5) **Cold Crushing Strength:**

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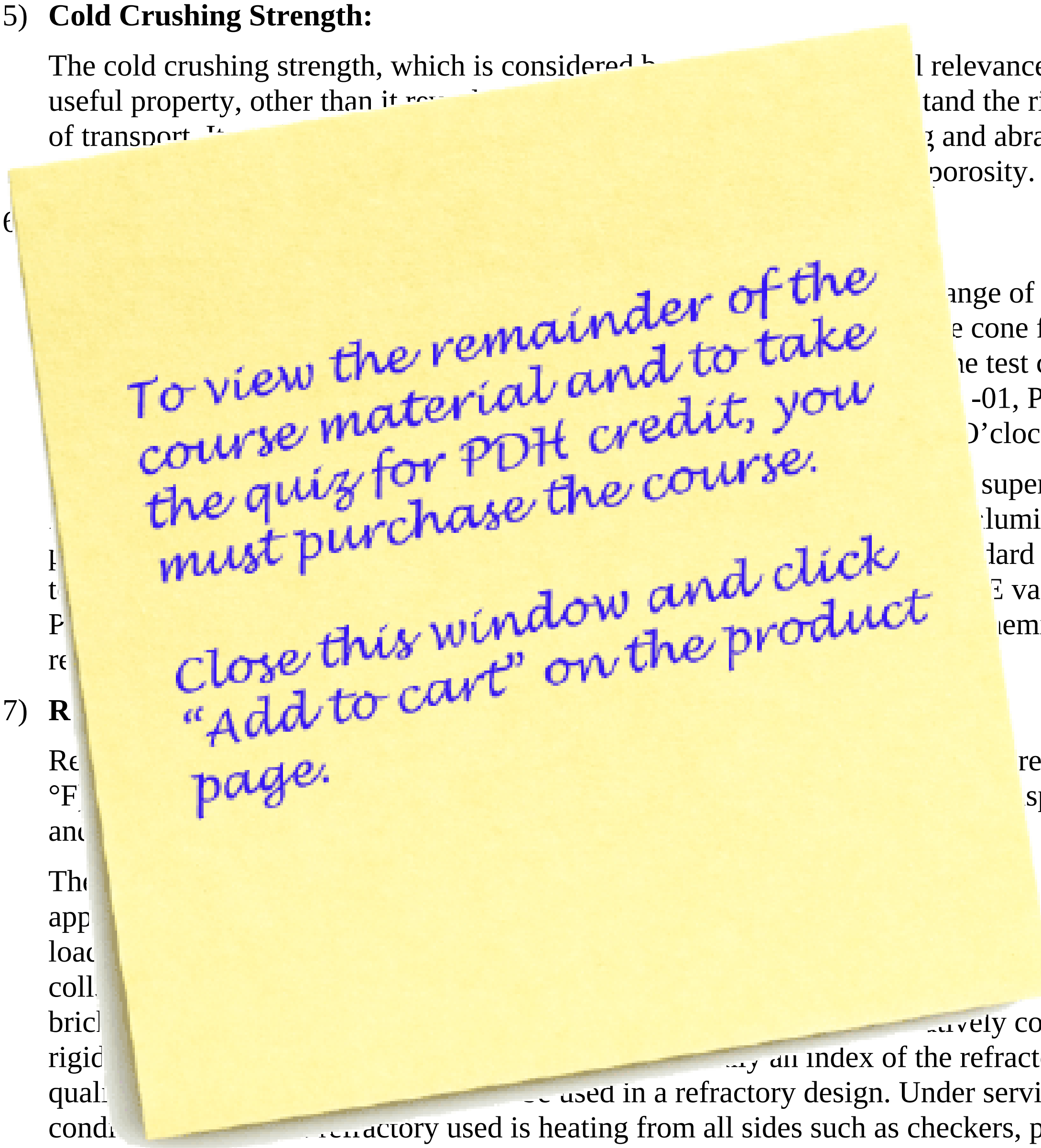

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The... app... s under load... l coll... here the bric... tively cooler rigid... ly an index of the refractory quali... e used in a refractory design. Under service cond... refractory used is heating from all sides such as checkers, partition walls, etc. the RUL test data is quite significant.

8) **Creep at high temperature:**

Creep is a time dependent property which determines the deformation in a given time and at a given temperature by a material under stress. Refractory materials must maintain