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19.0.D Materials Readings Refractory

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What Are Refractories?
Refractories are heat-resistant materials that constitute the linings for high-temperature furnaces and reactors and other processing units. In addition to being resistant to thermal stress and other physical phenomena induced by heat, refractories must also withstand physical wear and corrosion by chemical agents. Refractories are more heat resistant than metals and are required for heating applications above 1000°F (538°C).

While this definition correctly identifies the fundamental characteristics of refractories—their ability to provide containment of substances at high temperature—refractories comprise a broad class of materials having the above characteristics to varying degrees, for varying periods of time, and under varying conditions of use. There are a wide variety of refractory compositions fabricated in a vast variety of shapes and forms which have been adapted to a broad range of applications. The common denominator is that when used they will be subjected to temperatures above 1000°F (538°C) when in service. Refractory products fall into two categories: brick or fired shapes, and specialties or monolithic refractories. Refractory linings are made from these brick and shapes, or from specialties such as plastics, castables, gunning mixes or ramming mixes, or from a combination of both.

Many refractory products, in final shape, resemble a typical construction brick. However, there are many different shapes and forms. Some refractory parts are small and may possess a complex and delicate geometry; others are massive and may weigh several tons in the form of precast or fusion cast blocks.

What Are Refractories Made Of?
Refractories are produced from natural and synthetic materials, usually nonmetallic, or combinations of compounds and minerals such as alumina, fireclays, bauxite, chromite, dolomite, magnesite, silicon carbide, zirconia, and others.

What Are Refractories Used For?
In general, refractories are used to build structures subjected to high temperatures, ranging from the simple to sophisticated, e.g. fireplace brick linings to reentry heat shields for the space shuttle. In industry, they are used to line boilers and furnaces of all types—reactors, ladles, stills, kilns—and so forth.

Depending upon the application, refractories must resist chemical attack, withstand molten metal and slag erosion, thermal shock, physical impact, catalytic heat and similar adverse conditions. Since the various ingredients of refractories impart a variety of performance characteristics and properties, many refractories have been developed for specific purposes. It is a tribute to the refractory engineers, scientists and technicians, and plant personnel that more than 5000 brand name products are listed in the latest Product Directory of the Refractories Industry in the United States.

(http://www.refractoriesinstitute.org/aboutrefractories.htm)
Steel Introduction
Hot finished carbon steel begins to lose strength at temperatures above 300°C and reduces in strength at steady rate up to 800°C. The small residual strength then reduces more gradually until the melting temperature at around 1500°C. This behaviour is similar for hot rolled reinforcing steels. For cold worked steels including reinforcement, there is a more rapid decrease of strength after 300°C (Lawson & Newman 1990). In addition to the reduction of material strength and stiffness, steel displays a significant creep phenomena at temperatures over 450°C. The phenomena of creep results in an increase of deformation (strain) with time, even if the temperature and applied stress remain unchanged (Twilt 1988).

High temperature creep is dependent on the stress level and heating rate. The occurrence of creep indicates that the stress and the temperature history have to be taken into account in estimating the strength and deformation behaviour of steel structures in fire. Including creep explicitly within analytical models, is complex. For simple design methods, it is widely accepted that the effect of creep is implicitly considered in the stress-strain-temperature relationships.

The thermal properties of steel at elevated temperatures are found to be dependent on temperature and are less influenced by the stress level and heating rate. This simplified the consideration of the thermal properties of steel in design methods.

(http://www.mace.man.ac.uk/project/research/structures/strucfire/materialInFire/Steel/default.htm)

Heat deformed steel girders of the Al-Shifa Pharmaceutical factory in Sudan that was hit and destroyed by 3 tomahawk missiles in 1998
How Cement is made (http://www.cement.org/cement-concrete-basics/how-cement-is-made)

Portland cement is the basic ingredient of concrete. Concrete is formed when portland cement creates a paste with water that binds with sand and rock to harden. Cement is manufactured through a closely controlled chemical combination of calcium, silicon, aluminum, iron and other ingredients. Common materials used to manufacture cement include limestone, shells, and chalk or marl combined with shale, clay, slate, blast furnace slag, silica sand, and iron ore. These ingredients, when heated at high temperatures form a rock-like substance that is ground into the fine powder that we commonly think of as cement.

Bricklayer Joseph Aspdin of Leeds, England first made portland cement early in the 19th century by burning powdered limestone and clay in his kitchen stove. With this crude method, he laid the foundation for an industry that annually processes literally mountains of limestone, clay, cement rock, and other materials into a powder so fine it will pass through a sieve capable of holding water. Cement plant laboratories check each step in the manufacture of portland cement by frequent chemical and physical tests. The labs also analyze and test the finished product to ensure that it complies with all industry specifications.

The most common way to manufacture portland cement is through a dry method. The first step is to quarry the principal raw materials, mainly limestone, clay, and other materials. After quarrying the rock is crushed. This involves several stages. The first crushing reduces the rock to a maximum size of about 6 inches. The rock then goes to secondary crushers or hammer mills for reduction to about 3 inches or smaller. The crushed rock is combined with other ingredients such as iron ore or fly ash and ground, mixed, and fed to a cement kiln.

The cement kiln heats all the ingredients to about 2,700 degrees Fahrenheit in huge cylindrical steel rotary kilns lined with special firebrick. Kilns are frequently as much as 12 feet in diameter—large enough to accommodate an automobile and longer in many instances than the height of a 40-story building. The large kilns are mounted with the axis inclined slightly from the horizontal. The finely ground raw material or the slurry is fed into the higher end. At the lower end is a roaring blast of flame, produced by precisely controlled burning of powdered coal, oil, alternative fuels, or gas under forced draft.

As the material moves through the kiln, certain elements are driven off in the form of gases. The remaining elements unite to form a new substance called clinker. Clinker comes out of the kiln as grey balls, about the size of marbles. Clinker is discharged red-hot from the lower end of the kiln and generally is brought down to handling temperature in various types of coolers. The heated air from the coolers is returned to the kilns, a process that saves fuel and increases burning efficiency. After the clinker is cooled, cement plants grind it and mix it with small amounts of gypsum and limestone. Cement is so fine that 1 pound of cement contains 150 billion grains. The cement is now ready for transport to ready-mix concrete companies to be used in a variety of construction projects.

Although the dry process is the most modern and popular way to manufacture cement, some kilns in the United States use a wet process. The two processes are essentially alike except in the wet process, the raw materials are ground with water before being fed into the kiln.
Cement Rotary Kiln

Process flow in a cement rotary kiln

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GLASS MANUFACTURING PROCESS
FROM SAND TO SOPHISTICATION
Since the beginning, when the earth itself was formed in the fiery forge of cosmic activity, nature has given us a substance that today forms an integral part of our lives – glass. We don't know how glass was discovered. It may have been after a chance lightning strike in a patch of sand, or by prehistoric nomads who found the hard, shiny, magical material in the ashes of their fire. But while it may have been discovered by chance, the manufacturing process continues to be perfected over centuries through sheer human and technical ingenuity.

Today, glass touches our lives in so many ways and is recognised as a trusted, versatile, and 100% recyclable packaging choice.
Consol Glass has been synonymous with glass packaging for over 65 years and is Africa's leading glass packaging manufacturing company. Join us on a journey as we explain the glass making process; a magical, passion filled process to produce nature's packaging.

RAW MATERIALS
Making glass requires the correct recipe for a perfect result. Glass starts its life as a range of raw materials combined in a very specific ratio. The recipe calls for:
sand
soda ash
limestone and
other ingredients, such as iron and carbon which provide colour
Another important ingredient in the glass manufacturing process is cullet or recovered glass, obtained from recycling centres and bottle banks. Cullet usage can vary quite considerably, with as much as 40% utilization per batch. Its inclusion in production is most important, as it means that less virgin raw materials are used. It also melts at a lower temperature, enabling us to reduce emissions and save energy.

Consol has invested an estimated R240 million in equipment and cullet processing plants, to facilitate the glass recycling process.
BATCHING
Raw materials are stored in large silos, from where they are measured and delivered to batch mixers, according to pre-programmed recipes. Consol’s batch houses are among the most modern in the world and use leading-edge technology to ensure that the mixed material or "batches" delivered to our furnaces meet our stringent quality standards.

MELTING
The batch is continuously fed into the furnace, which is the beginning of what is known in the glass industry as the "hot end". And hot it is indeed: the temperature of a furnace is approximately 1500°C. Operating 24 hours a day, 7 days a week, it is no surprise that a furnace has a limited lifespan, lasting between 8 to 10 years, before requiring a rebuild.

It takes some 24 hours for a batch of raw materials to be converted into molten glass. Red-hot liquid glass is continuously drawn from the furnace through a submerged throat.

From the furnace, the molten glass makes its way to the refiner area, where it is cooled to approximately 1200°C. Maintaining the correct temperature is extremely important, not just to keep the flow of the molten glass correct, but also because it influences the quality of the end product.

From the refiner, the forehearth delivers glass to the individual bottle-making machines. Having been conditioned for bottle-making by careful temperature control in the refiner and forehearth, the molten glass enters the feeder and flows through cavities in an orifice plate.

Streams of glass are cut into gobs of a predetermined weight – exactly as much as is needed to make a single bottle. These gobs are then guided into the individual moulds of the bottle-making equipment, as part of a process known as forming.

Bottles are formed in two moulding stages:
In the first stage the gob of glass falls into a blank mould to produce a parison. The opening of the bottle is moulded into its finished shape during this stage, but the body of the container is initially much smaller than its final size.
There are two primary methods of making a glass container. The first, known as the Blow-Blow process, is used for narrow-neck containers. In this process, compressed air is blown into the molten gob to create a cavity while it is in the blank mould and this results in a hollow and partly formed container. This is then transferred to the second moulding stage. Compressed air is used again in the second stage to blow mould the final shape.

The second process, known as the Press-Blow method, is used for jars and tapered narrow-neck containers. Here, a metal plunger instead of air is used to press a cavity into the gob in the blank mould before compressed air is used to form the container in the blow mould.

The newly formed bottle is then removed from the mould and transferred by conveyor to the annealing oven or lehr. The external surface of the bottle is first coated with a thin layer of tin oxide to strengthen it. In the lehr it is cooled from 600° C to 100° C in a controlled manner.

Doing so prevents uneven cooling, relieves stresses within the bottle and ensures that it is stable and safe to handle. This process takes anything between 30 minutes and 2 hours. When the bottle exits the lehr it is cooled and this is referred to as the "cold end" of the plant.

Before leaving the annealing lehr, the bottles external surface is coated with polyethylene wax to protect the surface of the glass and prevent scuffing between bottles.

(http://www.consol.co.za/business/why-glass/glass-manufacturing-process)
Iron Ore Processing for the Blast Furnace
(Courtesy of the National Steel Pellet Company)

The following describes operations at the National Steel Pellet Company, an iron ore mining and processing facility located on the Mesabi Iron Range of Minnesota.

Creating steel from low-grade iron ore requires a long process of mining, crushing, separating, concentrating, mixing, pelletizing, and shipping. The process of mining low-grade iron ore, or taconite, requires massive resources. Heavy industrial mining equipment, expansive mines, and a skilled labor pool are all required. The equipment used includes diamond-bit rotary drills, hydraulic shovels and loaders, water wagons, production trucks and heavy-duty conveyors.

National Steel Pellet Company’s plant is capable of producing 5.35 million tons of pellets each year. It employs approximately 500 workers.
Mining Iron Ore

Mining iron ore begins at ground level. Taconite is identified by diamond drilling core samples on a grid hundreds of feet into the earth. Taconite rock comprises about 28 percent iron; the rest is sand or silica. These samples are analyzed and categorized so that mining engineers can accurately develop a mine plan.

To uncover taconite reserves, the mine area is first "stripped" of the overburden or glacial drift, comprised primarily of rock, clay and gravel. The overburden is loaded by large hydraulic shovels into production trucks, which haul it to contour dumps. These dumps are environmentally designed to match the surrounding area.

Once the taconite rock is exposed, large drilling rigs drill blast holes 16" in diameter by 40' deep, in some cases. Nearly 400 of these holes are drilled in a blast pattern. Before the blast, the holes are filled with a special mixture of blasting agents. Once prepared, the mine site is cleared of workers and equipment, and the blast is detonated. Each of the holes is detonated just a millisecond apart, resulting in a pile of crude taconite that is broken apart to a minus 6' x 6' size.

After blasting, hydraulic face shovels and larger loaders load the taconite into 205-ton or 240-ton production trucks, which haul it to crushers. The taconite is ground to a fine powder and mixed with water. A series of magnets is run over the mixture. The magnets grab the iron particles and the rest is discarded. For every ton of iron retained, two tons of waste, or tailings, are discarded.

Crushing the Ore

The crude taconite is delivered to large gyrator crushers, where chunks as large as five feet are reduced to six inches or less. More than 6,000 tons of taconite can be crushed in one hour.

The crushed material is transferred by belt to an ore storage building, which holds up to 220,000 tons of taconite. An apron feeder sends the ore to the concentrator building for grinding, separating, and concentrating.
Concentrating

The crude taconite is now roughly the size of a football or smaller. A series of conveyor belts continuously feed the ore into ten large 27-foot-diameter, semi-autogenous primary grinding mills. Water is added at this point to transport it (94 percent of the water is recycled, while the rest is lost through evaporation).

Each primary mill contains several 4" steel balls that grind the ore as the mills turn. When the ore is reduced to 3/4" or less, it moves out of the mill in a slurry solution. The mill discharge is screened at 1/4" on trommel screens attached to the mill. Ore smaller than 1/4" is pumped in slurry solution to the wet cobber magnetic separator, which begins the process of separating the iron from the non-iron material. The magnetic iron ore is then laundered in two slurry surge tanks while the non-magnetics (silica/sand) go to the tailings disposal area.

Most of the material continues to be finely ground in one of five secondary ball mills, which are powered by electric motors ranging from 2,500 hp to 4,000 hp and are charged with 1-1/2" chrome grinding balls. Fine grinding is achieved using these smaller mills, bringing the ore to a similar grind as that found in face powder. The screen undersize is then moved to hydroseparators, where silica is floated off the top.
The hydroseparator underflow is pumped to the finisher magnetic separators. Once again, the magnetic separators grab the iron and discard the silica and sand. Thus, the ore is "concentrated" by removing the waste materials. The concentrate from the separators is pumped to fine screening.

The oversize material is returned to the balls mills, while the undersize (with the most impurities removed) becomes the final concentrate. Waste from the circuit goes to the tailings basin and the final concentrate travels to thickeners located in the pellet plant. The underflow from the thickeners is pumped to a storage tank and then to disc filters for dewatering.

The product is called "filter cake", and is now ready for mixing with the binding agent.

**Mixing with the Binding Agents**

Once the filter cake is complete, it is deposited into a surge bin. It then travels onto a feeder belt and from there to a conveyor where bentonite, a bonding agent, is added. Bentonite is a clay from Wyoming used to help iron ore concentrate stick together when rolled into pellets. About 16 pounds of Bentonite are added to every ton of iron ore concentrate.
Small amounts of limestone (1%) are also added and mixed with the concentrate at this point. Limestone is added to meet the requirements of steel customers in the blast furnace process.

The iron ore concentrate is now mixed and ready for the pelletizing process.

**Pelletizing**
A pellet plant contains a series of balling drums where the iron ore concentrate is formed into soft pellets, in much the same manner that one rolls a snowball, to make a pellet about the size of a marble (between 1/4" and 1/2"). Pellets are screened to meet the size specification, with undersized or oversized pellets crushed and returned to the balling drums.
The soft pellets are then delivered to the roller feeder for final removal of the fines, which are also returned to the balling circuits. Now the soft pellets, correctly sized, are delivered to the traveling grate furnace for further drying and preheating. The grate is fired by natural gas.

From this point, the pellets are charged into the large rotary kiln where they are heat-hardened at 2,400 degrees Fahrenheit. The pellets are discharged into the revolving cooler and then moved to the pellet screening plant, onto the pellet loadout system. The whole process consumes energy in the form of electricity and natural gas. Over the past several years, millions of dollars have been spent to improve energy efficiency and to recoup waste heat and re-use it in the process. These efforts have significantly reduced expenditures on energy.

The pelletizing process has now been completed. The pellets are run through a final screening to remove those not meeting size specifications or those that are chipped or broken into fines. Pellets that meet the necessary standards are conveyed to the pellet stockpile, which holds about 30,000 tons.

**Pellet Loadout and Shipping**
The pellets are now ready for shipping by train to customers or to ore docks. They are sent to blast furnaces and steel mills, where they will be turned into finished steel.

A trainload of iron ore pellets bound for the blast furnace
Aluminum Production
(http://www.aluminiumleader.com/en/facts/extraction/)

Aluminium is mainly produced from bauxite. Over 90% of the world's bauxite resources are concentrated on the tropical and sub-tropical belt in Australia, Guinea, Jamaica, Surinam, Brazil, and India.

In Russia there are also nepheline ore deposits located on the Kola Peninsula and in the Kemerovo Region. As a result of nepheline processing, significant volumes of by-products are generated including calcined soda, potash, fertilizers, and cement.

Alumina — or aluminium oxide (Al2O3), is produced from extracted ore. Despite its name, it has nothing to do with clay or black soil but resembles a flour or very white sand. Alumina is then transformed into aluminium through electrolytic reduction. One tonne of aluminium is produced from every two tonnes of alumina.

Bauxite consist of 40-60% alumina, as well as earth silicon, ferrous oxide, and titanium dioxide. To separate pure alumina, the Bayer process is applied. First, the ore is heated in an autoclave with caustic soda. It is then cooled and a solid residue — «red mud» — is separated from the liquid. Aluminium hydroxide is then extracted from this solution and calcined to produce pure alumina.

The final stage is the reduction of aluminium through the Hall-Heroult process. It is based on the following principle: when the alumina solution is electrolyzed in molten cryolite (Na3AlF6), pure aluminium is produced. The reduction cell bottom serves as a cathode, and coal bars immersed in cryolite serve as anodes. Molten aluminium is deposited under a cryolite solution with 3-5% alumina. During this process, temperatures reach 950°C, considerably higher than the melting point of the metal itself, which is 660°C.

In the Hall-Heroult reduction process, coal anodes are consumed very quickly and should be replaced with new ones. This problem can be solved with the renewable Soderberg electrode. It is formed in a special restoration chamber of coke and tar paste, which is fitted into a steel sheet cover which lies open at both ends. The paste is filled into the upper opening when necessary. It is heated before it reaches the cell with melt.

Aluminium production technology applies pre-baked anodes, a method used at many European and American aluminium smelters, and characterised by less power consumption and a negative impact on the environment. The anodes are baked in huge gas furnaces and then, having been fixed into holders, are lowered into a furnace. Consumed electrodes are replaced with new ones and remaining 'butts' are sent away for recycling.