

PRACTICAL WORKBOOK

MY-206 FURNACES & REFRACTORIES



Name: _____

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Roll No: _____

Department: _____

Metallurgical Engineering Department
NED University of Engineering & Technology

PRACTICAL WORKBOOK

MY-206 FURNACES & REFRACTORIES

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Metallurgical Engineering Department
NED University of Engineering & Technology

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Course Teacher

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Practical No: 1

Object:

To study various fuels, their significance & uses.

What is a Fuel?

Fuel is any material that is burned or altered in order to obtain energy and to heat or to move an object. Fuel releases its energy either through a chemical reaction means, such as combustion, or nuclear means, such as nuclear fission or nuclear fusion. An important property of a useful fuel is that its energy can be stored to be released only when needed, and that the release is controlled in such a way that the energy can be harnessed to produce work. Examples: Methane, Petrol and Oil.



All carbon-based life forms—from microorganisms to animals and humans—depend on and use fuels as their source of energy. Their cells engage in an enzyme-mediated chemical process called *metabolism* that converts energy from food or light into a form that can be used to sustain life. Additionally, humans employ a variety of techniques to convert one form of energy into another, producing usable energy for purposes that go far beyond the energy needs of a human body. The application of energy released from fuels ranges from heat to cooking and from powering weapons to combustion and generation of electricity. A large majority of currently-known fuels ultimately derive their energy from a small number of sources. Much of the chemical energy produced by life forms, such as fossil fuels, is derived from the utilization of solar energy through photosynthesis. Solar energy in turn is generated by the thermonuclear fusion process at the core of the Sun. The radioactive isotopes used as fuel to power nuclear plants were formed in supernova explosions.

Solid Fuels:

Solid fuels refer to various types of solid material that are used as fuel to produce energy and provide heating, usually released through combustion. Solid fuels include wood (see wood fuel), charcoal, peat, coal, Hexamine fuel tablets, and pellets made from wood (see wood pellets), corn, wheat, rye and other grains. Solid-fuel rocket technology also uses solid fuel (see solid propellants). Solid fuels have long been used by humanity to create fire. Coal was the fuel source, which enabled the industrial revolution, from firing furnaces, to running steam engines. Wood was also extensively used to run steam locomotives. Both peat and coal are still used in electricity generation today. The use of some solid fuels (eg. coal) is restricted or prohibited in some urban areas, due to unsafe levels of toxic emissions. The use of other solid fuels such as wood is increasing as heating technology and the availability of good quality fuel improves. In some areas, smokeless coal is often the only solid fuel used. In Ireland, peat briquettes are used as smokeless fuel. They are also used to start a coal fire.

Liquid Fuels:

Liquid fuels are those combustible or energy-generating molecules that can be harnessed to create mechanical energy, usually producing kinetic energy; they also must take the shape of their container. Most liquid fuels, in widespread use, are or derived from fossil fuels; however, there are several types, such as hydrogen fuel (for automotive uses), which are also categorized as a liquid fuel. It is the fumes of Liquid fuels that are flammable instead of the

fluid. This article deals primarily with the concept of liquid fuels in relation to ground transport. However, others such as rocket fuel also play an important role in the economy.

Bio Fuels:

Biofuel can be broadly defined as solid, liquid, or gas fuel consisting of, or derived from biomass. Biomass can also be used directly for heating or power—known as *biomass fuel*. Biofuel can be produced from any carbon source that can be replenished rapidly e.g. plants. Many different plants and plant-derived materials are used for biofuel manufacture. Perhaps the earliest fuel that was employed by humans is wood. Evidence shows controlled fire was used up to 1.5 million years ago at Swartkrans, South Africa. It is unknown which hominid species first used fire, as both *Australopithecus* and an early species of *Homo* were present at the sites. As a fuel, wood has remained in use up until the present day, although it has been superseded for many purposes by other sources. Wood has an energy density of 10–20 MJ/kg.

Fossil Fuels:

Fossil fuels are hydrocarbons, primarily coal and petroleum (liquid petroleum or natural gas), formed from the fossilized remains of dead plants and animal by exposure to heat and pressure in the Earth's crust over hundreds of millions of years. In common parlance, the term fossil fuel also includes hydrocarbon-containing natural resources that are not derived entirely from biological sources, such as tar sands. These latter sources are properly known as *mineral fuels*. Modern largescale industrial development is based on fossil fuel use, which has largely supplanted water-driven mills, as well as the combustion of wood or peat for heat.

Nuclear Fuel:

Nuclear fuel is any material that is consumed to derive nuclear energy. Technically speaking this definition includes all matter because any element will under the right conditions release nuclear energy, the only materials that are commonly referred to as nuclear fuels though are those that will produce energy without being placed under extreme duress.

Gasoline:

It is the most widely used liquid fuel. Gasoline, as it is known in United States and Canada, or petrol in India, Britain, Australia, New Zealand, South Africa and many English-speaking countries, is made of hydrocarbon molecules forming aliphatic compounds, or chains of carbons with hydrogen atoms attached. However, many aromatic compounds (carbon chains forming rings) such as benzene are found naturally in gasoline and cause the health risks associated with prolonged exposure to the fuel. Production of gasoline is achieved by distillation of crude oil. The desirable liquid is separated from the crude oil in refineries. Crude oil is extracted from the ground in several processes; the most commonly seen may be beam pumps. To create gasoline, petroleum must first be removed from crude oil.

Diesel:

Conventional **diesel** is similar to gasoline in that it is a mixture of aliphatic hydrocarbons extracted from petroleum. Diesel may cost more or less than gasoline, but generally costs less to produce because the extraction processes used are simpler. Many countries (particularly in Europe, as well as Canada) also have lower tax rates on diesel fuels. After distillation, the diesel fraction is normally processed to reduce the amount of sulfur in the fuel. Sulphur causes corrosion in vehicles, acid rain and higher emissions of soot from the tail pipe

(exhaust pipe). In Europe, lower sulfur levels than in the United States are legally required. However, recent US legislation will reduce the maximum sulphur content of diesel from 3,000 ppm to 500 ppm by 2007, and 15 ppm by 2010. Similar changes are also underway in Canada, Australia, New Zealand and several Asian countries. Biodiesel is similar to diesel, but has differences akin to those between petrol and ethanol. For instance, biodiesel has a higher cetane rating (45-60 compared to 45-50 for crude-oil-derived diesel) and it acts as a cleaning agent to get rid of dirt and deposits.

Liquefied Natural Gas:

Liquefied natural gas or **LNG** is natural gas (primarily methane, CH_4) that has been converted to liquid form for ease of storage or transport. Liquefied natural gas takes up about 1/600th the volume of natural gas at a stove burner tip. It is odorless, colorless, non-toxic and non-corrosive. Hazards include flammability, freezing and asphyxia.

IMPORTANCE OF VARIOUS FUELS:

Fossil fuels are of great importance because they can be burned (oxidized to carbon dioxide and water), producing significant amounts of energy. The use of coal as a fuel predates recorded history. Coal was used to run furnaces for the melting of metal ore. Semi-solid hydrocarbons from seeps were also burned in ancient times, but these materials were mostly used for waterproofing and embalming. Commercial exploitation of petroleum, largely as a replacement for oils from animal sources (notably whale oil) for use in oil lamps began in the nineteenth century. Natural gas, once flared-off as an un-needed byproduct of petroleum production, is now considered a very valuable resource. Heavy crude oil, which is very much more viscous than conventional crude oil, and tar sands, where bitumen is found mixed with sand and clay, are becoming more important as sources of fossil fuel. Oil shale and similar materials are sedimentary rocks containing kerogen, a complex mixture of high-molecular weight organic compounds, which yield synthetic crude oil when heated (pyrolyzed). These materials have yet to be exploited commercially. These fuels are employed in internal combustion engines, fossil fuel power stations and other uses. Prior to the latter half of the eighteenth century, windmills or watermills provided the energy needed for industry such as milling flour, sawing wood or pumping water, and burning wood or peat provided domestic heat. The wide-scale use of fossil fuels, coal at first and petroleum later, to fire steam engines, enabled the Industrial Revolution. At the same time, gas lights using natural gas or coal gas were coming into wide use. The invention of the internal combustion engine and its use in automobiles and trucks greatly increased the demand for gasoline and diesel oil, both made from fossil fuels. Other forms of transportation, railways and aircraft also required fossil fuels. The other major use for fossil fuels is in generating electricity. Fossil fuels are also the main source of raw materials for the petrochemical industry.

TEST YOURSELF:

Q.1: What is the main difference b/w fossil fuel and Bio-fuel?

A: _____

_____.

Q.2: Coal was the fuel source which enabled the industrial revolution? Explain in three lines:

A: _____

_____.

Fill in the blanks:

1. Wood has an energy density of _____ MJ/kg
2. Liquefied natural gas takes up about _____ the volume of natural gas at a stove burner tip.
3. Solid fuels include _____, _____, _____, _____, _____, and _____
4. Recent US legislation will reduce the maximum sulphur content of diesel from _____. ppm to _____ ppm by 2007, and _____ ppm by 2010
5. Biomass can also be used directly for heating or power known as _____.

Investigation corner:

Uses of Bio-fuels are:

1. _____
2. _____
3. _____
4. _____

Practical No: 02

Object:

To study different furnaces their uses and types.

What is a Furnace?

A **furnace** is a device used for heating. The name derives from Latin *fornax*, oven. The earliest furnace was excavated at Balakot, a site of the Indus Valley Civilization, dating back to its mature phase (c. 2500-1900 BC). The furnace was most likely used for the manufacturing of ceramic objects. In American English and Canadian English, the term *furnace* on its own is generally used to describe household heating systems based on a central furnace (known either as a boiler or a heater in British English), and sometimes as a synonym for kiln, a device used in the production of ceramics. In British English the term *furnace* is used exclusively to mean industrial furnaces which are used for many things, such as the extraction of metal from ore (smelting) or in oil refineries and other chemical plants, for example as the heat source for fractional distillation columns. The term *furnace* can also refer to a direct fired heater, used in boiler applications in chemical industries or for providing heat to chemical reactions for processes like cracking, and are part of the standard English names for many metallurgical furnaces worldwide. The heat energy to fuel a furnace may be supplied directly by fuel combustion, by electricity such as the electric arc furnace, or through Induction heating in induction furnaces.

In metallurgy, several specialized furnaces are used. These include:

- ✓ Furnaces used in smelters, including:
 - The blast furnace, used to reduce iron ore to pig iron
- ✓ Steelmaking furnaces, including:
 - Puddling furnace
 - Reverberatory furnace
 - Bessemer converter
 - Open hearth furnace
 - Electric arc furnace
 - Electric induction furnace

Blast Furnace:

A **blast furnace** is a type of metallurgical furnace used for smelting to produce metals, generally iron. In a blast furnace, fuel and ore are continuously supplied through the top of the furnace, while air (sometimes with oxygen enrichment) is blown into the bottom of the chamber, so that the chemical reactions take place throughout the furnace as the material moves downward. The end products are usually molten metal and slag phases tapped from the bottom, and flue gases exiting from the top of the furnace.

Puddling Furnace:

The **puddling furnace** is a metal making technology used to create wrought iron or steel from the pig iron produced in a blast furnace. The furnace is constructed to pull the hot air over the iron without it coming into direct contact with the fuel, a system generally known as a reverberatory furnace or open-hearth process. The major advantage of this system is keeping the impurities of the fuel separated from the charge.

Reverberatory Furnace:

A **reverberatory furnace** is a metallurgical or process furnace that isolates the material being processed from contact with the fuel, but not from contact with combustion gases. The term reverberation is used here in a generic sense of rebounding or reflecting, not in the acoustic sense of echoing.

Bessemer Converter:

The process is carried on in a large ovoid steel container lined with clay or dolomite called the Bessemer converter. The capacity of a converter was from 8 to 30 tons of molten iron with a usual charge being around 15 tons. At the top of the converter is an opening, usually tilted to the side relative to the body of the vessel, through which the iron is introduced and the finished product removed. The bottom is perforated with a number of channels called tuyères through which air is forced into the converter. The converter is pivoted on trunnions so that it can be rotated to receive the charge, turned upright during conversion, and then rotated again for pouring out the molten steel at the end.

Open Hearth Furnace:

Open hearth furnaces are one of a number of kinds of furnace where excess carbon and other impurities are burnt out of the pig iron to produce steel. Since steel is difficult to manufacture due to its high melting point, normal fuels and furnaces were insufficient and the open hearth furnace was developed to overcome this difficulty. Most open hearth furnaces were closed by the early 1990s, not least because of their fuel inefficiency, being replaced by the basic oxygen furnace or electric arc furnace. Technically perhaps, the first primitive open hearth furnace was the Catalan forge, invented in Spain in the 8th century, but it is usual to confine the term to certain 19th century and later steelmaking processes, thus excluding bloomeries (including the Catalan forge), finery forges, and puddling furnaces from its application.

Electric Arc Furnace:

An electric arc furnace (EAF) is a furnace that heats charged material by means of an electric arc. Arc furnaces range in size from small units of approximately one ton capacity (used in foundries for producing cast iron products) up to about 400 ton units used for secondary steelmaking. Arc furnaces used in research laboratories and by dentists may have a capacity of only a few dozen grams. Electric arc furnace temperatures can be up to 1,800 degrees Celsius. Arc furnaces differ from induction furnaces in that the charge material is directly exposed to the electric arc, and the current in the furnace terminals passes through the charged material.

Induction Furnace:

An **induction furnace** is an electrical furnace in which the heat is applied by induction heating of a conductive medium (usually a metal) in a crucible placed in a water-cooled alternating current solenoid coil. The advantage of the induction furnace is a clean, energy-efficient and well-controllable melting process compared to most other means of metal melting. Most modern foundries use this type of furnace and now also more iron foundries are replacing cupolas with induction furnaces to melt cast iron, as the former emit lots of dust and other pollutants. Induction furnace capacities range from less than one kilogram to one hundred tonnes capacity, and are used to melt iron and steel, copper, aluminium, and precious metals. The one major drawback to induction furnace usage in a foundry is the lack of refining capacity; charge materials must be clean of oxidation products and of a known composition, and some alloying elements may be lost due to oxidation (and must be re-added to the melt).

BLAST FURNACE



INDUCTION FURNACE



LADLE FURNACE



ELECTRIC ARC FURNACE



OPEN HEARTH FURNACE



REVERBERATORY FURNACE



TEST YOURSELF:

Q1: What are the main differences b/w Blast furnace and other furnace?

Ans: _____

Q2: Why not Electric Arc furnace is using everywhere in the world?

Ans: _____

Q3. What is the major advantage of Puddling Furnace?

Ans: _____

Q4: what is the purpose of using pig iron in steelmaking?

Ans: _____

Fill in the blanks:

1. The term *reverberation* is used in a generic sense of _____.
2. An _____ **furnace** is a furnace that heats charged material by means of an electric arc
3. The capacity of a Bessemer converter was from ___ to ___ tons of molten iron with a usual charge being around ___ tons.
4. _____ are one of a number of kinds of furnace where excess carbon and other impurities are burnt out of the pig iron to produce steel.
5. The major advantage of this system is _____

Investigation Corner:

Name some furnaces & their locations which are using in Pakistan

1. _____ Location _____
2. _____ Location _____
3. _____ Location _____
4. _____ Location _____

Practical No: 03

Object:

To study & analyze Blast furnace and its functions.

WHAT IS BLAST FURNACE?

A **blast furnace** is a type of metallurgical furnace used for smelting to produce metals, generally iron. Blast furnaces are usually tall shaft-type steel vessels, up to ten stories high, internally lined with refractory brick, and superimposed over a crucible-like hearth. The necessary charge to produce molten pig iron consists of iron-bearing materials, coke, and flux. The charge is introduced into the furnace at the top. Blasts of heated air from large blast stoves, and in most cases gaseous, liquid, or powdered fuel, are injected into the furnace through openings (tuyeres) at the bottom of the shaft just above the hearth crucible. As the hot air encounters the coke, the coke is burned along with the injected fuels, producing the necessary heat and reducing gas to remove oxygen from the ore in the reduction process. As the iron melts, it descends and accumulates in the crucible. The molten pig iron and slag are drained from the crucible through different tapping holes. The gas that exits from the top of the furnace goes through a cleaning process. The cleaned hot gas is then used in other operations of the plant, e.g. to pre-heat the blast air, while the collected dust is sent to the sintering plant for recycling back into the blast furnace. Once fired-up, a blast furnace burns continuously until the lining needs replacement (approximately 5-6 years). The first blast furnace in Russia opened in 1637 near Tula and was called the Gorodishche Works.

Components of Blast Furnace:

Blast furnaces are large intricate systems that are constructed from a combination of off-the-shelf equipment and custom constructed components. The largest components of the blast furnace proper include the furnace shell, the furnace internal refractory lining, and the crucible-like hearth. Most of the stand-alone equipment such as motors, burners, etc., are associated with the following:

- ❖ Raw material assembly and transport
- ❖ Hot metal and slag transfer
- ❖ Off-gas cleaning
- ❖ Hot-blast stoves

While all of the equipment used in the above operations may be of interest, the focus here is placed on the equipment and components specific to the blast furnace.

Skip Car (conveyors) - The skip cars, and in some installations conveyors, are used to deliver the blast furnace charge to the top of the furnace.

Bosh - The bosh is an inverted conical section in which the melting starts.

Receiving Hopper - The blast furnace charge is loaded into the receiving hopper, which in turn delivers the charge to the rotating distributor. The rotating distributor helps assure a uniform distribution of the charge in the furnace stack.

Hearth - The hearth is an intricately constructed crucible-like vessel upon which the vertical shaft portion of the furnace sits. All the molten metal and slag collect in the hearth before being drained.

Bells (large and small) - the large and small bells are conically shaped devices that form a gas-tight lock hopper. The hopper prevents gas from escaping from the furnace while it is being charged.

Bustle Pipe - The bustle encircles the blast furnace and delivers the hot blast air from the hot-blast line to the furnace.

Stack - The stack is the upper portion of the furnace where the burden is pre-heated.

Injection Lance - The injection lance is inserted into the blowpipe that leads up to the tuyeres. The supplemental fuel is delivered to the furnace through the injection lance.

Iron and Slag Notches- The molten metal is removed from the hearth through the iron notches. The metal is placed into transfer ladles, while the slag may be transferred to slag pots, drawn off into dry pits for solidification, or granulated with a stream of water and flushed into a well pit.

Tuyeres - The hot blast air is delivered to the furnace through water-cooled openings called tuyeres. The tuyeres are located at the top of the hearth.

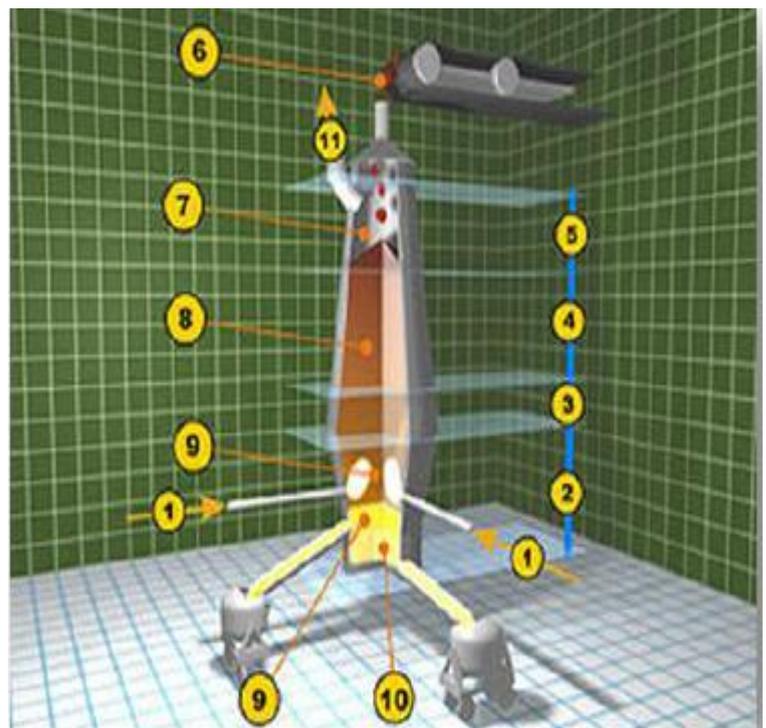
Iron-bearing materials - The iron-bearing materials are usually iron ore, sinter, pellets, mill scale, steelmaking slag, scrap, and other materials.

Coke - The coke is added to provide the main chemical reagents (carbon and carbon monoxide) for the iron ore reduction.

Flux - The flux, limestone and/or dolomite, is added to combine with ash in the coke and gangue in the ores, to produce a slag that rises to the top of the pool of molten pig iron that collects in the crucible.

Blast Furnace Diagram

1. Hot blast from Cowper stoves
2. Melting zone (*bosh*)
3. Reduction zone of ferrous oxide (*barrel*)
4. Reduction zone of ferric oxide (*stack*)
5. Pre-heating zone (*throat*)
6. Feed of ore, limestone, and coke
7. Exhaust gases
8. Column of ore, coke and limestone
9. Removal of slag
10. Tapping of molten pig iron
11. Collection of waste gases



TEST YOURSELF

Q1: Define Blast Furnace in 2 lines?

Ans: _____

Q2: What is the main difference b/w Blast Furnace and ordinary furnaces?

Ans: _____

Fill in the blanks:

1. Modern furnace can produce around _____ tonnes of iron per week.
2. The largest components of the blast furnace proper include the _____ and _____.
3. _____ is an inverted conical section in which the melting starts
4. The largest blast furnaces have a volume around _____.
5. Pakistan Steel Mills is producing _____ million tons of Pig iron.
6. Pakistan Steel Mills has _____ blast furnaces.

Self-Investigation:

List some world wide mills which have Blast furnaces:

1. Name _____ Location: _____
2. Name _____ Location: _____
3. Name _____ Location: _____
4. Name _____ Location: _____
5. Name _____ Location: _____

Practical No: 04

Object:

To study about Cupola Furnace & its operations.

What is a Cupola or Cupola furnace?

A **Cupola** or **Cupola furnace** is a melting device used in foundries that can be used to melt cast iron, ni-resist iron and some bronzes. The cupola can be made almost any practical size. The size of a cupola is expressed in diameters and can range from 18 inches to 13 feet. The overall shape is cylindrical and the equipment is arranged vertically, usually supported by four legs. The overall look is similar to a large smokestack. The bottom of the cylinder is fitted with doors which swing down and out to 'drop bottom'. The top where gases escape can be open or fitted with a cap to prevent rain from entering the cupola. To control emissions a cupola may be fitted with a cap that is designed to pull the gases into a device to cool the gasses and remove particulate matter.

The shell of the cupola, being usually made of steel, has refractory brick and refractory patching material lining it. The bottom is lining in a similar manner but often a clay and sand mixture may be used, as this lining is temporary. The bottom lining is compressed or 'rammed' against the bottom doors. Some cupolas are fitted with cooling jackets to keep the sides cool and with oxygen injection to make the coke fire burn hotter.

Operations of Cupola Furnace:

- ❖ To begin a production run, called a 'cupola campaign' the furnace is filled with layers of coke and ignited with torches. Some smaller cupolas may be ignited with wood to start the coke burning. When the coke is ignited, air is introduced to the coke bed through ports in the sides called tuyeres.
- ❖ When the coke is very hot, solid pieces of metal are charged into the furnace through an opening in the top. The metal is alternated with additional layers of fresh coke. Limestone is added to act as a flux. As the heat rises within the stack the metal is melted. It drips down through the coke bed to collect in a pool at the bottom, just above the bottom doors. A thermodynamic reaction takes place. The carbon in the coke combines with the oxygen in the air to form carbon monoxide. The carbon monoxide further burns to form carbon dioxide. Some of the carbon is picked up by the falling droplets of molten steel and iron which raises the carbon content of the iron. Silicon carbide and ferromanganese briquettes may also be added to the charge materials. The silicon carbide dissociates and carbon and silicon enters into the molten metal. Likewise the ferromanganese melts and is combined into the pool of liquid iron in the 'well' at the bottom of the cupola.
- ❖ The operator of the cupola, the 'cupola tender', observes the amount of iron rising in the well of the cupola. When the metal level is sufficiently high, the cupola tender opens the taphole to let the metal flow into a ladle or other container to hold the molten metal. When enough metal is drawn off the taphole is plugged with a refractory plug made of clay.
- ❖ The cupola tender observes the iron through the sight glass for signs of slag formation, which is normal. Most slags will rise to the top of the pool of iron being formed. A slag tap hole, located higher up on the cylinder, and usually to the rear or side of the iron taphole, is opened to let the slag flow out. The viscosity is low (with

proper fluxing) and the red hot molten slag will flow easily. Sometimes the slag which runs out the slag hole is collected in a small cup shaped tool, allowed to cool and harden. It is fractured and visually examined. With acid refractory lined cupolas a greenish coloured slag means the fluxing is proper and adequate.

- ❖ After the cupola has produced enough metal to supply the foundry with its needs, the bottom is opened, or 'dropped' and the remaining materials fall to the floor between the legs. This material is allowed to cool and subsequently removed. The cupola can be used over and over. A 'campaign' may last a few hours, a day, weeks or even months.

During the production, samples may be taken from the metal and poured into small molds. A chill wedge is often poured to monitor the iron quality. These small, approx 18 mm (3/4") wide x 38 mm (1-1/2") tall triangular shaped pieces are allowed to cool until the metal has solidified. They are then extracted from the sand mold and quenched in water, wide end first. After cooling in the mangled the wedges are fractured and the metal coloration is assessed. A typical fracture will have a whitish color towards the thin area of the wedge and greyish color towards the wide end. The width of the wedge at the point of demarcation between the white and grey areas is measured and compared to normal results for particular iron tensile strengths. This visual method serves as a control measurement.



*A cupola furnace in operation at
Wayne State University, in Detroit, Michigan*

TEST YOURSELF:

Q.1: How to control emissions a cupola?

A: _____

Q.2: Which factors differentiates Cupola Furnace from Blast Furnace?

A: _____

Fill in the blanks:

1. The size of a cupola is expressed in diameters and can range from ___ inches to ___ feet
2. Some cupolas are fitted with _____ to keep the sides cool and with _____ injection to make the coke fire burn
3. When enough metal is drawn off the taphole is plugged with a _____.
4. The _____ observes the amount of iron rising in the well of the cupola.
5. In Cupola _____ is added to act as a flux

Investigation corner:

What do you think is Cupola furnace is essential for a prime production mill or not?

Practical No: 05

Object:

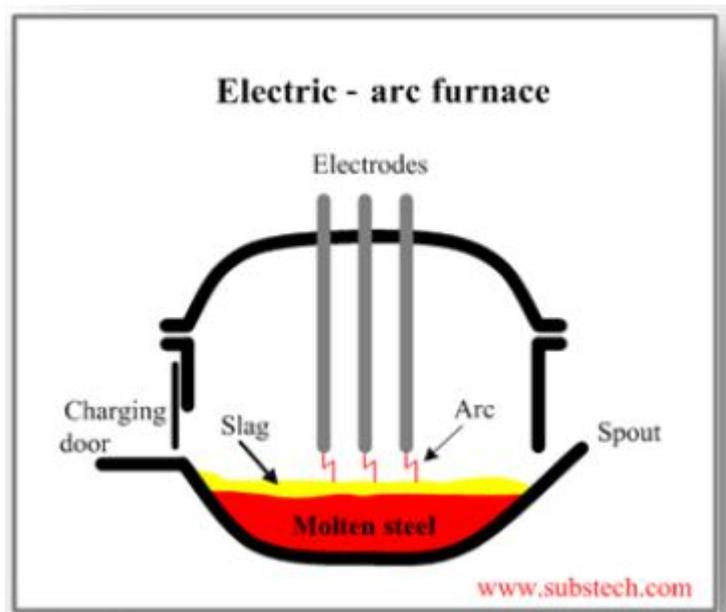
To study about Electric Arc Furnace & its operations.

What is an Electric Arc Furnace (EAF)?

An **electric arc furnace (EAF)** is a furnace that heats charged material by means of an electric arc. Arc furnaces range in size from small units of approximately one ton capacity (used in foundries for producing cast iron products) up to about 400 ton units used for secondary steelmaking. Arc furnaces used in research laboratories and by dentists may have a capacity of only a few dozen grams. Electric arc furnace temperatures can be up to 1,800 degrees Celsius. Arc furnaces differ from induction furnaces in that the charge material is directly exposed to the electric arc, and the current in the furnace terminals passes through the charged material.

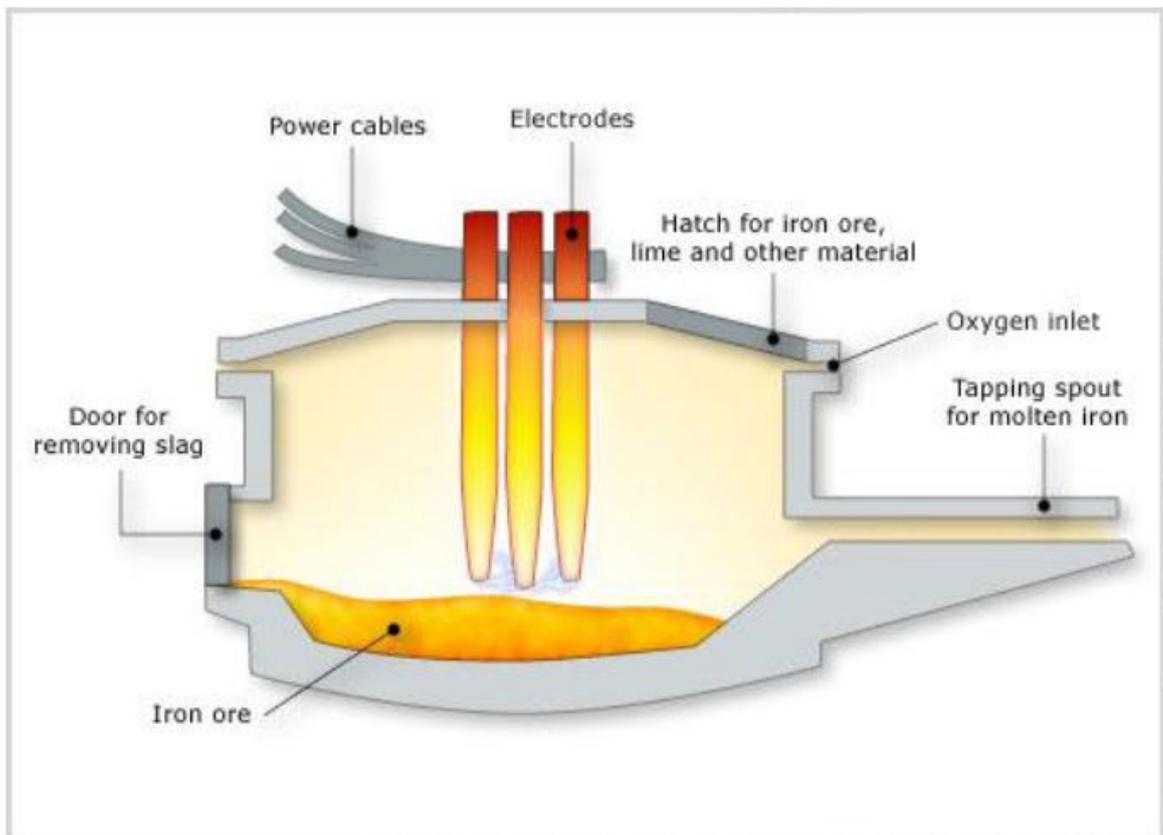
Operations of EAF:

- ❖ Scrap metal is delivered to a scrap bay, located next to the melt shop. Scrap generally comes in two main grades: shred (whitegoods, cars and other objects made of similar light-gauge steel) and heavy melt (large slabs and beams), along with some direct reduced iron (DRI) or pig iron for chemical balance. Some furnaces melt almost 100% DRI.
- ❖ The scrap is loaded into large buckets called baskets, with 'clamshell' doors for a base. Care is taken to layer the scrap in the basket to ensure good furnace operation; heavy melt is placed on top of a light layer of protective shred, on top of which is placed more shred. These layers should be present in the furnace after charging. After loading, the basket may pass to a scrap pre-heater, which uses hot furnace off-gases to heat the scrap and recover energy, increasing plant efficiency. The scrap basket is then taken to the melt shop, the roof is swung off the furnace, and the furnace is charged with scrap from the basket. Charging is one of the more dangerous operations for the EAF operators. There is a lot of energy generated by multiple tonnes of falling metal; any liquid metal in the furnace is often displaced upwards and outwards by the solid scrap, and the grease and dust on the scrap is ignited if the furnace is hot, resulting in a fireball erupting. In some twin-shell furnaces, the scrap is charged into the second shell while the first is being melted down, and pre-heated with off-gas from the active shell. Other operations are continuous charging - pre-



heating scrap on a conveyor belt, which then discharges the scrap into the furnace proper, or charging the scrap from a shaft set above the furnace, with off-gases directed through the shaft. Other furnaces can be charged with hot (molten) metal from other operations.

- ❖ After charging, the roof is swung back over the furnace and meltdown commences. The electrodes are lowered onto the scrap, an arc is struck and the electrodes are then set to bore into the layer of shred at the top of the furnace. Lower voltages are selected for this first part of the operation to protect the roof and walls from excessive heat and damage from the arcs. Once the electrodes have reached the heavy melt at the base of the furnace and the arcs are shielded by the scrap, the voltage can be increased and the electrodes raised slightly, lengthening the arcs and increasing power to the melt. This enables a molten pool to form more rapidly, reducing tap-to-tap times. Oxygen is also lanced into the scrap, combusting or cutting the steel, and extra chemical heat is provided by wall-mounted oxygen-fuel burners. Both processes accelerate scrap meltdown.



- ❖ An important part of steelmaking is the formation of slag, which floats on the surface of the molten steel. Slag usually consists of metal oxides, and acts as a destination for oxidized impurities, as a thermal blanket (stopping excessive heat loss) and helping to reduce erosion of the refractory lining. For a furnace with basic refractories, which includes most carbon steel-producing furnaces, the usual slag formers are calcium oxide (CaO , in the form of burnt lime) and magnesium oxide (MgO , in the form of dolomite and magnesite). These slag formers are either charged with the scrap, or blown into the furnace during meltdown. Later in the heat, carbon (in the form of coke or coal) is lanced into this slag layer, partially combusting to form carbon monoxide gas, which then causes the slag to foam, allowing greater thermal

efficiency, and better arc stability and electrical efficiency. The slag blanket also covers the arcs, preventing damage to the furnace roof and sidewalls from radiant heat.

- ❖ Once flat bath conditions are reached, i.e. the scrap has been completely melted down, another bucket of scrap can be charged into the furnace and melted down, although EAF development is moving towards single-charge designs. After the second charge is completely melted, refining operations take place to check and correct the steel chemistry and superheat the melt above its freezing temperature in preparation for tapping. More slag formers are introduced and more oxygen is lanced into the bath, burning out impurities such as silicon, sulfur, phosphorus, aluminium, manganese and calcium and removing their oxides to the slag. Removal of carbon takes place after these elements have burnt out first, as they have a greater affinity for oxygen. Metals that have a poorer affinity for oxygen than iron, such as nickel and copper, cannot be removed through oxidation and must be controlled through scrap chemistry alone, such as introducing the direct reduced iron and pig iron mentioned earlier. A foaming slag is maintained throughout, and often overflows the furnace to pour out of the slag door into the slag pit. Temperature sampling and chemical sampling (in the form of a 'chill' - a small, solidified sample of the steel) take place via automatic lances.
- ❖ Once the temperature and chemistry are correct, the steel is tapped out into a preheated ladle through tilting the furnace. As soon as slag is detected during tapping the furnace is rapidly tilted back towards the deslagging side, minimising slag carryover into the ladle. During tapping some alloy additions are introduced into the metal stream. Often, a few tonnes of liquid steel and slag is left in the furnace in order to form a 'hot heel', which helps preheat the next charge of scrap and accelerate its meltdown. During and after tapping, the furnace is 'turned around': the slag door is cleaned of solidified slag, repairs may take place, and electrodes are inspected for damage or lengthened through the addition of new segments; the taphole is filled with sand at the completion of tapping. For a 90-tonne, medium-power furnace, the whole process will usually take about 60-70 minutes from the tapping of one heat to the tapping of the next (the tap-to-tap time).

Advantages of electric arc furnace for steelmaking

- ❖ The use of EAFs allows steel to be made from a 100% scrap metal feedstock, commonly known as 'cold ferrous feed' to emphasize the fact that for an EAF, scrap is a regulated feed material. The primary benefit of this is the large reduction in specific energy (energy per unit weight) required to produce the steel. Another benefit is flexibility: while blast furnaces cannot vary their production by much and are never stopped, EAFs can be rapidly started and stopped, allowing the steel mill to vary production according to demand. Although steelmaking arc furnaces generally use scrap steel as their primary feedstock, if hot metal from a blast furnace or direct-reduced iron is available economically, these can also be used as furnace feed.
- ❖ A typical steelmaking arc furnace is the source of steel for a mini-mill, which may make bars or strip product. Mini-mills can be sited relatively near to the markets for steel products, and the transport requirements are less than for an integrated mill, which would commonly be sited near a harbour for access to shipping.

TEST YOURSELF:

Q.1: How Arc furnaces differ from induction furnaces?

A: _____

Q.2: Write the three main advantages of EAF:

A: _____

Fill in the blanks:

1. Electric arc furnace temperatures can be up to _____ degrees Celsius
2. The use of EAFs allows steel to be made from a 100% scrap metal feedstock, commonly known as _____.
3. Steelmaking arc furnaces generally use _____ as their primary feedstock
4. After _____, the roof is swung back over the furnace and meltdown commences.
5. Scrap generally comes in two main grades _____ & _____.

Investigation corner:

Write some more advantages regarding EAF except mentioned above:

Practical No: 06

Object:

To study about Induction Furnace & its operations.

THE INDUCTION FURNACE

An **induction furnace** is an electrical furnace in which the heat is applied by induction heating of a conductive medium (usually a metal) in a crucible placed in a water-cooled alternating current solenoid coil. The advantage of the induction furnace is a clean, energy-efficient and well-controllable melting process compared to most other means of metal melting. Most modern foundries use this type of furnace and now also more iron foundries are replacing cupolas with induction furnaces to melt cast iron, as the former emit lots of dust and other pollutants. Induction furnace capacities range from less than one kilogram to one hundred tonnes capacity, and are used to melt iron and steel, copper, aluminium, and precious metals. The one major drawback to induction furnace usage in a foundry is the lack of refining capacity; charge materials must be clean of oxidation products and of a known composition, and some alloying elements may be lost due to oxidation (and must be re-added to the melt).



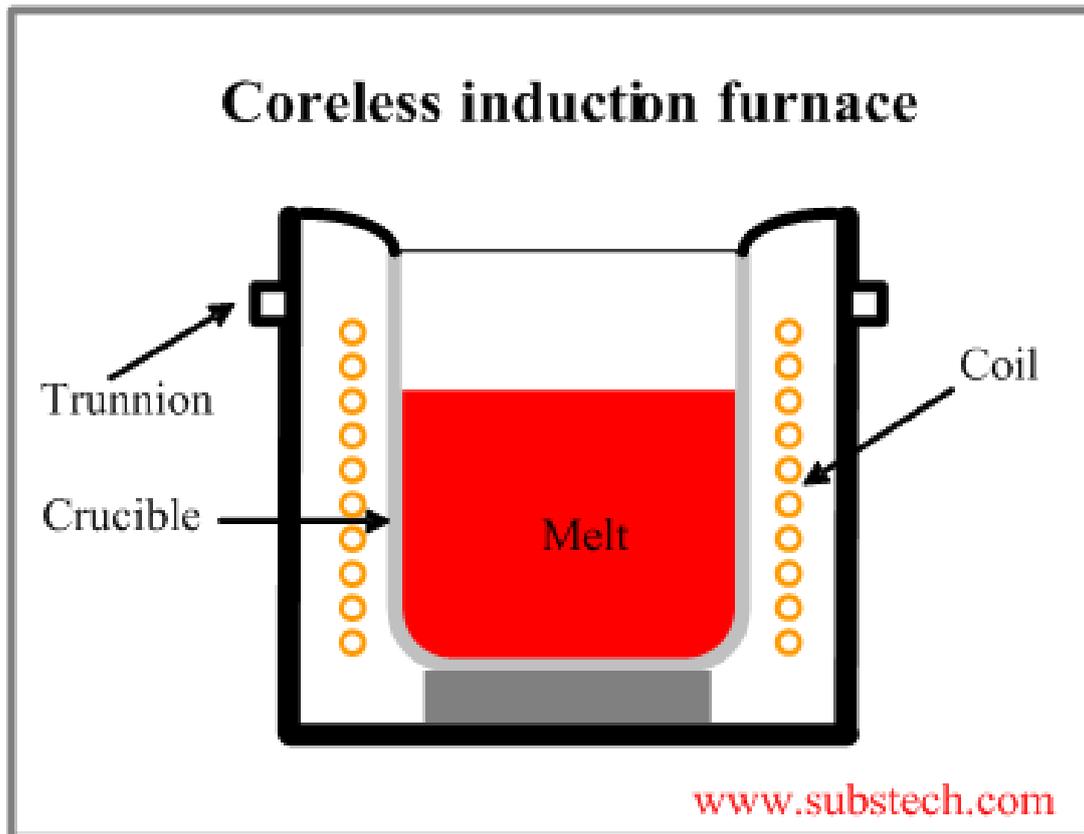
An induction furnace, with fume hood closed, tapping a melt

Operating frequencies range from utility frequency (50 or 60 Hz) to 400 kHz or higher, usually depending on the material being melted, the capacity (volume) of the furnace and the melting speed required. Generally the smaller the volume of the melts the higher the frequency of the furnace used; this is due to the skin depth which is a measure of the distance an alternating current can penetrate beneath the surface of a conductor. For the same

conductivity the higher frequencies have a shallow skin depth - that is less penetration into the melt. Lower frequencies can generate stirring or turbulence in the metal.

A preheated 1-tonne furnace melting iron can melt cold charge to tapping readiness within an hour.

An operating induction furnace usually emits a hum or whine (due to magnetostriction), the pitch of which can be used by operators to identify whether the furnace is operating correctly, or at what power level.



TEST YOURSELF

Q.1: Define Induction Furnace in your own words?

A: _____

Q.2: What is the main purpose of using Induction furnace?

A: _____

Q.3: How you will distinguish an induction furnace with reduction furnace?

A: _____

Q.4: What is the similarity b/w induction furnace and electric arc furnace?

A: _____

TEST YOURSELF

Q.1: Why we are doing sieve analysis?

A: _____

Q.2: What are Limitations of sieve analysis?

A: _____

Q.3: What are modern alternate methods of sieve analysis?

A: _____

Practical No: 09

Object:

How slip casting is made by mold of plaster of Paris.

Materials:

Mold (commonly made plaster of Paris).

Theory:

Ceramic shapes can be cast by using a unique process is called slip casting. This method consist of suspending powdered raw material in liquid to sullary of slip casually clays water. That is powder into porous mold which is usually made of gypsum.

Procedure:

1. Preparation of powdered ceramic material and a liquid usually clays & water, into a stable suspension called slop.
2. Pouring the slop into a porous mold (commonly made of plaster of pairs allowing the liquid portion (water) of the slop to be absorbed by the mold, as the liquid is removed from the slop a layer of semi hard material is formed against the mold surface.
3. This process may be continued initial the entire mold cavity become solid and it may be turbinate when the solid shell wall reaches the desire surface by inverting the mold & pouring out the excess.
4. The material in the mold allow to dry (as cast piece dried) to provide adductors strength for hard longs the subsequent parts may relies from the mold wall at this time.
5. Finally the cast part is fired to attention the required microstructure & properties.

Practical No: 10

Object:

To Study about the Manufacturing of Refractories.

Procedure:

The following physical operation and chemical conversion are used in the manufacturing of refractories, Grinding, Screening, Mixing, Pressing or Molding and repressing-drying and burning.

Grinding:

Obviously one of the most important factors in the size of the particles in batch is known as that a mixture in which the proportion of coarse and fine particles is about 55:45 with only few intermediate particles, gives the densest mixture.

Mixture:

This stage the process of manufacturing or processing is very important and it is essential that a through an intimate mixture of sand, lime and water should be formed to facilitate this. The real function of the mixing is the distribution of the plastic material.

Molding:

The great demand for refractory bricks of greater strength, volume and uniformity has a resulted in the dry-press method of molding with a mechanically operated pressure (In this pressure the machine is used where the pressure of about 100kh/square cm is applied.

Hardening:

After pressing back slash molding the bricks are sent directly to hardening cylinder. In this process the long steel cylinder of about 15 meter length and 2 m in dia carrying the press bricks are directly pugged in these cylinder and doors are directly close.

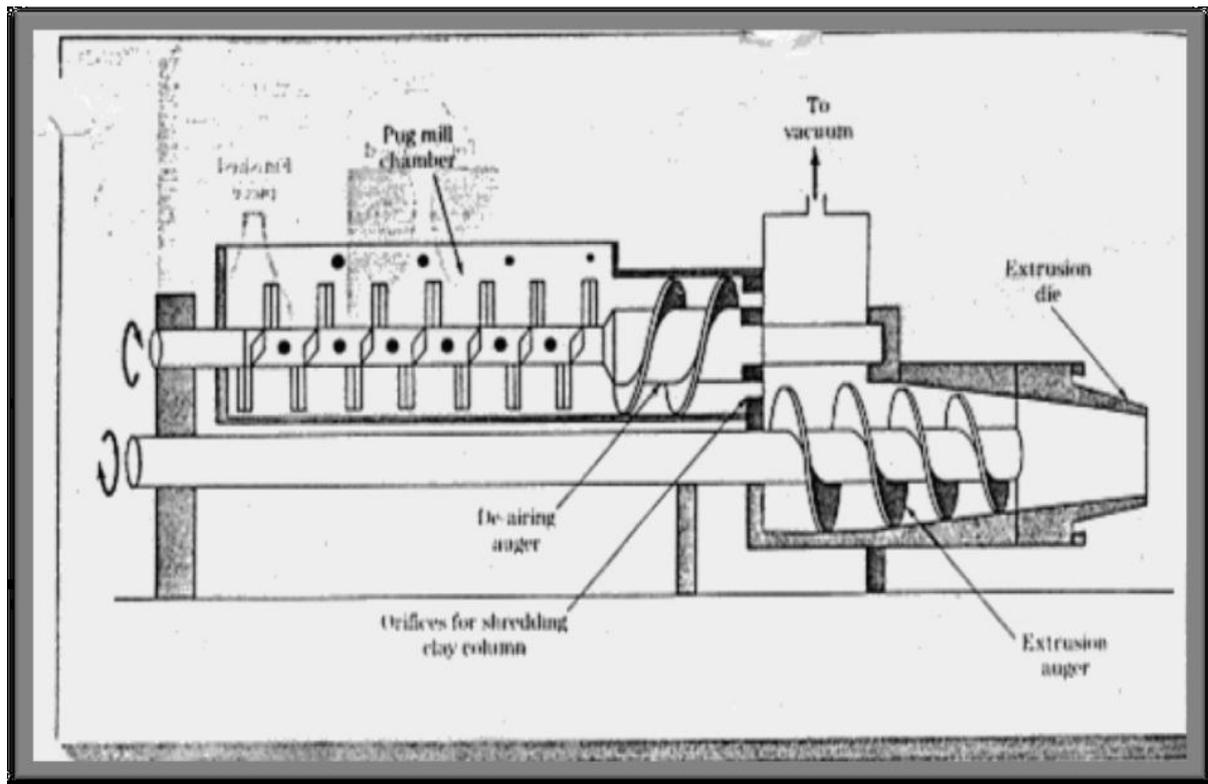


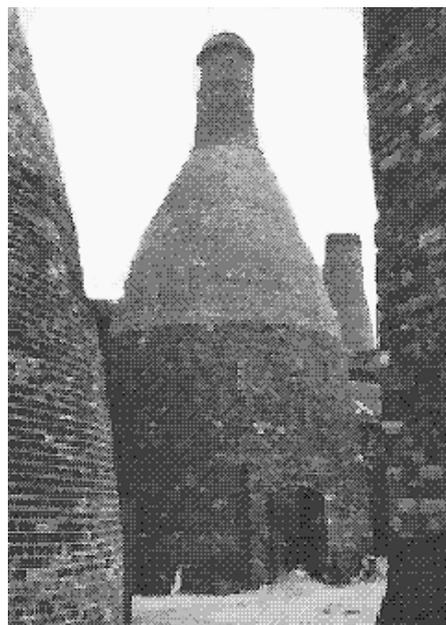
Fig: Mixing Mill (Pug Mill)

Manufacturing of fire clay Refractories:

Furnaces use in the manufacturing are:

(i) Down draught kilns:

This is the most important type firing refractories. It is either round or rectangular in shape. Refractories are stacked over the floor of the kiln and heating is commenced. The temperature is raised at a fixed rate. Flue gases and other combustion products go down downward, pass over the reformatories and ultimately go to chimney.



Practical No: 11

Object:

Determination of Refractoriness (P.C.E.)

Principle:

The object of this test is to compare the behaviour of a standard pyramidal test piece with that of British pyrometric cones under specified conditions and to express its refractoriness as a cone value from the number of the pyrometric cone that approximates most closely in behaviour to the test cone. A similar test has been developed under the aegis of the International Organization for Standardization (ISO) and is at present listed as DR 567, Draft ISO Recommendation for the determination of the pyrometric cone equivalent (P.C.E.) of refractory products.

METHOD OF TEST

A. Apparatus. A furnace is required in which an atmosphere containing free oxygen can be maintained throughout the test. It shall be possible to raise the temperature of the test piece and the pyrometric cones at the specified rate to the required temperature. The furnace shall have a zone of uniform temperature extending a short distance above and below the test piece.

B. Test of Material.

(i) Bricks and shapes. The test piece, cut from the body of the brick to be tested and not including any of the original face, shall be ground on a suitable abrasive wheel to the shape of a pyramid with a triangular base. One edge of the pyramid shall be perpendicular to the base and 3/2 in. long; the sides of the triangular base shall be 1/2 in. A tolerance of 1/16 in shall be allowed in the dimensions of the base; when the base is larger, within the tolerance, the height shall be proportionately larger, and vice versa.

It may be found impossible, by the specified method, to prepare a test piece of the stipulated dimensions from certain loosely bonded, highly grogged bricks. In this case the test piece may be prepared either by crushing the brick to a powder and moulding it with an organic binder as described in Subclause B(iii) or a piece of the brick may be impregnated with a suitable resin giving less than 0.5 per cent ash (e.g. Canada balsam) and the test piece cut from this impregnated material. It may also be impossible to prepare a representative test piece from heavily iron-spotted bricks. In this case the test piece may be prepared by crushing the brick to a powder and moulding it as described in Subclause B(iii). Such departures from the standard procedure shall be noted in the report.

(ii) Wet or dry refractory cements. Test pieces of the size and shape set out in Subclause B(i) shall be molded from the cement, if necessary with the addition of water. An organic binder as described in Subclause B(iii) may also be used. The molded cones are dried and then fired at 700-800°C to remove combined water and organic matter.

In cements containing sodium silicate or other soluble fluxes, migration of the flux towards the surfaces occurs during the drying of the test cone and may lead to a faulty assessment of the refractoriness of the material. In the use of such cements, on the other hand, some of the soluble matter will be absorbed by the brick so that the joint may be poorer in fluxes than the cement itself. With such cements, additional useful information may be obtained if a

refractoriness test is carried out on a cone cut from the interior of a dried block of the cement of dimensions, for example, 3 in by 1 in by 1 in.

(iii) Raw materials and powders (excluding cements). A representative sample of the material is ground to pass a 30 mesh B.S. test sieve* and 50 g are ground in an agate mortar to pass a 72 mesh B.S. test sieve*. The material should be sieved frequently while it is being ground in order to avoid an excess of very fine powder. If necessary, a magnet should be used to separate any metallic iron that may be introduced by the grinding and crushing operations (except in the case of materials that are themselves magnetic). The sample shall be thoroughly mixed.

The material is made into a plastic mass with water to which, if necessary, an organic binder, e.g. dextrin, having a maximum of 0.5 per cent of ash is added; if the material reacts with water some other suitable liquid (e.g. paraffin) should be used. The test piece is formed in a suitable mould. Test pieces prepared from materials which are subject to considerable modification during heating should be stabilized by calcination before the test. Clays should be calcined at about 1000°C. After calcination the test pieces should comply with the requirements of size and shape set out in Subclause B(i).

C. Procedure. The test piece shall be mounted at the centre of a refractory plaque, which may conveniently be circular, square or rectangular according to the shape of the furnace. The test piece shall be fixed with a cement consisting of calcined alumina, or well-fired and finely ground sillimanite, bonded with 10 per cent of china clay. The test piece shall be mounted so that the edge perpendicular to its base shall be vertical. British pyrometric cones shall be cemented to the plaque, oriented so that they will bend away from the test piece, i.e. with their numbers facing inwards. The edges opposite the numbers shall be vertical.

The test piece with the surrounding pyrometric cones shall be placed in the furnace, and the temperature shall be raised at a rate of 10-15 degC/min to a temperature estimated to be approximately 200 deg C below the squatting temperature; from then onwards the rate of rise of temperature shall be maintained constant at 5 degC/min. This can be checked by means of an optical pyrometer or thermocouple.

The test shall be continued till the tip of the test cone has bent over level with the base; the plaque bearing the specimen shall then be removed from the furnace and the test piece examined when cold.

D. Reporting of Results. The refractoriness shall be reported as the number of the pyrometric cone that has bent over to a similar extent to the test cone. Should it be found that the tip of one pyrometric cone is below the base, whereas the tip of that next in order is above the base, the refractoriness shall be reported as lying between the two cone numbers. In the event of the test piece not bending in the normal manner an indication of the type of squatting and of the cone number at which it occurs shall be given.

* B.S. 410, 'Test sieves'.

OBSERVATIONS:

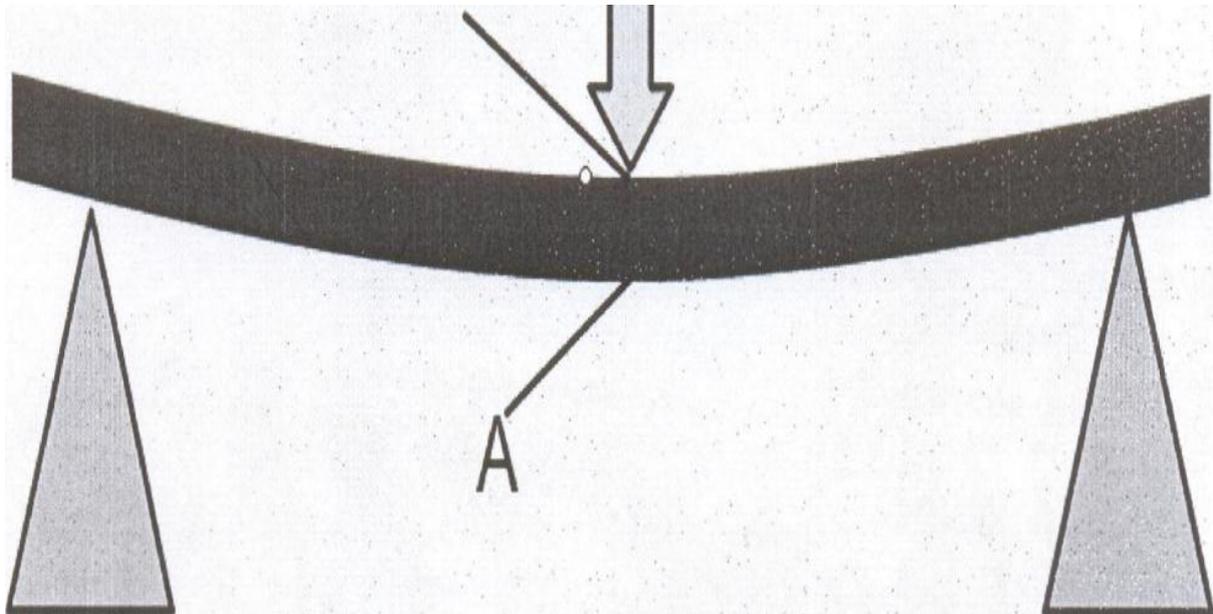
Practical No: 12

Object:

Determination of Modulus of Rupture.

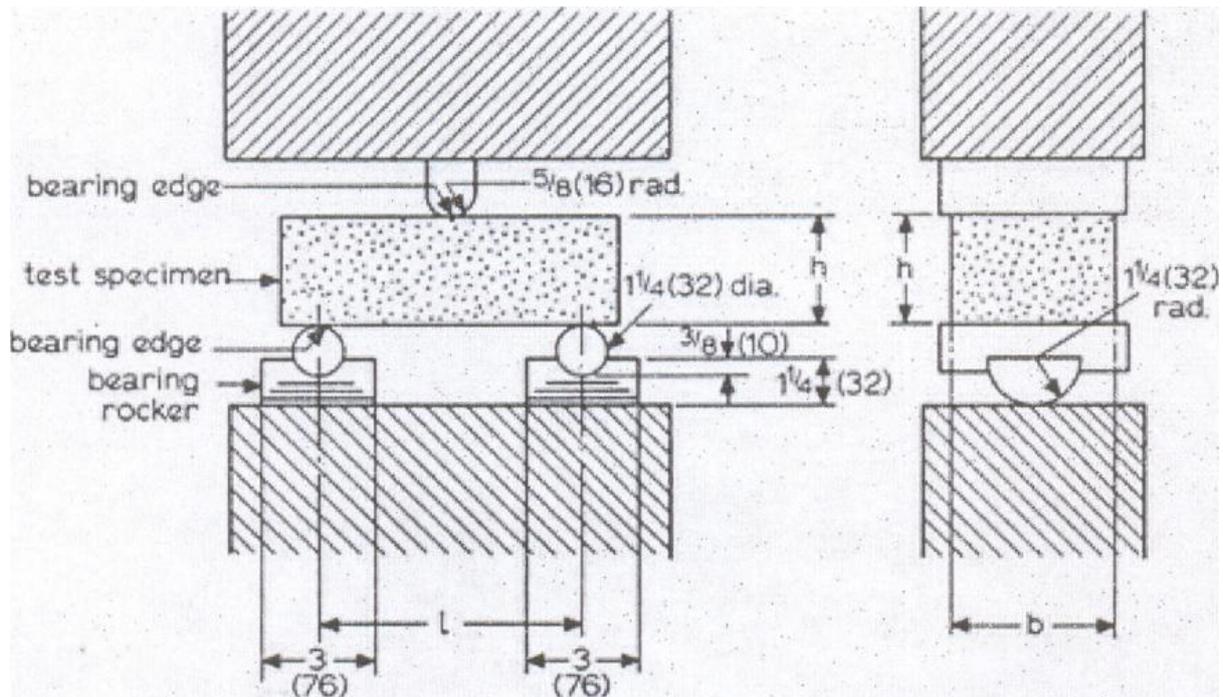
Theory:

Modulus of rupture is defined as a material's ability to resist deformation under load. A measure of the ultimate load-carrying capacity of a beam; equal to the ratio of the bending moment at rupture to the section modulus of the beam. Special strength-testing methods have been established for refractory ceramics, which are of a mostly heterogeneous composition. The Refractoriness under Load (RUL) and Creep in Compression (CIC) identify the deformation resistance of a test piece under a defined load and temperature/time factors. The modulus of rupture at high temperatures (HMOR) is determined with a hot modulus of rupture tester. The melting behavior of these heterogeneous ceramics is determined indirectly through comparison with so-called Seger cones (PCE — Pyrometric Cone Equivalent).



Apparatus:

A compression testing machine complying with Class B of B.S. 1610* in the range 0-10 tons is suitable. The bearing edges shall be in accordance with Fig. IS.



Test Material:

The test specimens shall be dried whole bricks measuring approximately 9 X 4t X 3 in or 2t in (229 X 114 X 76 or 64 mm) or specimens of either size cut from a larger shape. Ten specimens shall be tested.

Procedure:

The test specimens shall be placed in the machine so that the 4t in (114 mm) dimension is parallel to the bearing edges. The load shall be applied to the centre of the specimen at a rate of 1500 ± 100 lbf/min (680 ± 45 kgt/min).

Reporting of Results:

The modulus of rupture shall be calculated from the following formula: $R = \frac{3W}{l^2bh^2}$ = modulus of rupture in lbf/in²,

W = load in pounds-force at which the specimen failed,

l = distance in inches, normally 10, between the centre lines of the lower bearing edges, b

= width of specimen in inches, h = height of specimen in inches.

Metric units may be used. R will then be expressed in kgf/cm², W in kgf and l, b and h in mm.

The report shall state the value for each specimen and the mean value.

The test pieces shall be placed in the cold furnace. The furnace shall then be heated at a uniform rate so that it attains the test temperature in 3 hours. For silica bricks a temperature of 450°C is recommended; for firebricks, siliceous bricks or high alumina bricks either 1000°C or 1200°C may be chosen unless there is reason to believe that the latter temperature will cause serious changes in the character of the brick. The testing temperature shall be maintained for 30 minutes and the test pieces shall then be removed from the furnace with a pair of light tongs, which shall have been warmed in the furnace for a short time before use. The test pieces shall be placed on end on cold firebricks in a position free from draughts*.

Practical No: 13

Object:

Determination of Resistance to Thermal Shock (Spalling).

Theory:

The resistance to thermal shock is an important attribute for a refractory in many applications to avoid cracking, spalling and premature failure. Over the years a number of tests have been used to measure thermal shock resistance. These tests include ASTM's C-1171-91 and C-1100-88, and the prism spalling test. Thermal shock resistance parameters have also been estimated, which can be correlated to some of these test results.

Thermal cycling testing

ASTM C-1171-91 uses 6 x 1 x 1 in. (15.2 x 2.5 x 2.5 cm) bars to measure the loss of strength when cycled from 1200 [degrees] C to room temperature. A total of five cycles from 1200 [degrees] C to ambient temperature are required. After cycling, the bars are tested for modulus of elasticity (MOE) and modulus of rupture (MOR).

Apparatus:

A furnace of the muffle or semi-muffle type is required, of such a size that when the cooled test pieces are inserted the fall in temperature does not exceed 20 degC and the test temperature is regained within 5 minutes. A thermocouple and temperature indicator, tongs and protective gloves are also needed.

Test material:

Three test pieces shall be cut or ground to the shape of prisms 3 in high and with a square base of 2 in side. The test pieces shall be thoroughly, dried before being tested.

Procedure:

Period of heating and cooling. Towards the end of each cooling period, the test pieces shall be examined for cracks or loss of corners and a pull shall be exerted on the test piece either by hand or a stress by means of a rig*. The test shall be concluded when the specimens can be pulled apart in this way.

BS. Reporting of results. The report shall include a note of the temperature used, the number of complete cycles of heating and cooling required to promote fracture and a note of the cycle during which cracks first appeared, together with a description of the nature of the failure. The three individual results shall be reported.

OBSERVATIONS:
