# Construction Materials For Food Science and Engineering

## Construction Materials: Iron

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# Iron

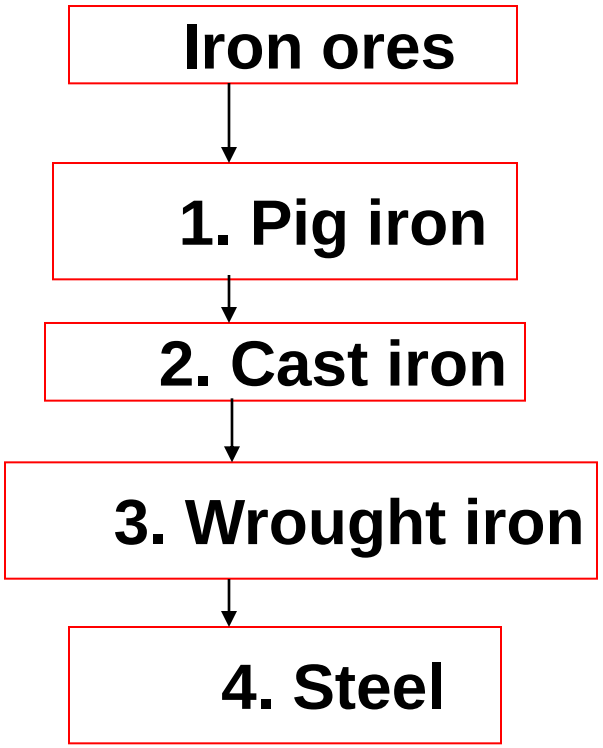
**Iron:** Iron is the most widely used engineering material in the world. It is a chemical element with symbol ‘Fe’ having atomic number 26. Iron is also called ferrous metal (Ferrous metal are those which have iron as their main constituent). Ferrous metals commonly used in engineering practice are cast iron, wrought iron, steels and alloy steels.

**Uses:** Applications of iron are almost beyond count:

- Skeletal frame work for large multistoried building,
- Hulls and superstructure of ships,
- Spans and trusses of bridges,
- Large/small engine, machine, tools and equipment,
- Ducts, flumes, overhead water tank, storage tank etc.
- Support for chemical/food processing equipment,
- Reinforcement in concretes and many others

# Iron

**Sources of Iron:** Iron is obtained from iron ores in the following sequence:



# Manufacturing of Pig Iron

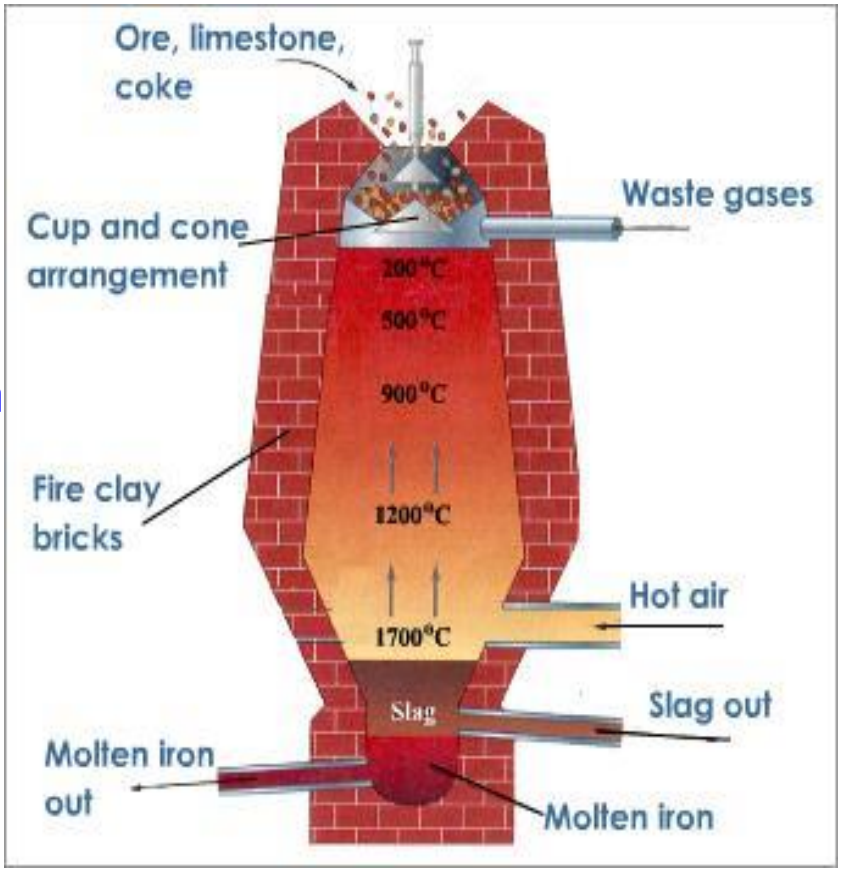
**Iron Ores:** Iron ores are Compounds of iron, Usually oxides of iron mixed with aluminum, silica, clay etc. Iron ores contain 25 to 75% metallic iron. The following are the chief iron ores from which pig iron is extracted:

| Iron ores | Chemical formula | Colour | Iron content (%) |
|---|---|---|---|
| 1. Magnetite | $Fe_3O_4$ | Black | 72 |
| 2. Hematite | $Fe_2O_3$ | Red | 70 |
| 3. Limonite | $FeO(OH).nH_2O$ | Brown | 60-65 |
| 4. Siderite | $FeCO_3$ | Brown | 40 |

**Pig iron:** Pig iron is obtained by heating and melting the first three iron ores with coke and limestone in the blast furnace at a temperature of about 2,000$^oC$

# Manufacturing of Pig Iron

Two processes take Place in the blast furnace: 1. de-oxidations of iron ores and 2. separation of iron from impurities like silica, alumina, clay, sand etc.




- In the first process(called reduction coke burns to carbon monoxide, which releases the iron from the ore.
- In the second process, limestone Becomes chemically active at high temperature and forms silicates and aluminates of calcium, called slag

which are lighter and floats on the top of the molten metallic iron. The slag is allowed to flow out into a separate container and heavier molten iron is collected into another container.

# Manufacturing of Pig Iron

**Blast furnace processing (Chemical reaction):**

- In the furnace, the coke reacts with oxygen in the air blast to produce carbon monoxide:
  - $2\ C + O_2 \rightarrow 2\ CO$
- The carbon monoxide reduces the iron ore (in the chemical equation below, hematite) to molten iron, becoming carbon dioxide in the process:
  - $Fe_2O_3 + 3\ CO \rightarrow 2\ Fe + 3\ CO_2$
- Some iron in the high-temperature lower region of the furnace reacts directly with the coke:
  - $2\ Fe_2O_3 + 3\ C \rightarrow 4\ Fe + 3\ CO_2$
- The flux present to melt impurities in the ore is principally limestone (calcium carbonate) and dolomite (calcium-magnesium carbonate). Other specialized fluxes are used depending on the details of the ore. In the heat of the furnace the limestone flux decomposes to calcium oxide (also known as quicklime):
  - $CaCO_3 \rightarrow CaO + CO_2$

# Manufacturing of Pig Iron

- Then calcium oxide combines with silicon dioxide to form a liquid slag.
  - $CaO + SiO_2 \rightarrow CaSiO_3$
- The slag melts in the heat of the furnace. In the bottom of the furnace, the molten slag floats on top of the denser molten iron, and apertures in the side of the furnace are opened to run off the iron and the slag separately. The iron, once cooled, is called pig iron, while the slag can be used as a material in road construction or to improve mineral-poor soils for agriculture.

# Composition of Pig Iron

**Composition of pig iron:**

| Constituent | Percentage of composition |
|---|---|
| 1. Iron | 92-94 |
| 2. Carbon (both free and combined) | 4-5 |
| 3. Silicon | 1-2 |
| 4. Manganese | 1-2 |
| 5. Sulphur and phosphorus | 1-2 |

**Classification of Pig iron:**

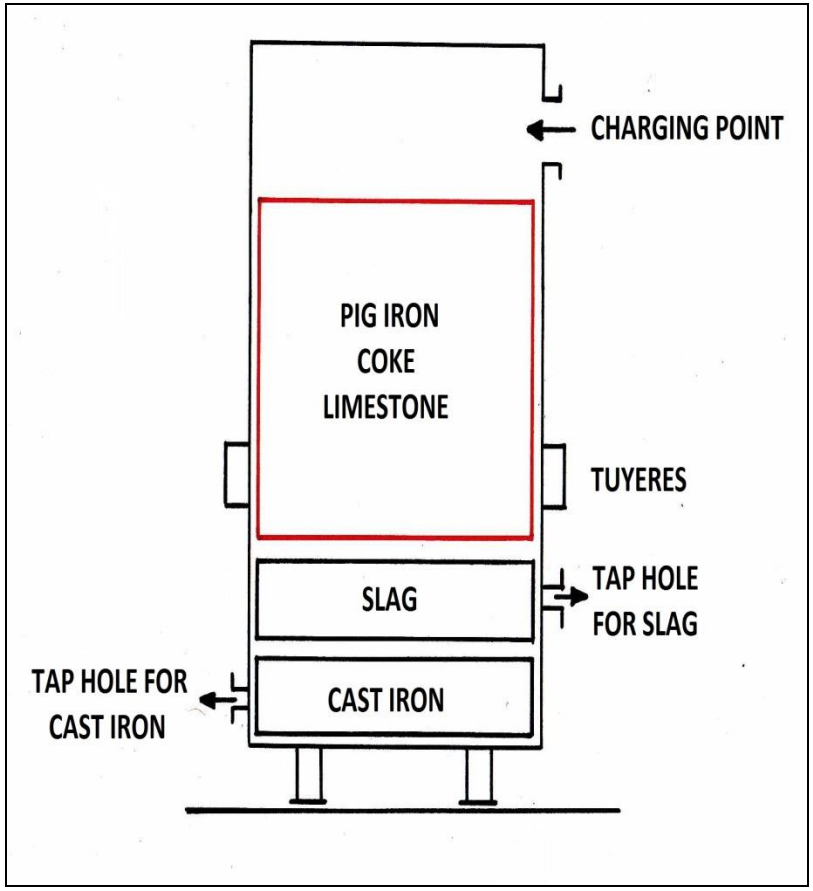
1. Gray Pig Iron: Contains 3-4% free carbon (graphite), <1% combined carbon. Silicon also 3-4%. Soft variety of pig iron.
2. White Pig Iron: Contains 3 or >3% combined carbon and <1% free carbon. Silicon <1%. Hard and strong. Wrought iron is made from it
3. Mottled Pig Iron: Contains equal amount of free & combined carbon

# Manufacture of Cast Iron

**Cast Iron:** Cast iron is manufactured by remelting gray pig iron (foundry pig iron) in a cupola furnace and running it into moulds of shape required. Cast iron differs considerably from wrought iron in chemical composition and physical characteristics. The most important consideration affecting the character and properties of cast iron is the carbon content. Cast iron is divided into 3 classes based on the different state of carbon content:

1. **Gray Cast Iron:** In it carbon occurs chiefly in the graphite state (free carbon).
2. **White Cast Iron:** In it carbon occurs chiefly as the carbide of iron (carbon in chemical combination with iron).
3. **Mottled Cast iron:** It is a mixture of gray iron with particles of white iron.

# Cupola Furnace



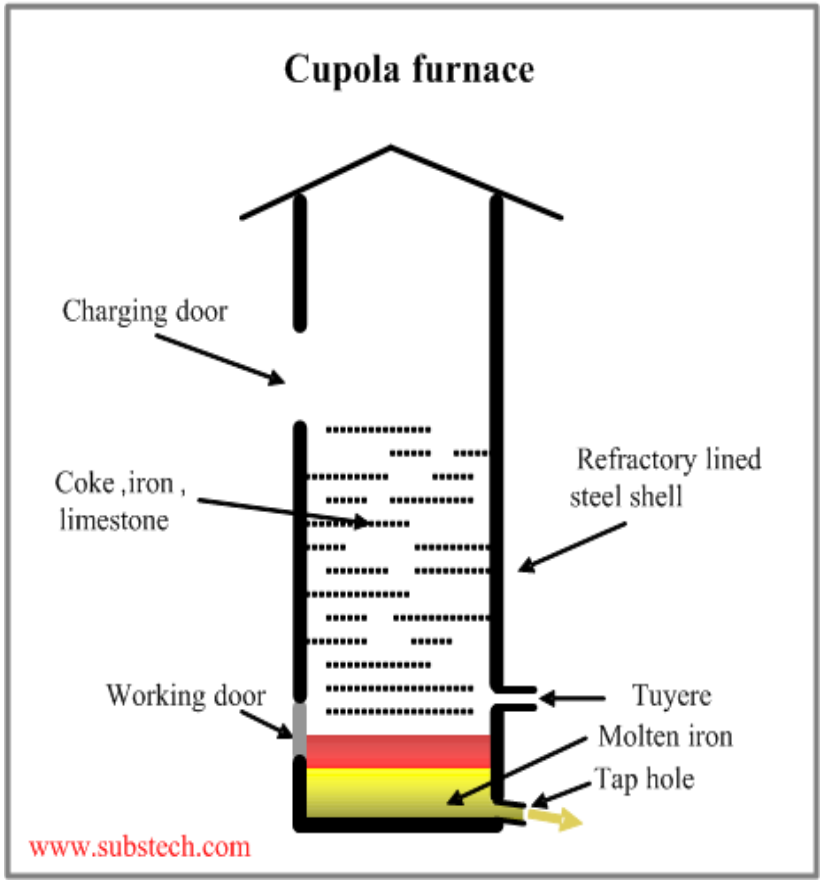
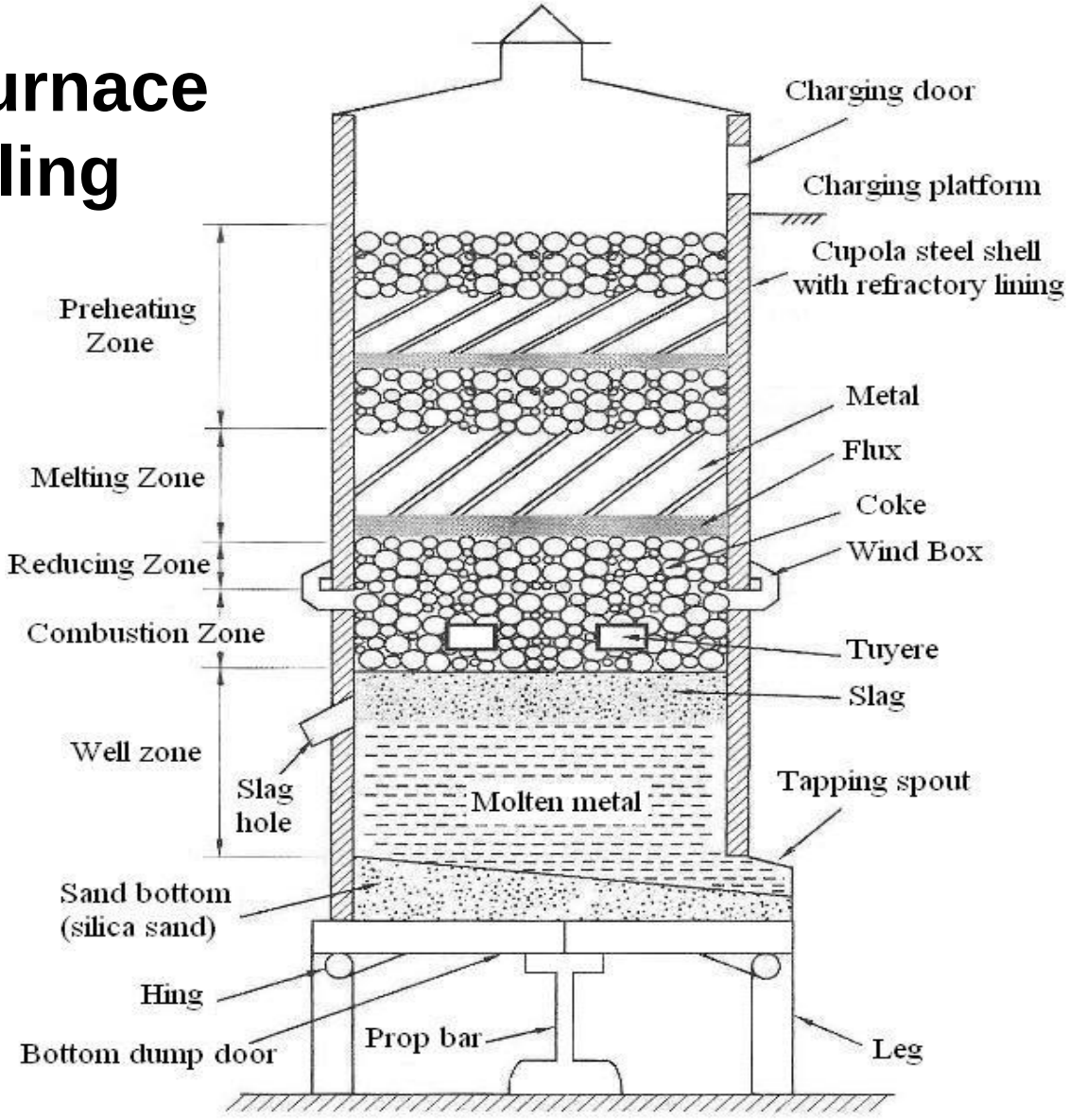




Fig. Cupola furnace in simplified form

# Fig. Cupola Furnace With leveling

Refractory materials must be chemically and physically stable at high temperatures

The oxides of aluminium (alumina), silicon (silica) and magnesium (magnesia) are the most important materials used in the manufacturing of refractories. Another oxide usually found in refractories is the oxide of calcium (lime).[4]Fire clays are also widely used in the manufacture of refractories.




Cupola Furnace

# Properties and Uses of Cast Iron

**Properties of Cast Iron:**

1. Cast iron is strong in compression but weak in tension.
2. It is brittle and does not absorb shocks.
3. It does not posses the property of ductility and malleability.
4. Shrinkage of cast iron is high ranges from 0.5 to 3 percent.

**Uses of Cast Iron:**

1. It is used to make CI pipes (used for water mains and sewers)
2. Making manhole covers, columns with their caps and bases.
3. Carriage wheels, parts of machinery and their structure subject to compression.
4. Gates, railings, window frames, gratings and other ornamental works.

# Malleable Cast Iron

**Malleable Cast Iron:** When cast iron is rendered malleable by a process of annealing, it is called malleable cast iron. Annealing is a process of heating metal above the critical temperature range, holding at that temperature for a specific period of time and then slowly cooling. Annealing makes the free carbon in combined form and increases considerably the degree of toughness, ductility and strength.

**Uses of malleable cast iron:** Malleable cast iron is used in automobile construction for rear axle housing, brake supports, steering-rear housing, hubs and pedals. Couplers, journal boxed, brake fittings etc. use to make many parts of agricultural machinery, pipes fittings, elbows, union sockets, valves, rings, window and door fitings. Carpenters' tool like hammers, saws, chisels etc. are made from malleable cast iron.

# Manufacture of Wrought Iron

**Wrought Iron:** Wrought iron is manufactured by melting the white pig iron is a puddling furnace. Wrought iron is the purest form of iron containing less than 0.12 percent of carbon.

Table. Constituents of typical high quality wrought iron

| Constituents | Composition (%) |
|---|---|
| 1. Iron | 96.00 |
| 2. Carbon | 0.10 |
| 3. Silicon | 0.20 |
| 4. Phosphorus | 0.25 |
| 5. Sulphur | 0.05 |
| 6. Manganese | 0.10 |
| 7. Slag | 3.25 |

# Fig. Puddling Furnace

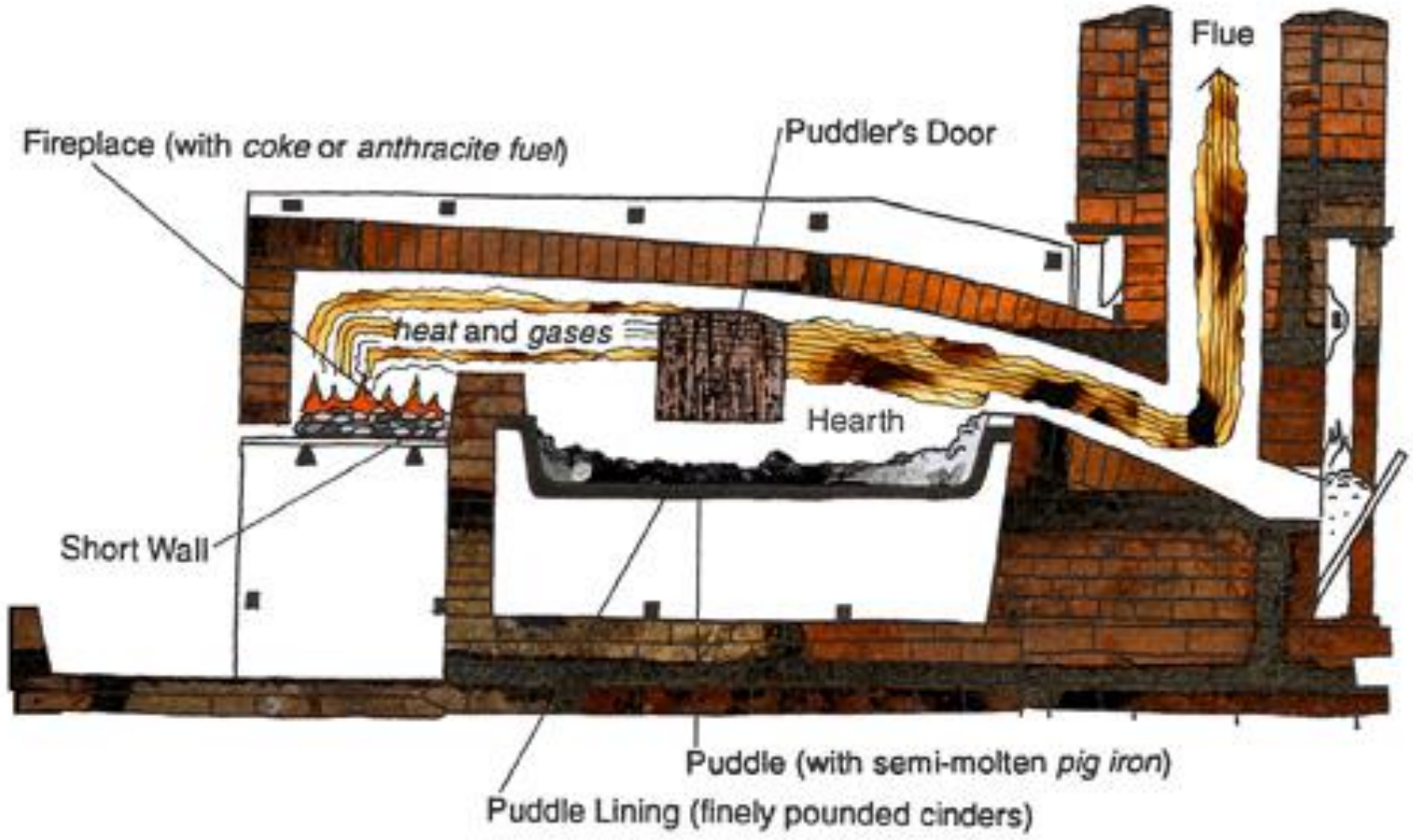



*Fig. 9 Diagram of a rolling-mill puddling furnace.*

# Properties and Uses of Wrought Iron

**Properties of wrought iron:** Principal properties of wrought iron are:

1. It becomes pasty and very plastic at red heat and could be forged about 1650$^{o}$F. It melts at 2800$^{o}$F.
2. Wrought iron is very malleable and ductile.
3. Its tensile strength varies from 48,000 to 50,000 psi.
4. It is stronger in compression by 25 percent.
5. Shearing strength varies from 20,000 to 35,000 psi.
6. Wrought shows good resistance to fatique and corrosion.
7. Important property, it can be welded with ease.

**Uses of wrought iron:** Principal uses of wrought iron are:

For standard pipes, bars, rods, wires, plates, sheets, welding fittings, rivets, etc. Wrought iron products are used for constructing building, bridge, chemical industries, corrugated sheets (CI Sheets) and ornamental works.

# The End