UNIT 1  METALS AND MELTING PRACTICES

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1.1 INTRODUCTION

Metal melting is the process of producing a liquid metal of the required composition at the required rate, and with required amount of superheat while incurring the minimal cost. It is one of the most important foundry practices, as it decides the quality of the casting. There are number of methods available for melting foundry alloys such as pit furnace, open hearth furnace, rotary furnace, cupola furnace, etc. The choice of the furnace depends on several factors, primary among them are the compositional range of the material to be melted, the fuel or energy used to melt the charge, the degree of refining and control over the process and type and size of the melting unit.

Objectives

After studying this unit, you should be able to

- know the various types of furnaces used for melting the metal,
- know the details of the operations carried out while melting a metals, and
- appreciate the importance of other melting practice with the melting of metals in the furnaces.
1.2 METAL MELTING

The basic melting process operations are:

- **furnace charging**, in which metal, scrap, alloys, carbon, and flux are added to the furnace,
- **melting**, during which the furnace remains closed,
- **back charging**, which involves the addition of more metal and alloys, as needed,
- **refining and treating**, during which the chemical composition is adjusted to meet product specifications as will be described later,
- **slag removing** (another step in the metal melting process) involves removing the slag in the furnace through a tapping hole or door. Since slag is lighter than molten iron, it remains atop the molten iron and can be raked or poured out of cupola furnaces through the slag hole located above the level of the molten iron. Electric arc and induction furnaces are tilted backwards, and their slag is removed through a slag door, and
- **tapping** molten metal into a ladle or directly into moulds.

Foundries melt metals is one of several types of furnaces depending on the type of metal being used (Table 1.1). Furnaces types include cupolas, electric arc, induction, or reverberatory etc. Because of the different nature of metals, different inputs are required.

Table 1.1: Common Types of Metal Melting Furnaces

<table>
<thead>
<tr>
<th>Furnace Type</th>
<th>Raw Materials</th>
<th>Outputs</th>
<th>Process</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cupola Furnace</td>
<td>Iron ore, scrap iron, lime,</td>
<td>Molten iron</td>
<td>Alternative layers of metal and coke are fed into the top of the furnace. The metal is melted by the hot gases from the coke combustion. Impurities react with the lime and are separated.</td>
</tr>
<tr>
<td></td>
<td>coke</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Electric Arc Furnace</td>
<td>Scrap iron, flux</td>
<td>Molten iron and steel</td>
<td>Electric arcs from carbon electrodes melt the scrap metal. The flux reacts with impurities.</td>
</tr>
<tr>
<td>Blast Furnace</td>
<td>Iron ore, pallets and sinters</td>
<td>Molten pig iron</td>
<td>Blast furnaces melt metal using blast of hot air, which causes coke to burn and produce gases resulting in reduction of oxygen from the ore.</td>
</tr>
<tr>
<td>Induction Furnace</td>
<td>Scrap iron or non-ferrous metals</td>
<td>Molten iron or non-ferrous metals</td>
<td>Induction furnaces are the most common type used by both ferrous and non-ferrous foundries. Copper coils heat the metal using alternating currents. The flux reacts with impurities.</td>
</tr>
<tr>
<td>Reverberatory, Hearth, or</td>
<td>Non-ferrous metals, flux</td>
<td>Molten non-ferrous metals</td>
<td>Reverberatory furnaces melt metals in batches using a pot-shaped crucible that holds the metal over an electric heater or fuel-free burner. The flux reacts with impurities.</td>
</tr>
<tr>
<td>Crucible Furnace</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

In the next sections of this unit, above mentioned different furnaces are discussed in detail. There are many other types of furnaces available but it is not possible to discuss
Metals and Melting Practices

1.3 CUPOLA FURNACES

Cupola furnaces are the oldest type of furnaces used in foundries. They are tall and roughly cylindrical and are most often used for melting iron and ferro alloys. Alternating layers of metal and ferro alloys, coke, and limestone are fed into the furnace from the top. Coke makes up 8 - 16% of the total charge to provide the heat that melts the metal. Limestone is added to react with impurities in the metal and floats to the top of the metal as it melts. As in steel melting, this limestone/impurities combination is called slag. By floating on top of the metal while it melts, the slag protects the metal from oxidation.

Cupola furnaces are lined with refractories, or hard, heat resistant substances such as fire clay, bricks or blocks. The refractory protects the furnace shell from abrasion, heat and oxidation. Over time the refractory breaks down and eventually becomes part of the slag.

Cupola furnaces are usually attached to emissions control systems to capture air emissions. Usually, the air emission systems use either high energy wet scrubbers that use water to remove air pollution from the gas stream or dry baghouse systems that use fabric filters to capture the emissions.

Figure 1.1 : Cupola

The cupola furnace is made up of a vertical steel shell, 6-12 mm thick lined with refractory material down the whole length. The lining is generally thicker in the lower region, i.e. beneath the charging door where the temperatures encountered are higher than in the upper region. A constant volume of air for combustion is obtained from a motorized blower of the positive displacement type. The air is carried from the blower through a pipe called the windpipe first to a circular jacket around the shell and then into the furnace through a number of openings called tuyeres. These tuyeres are generally 4, 6 or 8 in number depending on the size of the cupola. The combined area of air inlets or tuyeres should be about one-fourth of the cupola plan area. The height of the tuyeres from the bed of the cupola is about 450-500 mm. Opposite each tuyere a small window with mica covers makes the inspection of fire conditions possible. At the bottom of the bed a spout called the tapping spout is provided for the molten metal (as shown in...
Figure 1.1). Opposite this tap hole and somewhat above there is another hole called the slag hole which enables the slag to be taken out.

1.3.1 Cupola Operations

Preparation of Cupola
The slag and refuse on the lining from the previous run is removed and if necessary the lining itself is repaired or remade. The bottom plates are swung to closing position and the prop inserted beneath them. The sand bottom is then prepared with moulding sand such that it slopes towards the tap hole.

Firing the Cupola
The cupola is fired by kindling wood at the bottom. This should be done 2.5 to 3 hours before the molten metal is required. On top of the kindled wood a bed of coke is built. The height of this coke bed may vary from 50 cm to 125 cm according to the size of the cupola.

Charging the Cupola
When the coke bed has thoroughly ignited alternate layers of pig iron, coke and flux are charged from the charging door. Suitable scrap is also added with the pig iron to control the chemical composition of the iron produced. The thickness of the layers is kept about 150-200 mm. The purpose of adding flux is to eliminate the impurities and thereby refine the metal to protect the metal from oxidation and to render to slag more fluid for easy disposal. Besides limestone, fluorspar and soda ash also sometimes used as fluxing materials. The quantity of limestone, required may be 30-40 kg per ton of iron melted or 25% by weight of the coke charged.

Soaking of Iron
After the furnace has been fully charged it is so maintained for about 45 minutes. The charge gets slowly heated since the air blast is kept shut during this time. This causes the iron to get soaked.

Opening of Air Blast
At the end of the soaking period the air blast is opened. The tapping hole is kept closed by a plug called the bot till the time the metal gets molten and sufficient metal has accumulated. As the melting proceeds the contents of the charge move gradually downwards. The charge should therefore be replenished and the furnace be kept filled up to the charging door during the entire operation.

Pouring the Molten Iron
When sufficient metal has collected in the hearth above the sand bed, first the slag hole is opened to allow the slag to get ejected and then the hot metal from the tapping hole is removed. The molten metal that flows out of the spout is carried in ladles to the moulds for pouring. The same procedure is repeated until all the metal has melted and the operation is over. Sometimes a fore-hearth is used to collect molten metal from the cupola in a large quantity before it is transferred to the ladles.

Closing the Cupola
When the operation is over the blast is shut off and the prop knocked down so that the bottom plates swing open. This enables the sand inside the furnace to drop to the floor. They are then, quenched and removed from underneath the cupola.

1.4 ELECTRIC ARC FURNACES

Electric arc furnaces (EAF) are often used in large steel foundries and steel mills. The metal is charged into the furnace, with additives to make recovery of slag easier, and heat to melt the metal is produced with an electric arc from three carbon or graphite electrodes. The electric arc furnace is lined with refractories which slowly decompose and are removed with slag. Electric arc furnaces also usually employ air emissions.
equipment to capture most air pollution (see Figure 1.2). Furnace operations are discussed in detail below.

1.4.1 Furnace Operations

The electric arc furnace operates as a batch melting process producing batches of molten steel known as "heats". The electric arc furnace operating cycle is called the tap-to-tap cycle and is made up of the following operations:

**Furnace Charging**

The first step in the production of any heat is to select the grade of steel to be made. Preparation of the charge bucket is an important operation, not only to ensure proper melt-in chemistry but also to ensure good melting conditions. The scrap must be layered in the bucket according to size and density to promote the rapid formation of a liquid pool of steel in the hearth while providing protection for the sidewalls and roof from electric arc radiation. Other considerations include minimization of scrap cave-ins which can break electrodes and ensuring that large heavy pieces of scrap do not lie directly in front of burner ports which would result in blow-back of the flame onto the water cooled panels. The charge can include lime and carbon or these can be injected into the furnace during the heat. Many operations add some lime and carbon in the scrap bucket and supplement this with injection.

The roof and electrodes are raised and are swung to the side of the furnace to allow the scrap charging crane to move a full bucket of scrap into place over the furnace. The bucket bottom is usually a clam shell design i.e., the bucket opens up by retracting two segments on the bottom of the bucket. The scrap falls into the furnace and the scrap crane removes the scrap bucket. The roof and electrodes swing back into place over the furnace. The roof is lowered and then the electrodes are lowered to strike an arc on the scrap. This commences the melting portion of the cycle. The number of charge buckets of scrap required to produce a heat of steel is dependent primarily on the volume of the furnace and the scrap density. Most modern furnaces are designed to operate with a minimum of back-charges. This is advantageous because charging is a dead-time where the furnace does not have power on and therefore is not melting. Minimizing these dead-times helps to maximize the productivity of the furnace. In addition, energy is lost every time the furnace roof is opened.

**Melting**

The melting period is the heart of EAF operations. Melting is accomplished by supplying energy to the furnace interior. This energy can be electrical or chemical. Electrical energy is supplied via the graphite electrodes and is usually the largest contributor in melting operations. Initially, an intermediate voltage tap is selected until the electrodes bore into the scrap. Usually, light scrap is placed on top of the
charge to accelerate bore-in. Approximately 15% of the scrap is melted during the initial bore-in period. After a few minutes, the electrodes will have penetrated the scrap sufficiently so that a long arc (high voltage) tap can be used without fear of radiation damage to the roof. The long arc maximizes the transfer of power to the scrap and a liquid pool of metal will form in the furnace hearth. At the start of melting the arc is erratic and unstable. Wide swings in current are observed, accompanied by rapid movement of the electrodes. As the furnace atmosphere heats up the arc stabilizes and once the molten pool is formed, the arc becomes quite stable and the average power input increases.

Chemical energy is supplied via several sources including oxy-fuel burners and oxygen lances. Oxy-fuel burners burn natural gas using oxygen or a blend of oxygen and air. Heat is transferred to the scrap by flame radiation and convection by the hot products of combustion. Heat is transferred within the scrap by conduction. Large pieces of scrap take longer to melt into the bath than smaller pieces. In some operations, oxygen is injected via a consumable pipe lance to "cut" the scrap. The oxygen reacts with the hot scrap and burns iron to produce intense heat for cutting the scrap. Once a molten pool of steel is generated in the furnace, oxygen can be lanced directly into the bath. This oxygen will react with several components in the bath including, aluminum, silicon, manganese, phosphorus, carbon and iron. All of these reactions are exothermic (i.e., they generate heat) and supply additional energy to aid in the melting of the scrap. The metallic oxides that are formed will end up in the slag. The reaction of oxygen with carbon in the bath produces carbon monoxide, which either burns in the furnace if there is sufficient oxygen, and/or is exhausted through the direct evacuation system where it is burned and conveyed to the pollution control system.

**Refining**

Refining operations in the electric arc furnace have traditionally involved the removal of phosphorus, sulphur, aluminum, silicon, manganese and carbon from the steel. In recent times, dissolved gases, especially hydrogen and nitrogen, have been recognized as a concern. Traditionally, refining operations were carried out following meltdown i.e., once a flat bath was achieved. These refining reactions are all dependent on the availability of oxygen. Oxygen was lanced at the end of meltdown to lower the bath carbon content to the desired level for tapping. Most of the compounds which are to be removed during refining have a higher affinity for oxygen than the carbon. Thus the oxygen will preferentially react with these elements to form oxides which float out of the steel and into the slag.

In modern EAF operations, especially those operating with a "hot heel" of molten steel and slag retained from the prior heat, oxygen may be blown into the bath throughout most of the heat. As a result, some of the melting and refining operations occur simultaneously.

Phosphorus and sulphur occur normally in the furnace charge in higher concentrations than are generally permitted in steel and must be removed. Unfortunately the conditions favourable for removing phosphorus are the opposite of those promoting the removal of sulphur. Phosphorus removal is usually carried out as early as possible in the heat. Hot heel practice is very beneficial for phosphorus removal because oxygen can be lanced into the bath while its temperature is quite low. Early in the heat the slag will contain high FeO levels carried over from the previous heat thus aiding in phosphorus removal. High slag basicity (i.e., high lime content) is also beneficial for phosphorus removal but care must be taken not to saturate the slag with lime. This will lead to an increase in slag viscosity, which will make the slag less effective. Sometimes fluorspar is added to help fluidize the slag. Stirring the bath with inert gas like argon is also beneficial because it renews the slag/metal interface thus improving the reaction kinetics.

Sulphur is removed mainly as a sulphide dissolved in the slag. The sulphur partition between the slag and metal is dependent on slag chemistry and is
favoured at low steel oxidation levels. Removal of sulphur in the EAF is difficult. Most operations find it more effective to carry out desulphurization during the reducing phase of steelmaking. This means that desulphurization is performed during tapping (where a calcium aluminate slag is built) operations.

Control of the metallic constituents in the bath is important as it determines the properties of the final product. Oxygen reacts with aluminum, silicon and manganese to form metallic oxides, which are slag components. These metallics tend to react with oxygen before the carbon. They will also react with FeO resulting in a recovery of iron units to the bath. For example:

\[ \text{Mn} + \text{FeO} = \text{MnO} + \text{Fe} \]

Manganese will typically be lowered to about 0.06 % in the bath.

The reaction of carbon with oxygen in the bath to produce CO is important as it supplies a less expensive form of energy to the bath, and performs several important refining reactions. In EAF operations, the combination of oxygen with carbon can supply between 30 and 40 % of the net heat input to the furnace. Evolution of carbon monoxide is very important for slag foaming. Coupled with a basic slag, CO bubbles are tapped in the slag causing it to “foam” and helping to bury the arc. This gives greatly improved thermal efficiency and allows the furnace to operate at high arc voltages even after a flat bath has been achieved. Burying the arc also helps to prevent nitrogen from being exposed to the arc where it can dissociate and enter into the steel.

If the CO is evolved within the steel bath, it helps to strip nitrogen and hydrogen from the steel. Bottom tapping is beneficial for maintaining low nitrogen levels because tapping is fast and a tight tap stream is maintained. A high oxygen potential in the steel is beneficial for low nitrogen levels.

Decarburization is also beneficial for the removal of hydrogen. It has been demonstrated that decarburizing at a rate of 1 % per hour can lower hydrogen levels in the steel from 8 ppm down to 2 ppm in 10 minutes.

**De-slagging**

De-slagging operations are carried out to remove impurities from the furnace. During melting and refining operations, some of the undesirable materials within the bath are oxidized and enter the slag phase.

It is advantageous to remove as much phosphorus into the slag as early in the heat as possible (i.e., while the bath temperature is still low). The furnace is tilted backwards and slag is poured out of the furnace through the slag door. Removal of the slag eliminates the possibility of phosphorus reversion.

During slag foaming operations, carbon may be injected into the slag where it will reduce FeO to metallic iron and in the process produce carbon monoxide which helps foam the slag.

\[ \text{C} + \text{FeO} = \text{CO} + \text{Fe} \]

If the high phosphorus slag has not been removed prior to this operation, phosphorus reversion will occur. During slag foaming, slag may overflow the level in the EAF and flow out of the slag door.

The following table shows the typical constituents of an EAF slag:
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<table>
<thead>
<tr>
<th>Component</th>
<th>Source</th>
<th>Composition Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>CaO</td>
<td>Charged</td>
<td>40 - 60 %</td>
</tr>
<tr>
<td>SiO₂</td>
<td>Oxidation product</td>
<td>5 - 15 %</td>
</tr>
<tr>
<td>FeO</td>
<td>Oxidation product</td>
<td>10 - 30 %</td>
</tr>
<tr>
<td>MgO</td>
<td>Charged as dolomite</td>
<td>3 - 8 %</td>
</tr>
<tr>
<td>CaF₂</td>
<td>Charged - slag fluidizer</td>
<td></td>
</tr>
<tr>
<td>MnO</td>
<td>Oxidation product</td>
<td>2 - 5%</td>
</tr>
<tr>
<td>S</td>
<td>Absorbed from steel</td>
<td></td>
</tr>
<tr>
<td>P</td>
<td>Oxidation product</td>
<td></td>
</tr>
</tbody>
</table>

**Tapping**

Once the desired steel composition and temperature are achieved in the furnace, the tap-hole is opened, the furnace is tilted, and the steel pours into a ladle for transfer to the next batch operation (usually a ladle furnace or ladle station). During the tapping process bulk alloy additions are made based on the bath analysis and the desired steel grade as will be discussed in the end of this unit. De-oxidizers may be added to the steel to lower the oxygen content prior to further processing. This is commonly referred to as “blocking the heat” or “killing the steel”. Common de-oxidizers are aluminum or silicon in the form of ferrosilicon or silicomanganese. Most carbon steel operations aim for minimal slag carry-over. A new slag cover is "built" during tapping. For ladle furnace operations, a calcium aluminate slag is a good choice for sulphur control. Slag forming compounds are added in the ladle at tap so that a slag cover is formed prior to transfer to the ladle furnace. Additional slag materials may be added at the ladle furnace if the slag cover is insufficient.

**Furnace Turn-around**

Furnace turn-around is the period following completion of tapping until the furnace is recharged for the next heat. During this period, the electrodes and roof are raised and the furnace lining is inspected for refractory damage. If necessary, repairs are made to the hearth, slag-line, tap-hole and spout. In the case of a bottom-tapping furnace, the taphole is filled with sand. Repairs to the furnace are made using gunned refractories or mud slingers.

**SAQ 1**

(a) What is the purpose of adding flux in case of cupola?
(b) Where the slag hole should be positioned in the furnace and why?
(c) Why furnaces are designed to operate with minimum of back-charges?
(d) Describe the care that should be taken while removing phosphorus in Electric Arc Furnace.
(e) Why slag foaming is important in EAF furnaces?
(f) What is the procedure for slag foaming?
The purpose of a blast furnace is to chemically reduce and physically convert iron oxides into liquid iron called “hot metal”. The blast furnace is a huge, steel stack lined with refractory brick (as shown in Figure 1.3), where iron ore, coke and limestone are dumped into the top, and preheated air is blown from the bottom. The raw materials require 6 to 8 hours to descend to the bottom of the furnace where it becomes the final product of liquid slag and liquid iron. These liquid products are drained from the furnace at regular intervals. The hot air that was blown into the bottom of the furnace ascends to the top in 6 to 8 seconds after going through numerous chemical reactions. Once a blast furnace is started it continuously runs for four to ten years with only short stops to perform planned maintenance.

1.5.1 The Process

Iron oxide is added to the blast furnace in the form of raw ore, pellets or sinter. The raw ore is removed from the earth and sized into pieces that range from 0.5 to 1.5 inches. This ore is either Hematite ($\text{Fe}_2\text{O}_3$) or Magnetite ($\text{Fe}_3\text{O}_4$) and the iron content ranges from 50% to 70%. This iron rich ore can be charged directly into a blast furnace without any further processing. Iron ore that contains a lower iron content must be processed or beneficiated to increase its iron content. Pellets are produced from this lower iron content ore. This ore is crushed and ground into a powder so that the waste material called gangue can be removed. The remaining iron-rich powder is rolled into balls and fired in a furnace to produce strong, marble-sized pellets that contain 60% to 65% iron. Sinter is produced from fine raw ore, small coke, sand-sized limestone and numerous other steel plant waste materials that contain some iron. These fine materials are proportioned to obtain a desired product chemistry when mixed together. This raw material mix is then placed on a sintering strand, which is similar to a steel conveyor belt, where it is ignited by gas fired furnace and fused by the heat from the finer coke into larger size pieces that are from 0.5 to 2.0 inches. The iron ore, pellets and sinter then become the liquid iron producers in the blast furnace with any of their remaining impurities going to the liquid slag.

The coke is produced from a mixture of coals. The coal is crushed and ground into a powder and then charged into an oven. As the oven is heated the coal is cooked so most of the volatile matter such as oil and tar are removed. The cooked coal, called coke, is removed from the oven after 18 to 24 hours of reaction time. The coke is cooled and screened into pieces ranging from one inch to four inches. The coke contains 90 to 93% carbon, some ash and sulphur but compared to raw coal it is very strong. The strong pieces of coke with a high energy value provide permeability to heat and gases which are required to reduce and melt the iron ore, pellets and sinter.

The final raw material in the iron making process is limestone. The limestone is removed from the earth by blasting with explosives. It is then crushed and screened to a size that
Principle of Metal Casting

ranges from 0.5 inch to 1.5 inch to become blast furnace flux. This flux can be pure high calcium limestone, dolomitic limestone containing magnesia or a blend of the two types of limestone.

Since the limestone is melted to become the slag which removes sulphur and other impurities, the blast furnace operator may blend the different stones to produce the desired slag chemistry that create optimum properties such as a low melting point and a high fluidity.

All of the raw materials are stored in an ore field and transferred to the stockhouse before charging. Once these materials are charged into the furnace top, they go through numerous chemical and physical reactions while descending to the bottom of the furnace.

The iron ore, pellets and sinter are reduced which simply means the oxygen in the iron oxides is removed by a series of chemical reactions. These reactions occur as follows:

\[
\begin{align*}
(1) \quad & 3 \text{Fe}_2\text{O}_3 + \text{CO} = \text{CO}_2 + 2 \text{Fe}_3\text{O}_4 \\
\text{Begins at 850° F} \\
(2) \quad & \text{Fe}_3\text{O}_4 + \text{CO} = \text{CO}_2 + 3 \text{FeO} \\
\text{Begins at 1100° F} \\
(3) \quad & \text{FeO} + \text{CO} = \text{CO}_2 + \text{Fe} \\
\text{Begins at 1300° F} \\
\text{or} \\
(3) \quad & \text{FeO} + \text{C} = \text{CO} + \text{Fe} \\
\end{align*}
\]

At the same time the iron oxide is going through these purifying reactions, it begins to soften then melt and finally trickle as liquid iron through the coke to the bottom of the furnace.

The coke descends to the bottom of the furnace to the level where the preheated air or hot blast enters the blast furnace. The coke is ignited by this hot blast and immediately reacts to generate heat as follows:

\[
\text{C} + \text{O}_2 = \text{CO}_2 + \text{Heat}
\]

Since the reaction takes place in the presence of excess carbon at a high temperature the carbon dioxide is reduced to carbon monoxide as follows:

\[
\text{CO}_2 + \text{C} = 2\text{CO}
\]

The product of this reaction, carbon monoxide, is necessary to reduce the iron ore as seen in the previous iron oxide reactions.

The limestone descends in the blast furnace and remains a solid while going through its first reaction as follows:

\[
\text{CaCO}_3 = \text{CaO} + \text{CO}_2
\]

This reaction requires energy and starts at about 1600°F. The CaO formed from this reaction is used to remove sulphur from the iron which is necessary before the hot metal becomes steel. This sulphur removing reaction is:

\[
\text{FeS} + \text{CaO} + \text{C} = \text{CaS} + \text{Fe} + \text{CO}
\]

The CaS becomes part of the slag. The slag is also formed from any remaining Silica (SiO$_2$), Alumina (Al$_2$O$_3$), Magnesia (MgO) or Calcia (CaO) that entered with the iron ore, pellets, sinter or coke. The liquid slag then trickles through the coke bed to the bottom of the furnace where it floats on top of the liquid iron since it is less dense.

Another product of the ironmaking process, in addition to molten iron and slag, is hot dirty gases. These gases exit the top of the blast furnace and proceed through gas cleaning equipment where particulate matter is removed from the gas and the gas is cooled. This gas has a considerable energy value so it is burned as a fuel in the “hot blast stoves” which are used to preheat the air entering the blast furnace to become “hot blast”. Any of the gas not burned in the stoves is sent to the boiler house and is used to generate steam which turns a turbo blower that generates the compressed air known as “cold blast” that comes to the stoves.
In summary, the blast furnace is a counter-current reactor where solids descend and gases ascend. In this reactor there are numerous chemical and physical reactions that produce the desired final product which is hot metal. A typical hot metal chemistry follows:

- **Iron (Fe)**: 93.5 - 95.0%
- **Silicon (Si)**: 0.30 - 0.90%
- **Sulphur (S)**: 0.025 - 0.050%
- **Manganese (Mn)**: 0.55 - 0.75%
- **Phosphorus (P)**: 0.03 - 0.09%
- **Titanium (Ti)**: 0.02 - 0.06%
- **Carbon (C)**: 4.1 - 4.4%

### 1.6 INDUCTION FURNACES

Induction furnaces are the most widely used type of furnace for melting iron and are increasingly popular for melting non-ferrous metals. They are popular because they provide excellent metallurgical control and are relatively pollution free. Induction furnaces use alternating currents to create heat and melt the metal. The refractories are usually made of silica, alumina or magnesia. The two most common induction melting furnace designs are the coreless and channel furnaces. Coreless induction furnaces are used for smaller (5-10 ton) operations. Coreless furnaces are preferable where gas pickup and volatile metal alloy loss is a problem. Coreless melting furnaces use a refractory envelope to contain the metal, and surround that by the water-cooled, copper coil. Operating on the same basis as a transformer, the charge acts as a single secondary turn, thereby producing heat through eddy current flow when power is applied to the multi-turn primary coil as shown in Figure 1.4(a). When the metal melts, these electromagnetic forces also produce a stirring action.

**Figure 1.4(a) : Coreless-Induction Furnace**

For larger quantities, channel induction furnaces are used. In these furnaces the copper coils are surrounded by inductors to promote metal melting. Channel furnaces are commonly used to hold the molten metal prior to casting. In cored induction furnace, induction coil is essentially immersed within the metal bath. Electromagnetic induction pumps liquid metal through channels around the coil and simultaneously secondary currents (which act as the heating source) are induced in the liquid metal around the core (Refer Figure 1.4(b)). The major disadvantage of the cored induction furnace is that it requires a liquid metal starting charge therefore it is not suitable for intermittent operation. The cored furnace is used primarily for non-ferrous metals in applications where relatively long periods of continuous operations are desirable. Induction channel furnaces were used initially as molten metal holders, but are now used for some melting applications as well.
While all channel furnaces are line frequency, coreless furnaces can be line frequency (60 Hertz), medium frequency (200 Hertz through 1,200 Hertz) or high frequency (over 1,200 Hertz). Line frequency furnaces are slower to start from a cold charge resulting in growing preference for medium and high frequency units. Improvements in frequency converters and lower costs have also aided acceptance.

### 1.6.1 Melting Procedure for High Frequency Induction Furnace

The high-frequency induction furnace is essentially an air transformer in which the primary coil is a coil of water-cooled copper tubing and the secondary coil is the metal charge. Furnace capacity rarely exceeds 1 ton. Sketch of the furnace is shown in Figure 1.4. The shell of the furnace consists of asbestos board, and is supported on trunnions on which the furnace pivots when pouring. Inside the shell is placed the circular winding of copper tubing. Firebrick is placed on the bottom portion of shell, and the space between that and the coil is rammed with grain refractory. The furnace chamber may be a refractory crucible, or it may consist of a rammed and sintered lining. The general practice is to ganister rammed around a steel shell which melts down with the first heat, leaving a sintered lining. Basic linings are often preferred, and in this case either the lining may be rammed, using magnesia grain, or a clay-bonded magnesia crucible may be used.

The process consists of charging the furnace with steel scrap and then passing a high-frequency current through the primary coil, thus inducing a much heavier secondary current in the charge, which results in heating the metal charge by resistance. As soon as a pool of metal is formed, very pronounced stirring action in the molten metal takes place, which helps to accelerate melting. In this process, melting is quite rapid, so much so that there is only a slight loss of the easily oxidized elements. If a capacity melt is required, steel scrap is added continually during the melting-down period. As soon as melting is complete, the desired superheat temperature is obtained and the metal is deoxidized and tapped into ladles.

The time of melting depends upon the size of the furnace, the weight of the charge, and the power input. Since a period of only 10 or possibly 15 min elapses from the time the charge is melted down until the heat is tapped, there is not sufficient time for chemical analyses. Thus the charge is usually carefully selected from scrap and alloys of known composition so as to produce the desired analyses in the finished steel. A very close control of elements can be obtained in this manner.

In most cases, no attempt is made to melt under a slag cover, since the stirring action of the bath makes it difficult to maintain a slag blanket on the metal. However, a slag cover is not necessary since oxidation is slight.

### 1.6.2 Induction Furnace Advantages and Disadvantages

Induction furnaces offer certain advantages and disadvantages over other furnace systems. They include:

**Advantages**
Higher Yield: The absence of combustion sources reduces oxidation losses that can be significant in production economics. This can amount to 2 to 7 percent yield savings in aluminum melting.

Faster Startup: Full power from the power supply is available, instantaneously, thus reducing the time to reach working temperature. Cold charge-to-tap times of one to two hours are common.

Flexibility: No molten metal is necessary to start medium frequency coreless induction melting equipment. This facilitates repeated cold starting and frequent alloy changes.

Natural Stirring: Medium frequency units can give a strong stirring action resulting in a homogeneous melt.

Cleaner Melting: No by-products of combustion means a cleaner melting environment and no associated products of combustion pollution control systems.

Automatic Operation: Precise automatic control of power reduces furnace manpower to that required only for charging, tapping, and metallurgical measurements.

Compact Installation: High melting rates can be obtained from small furnaces. A coreless furnace capable of melting 2,500 lbs./hr. of aluminum has a crucible measuring 3’ in diameter by 6’ in depth.

Reduced Refractory: The compact size in relation to melting rate means induction furnaces require much less refractory than fuel-fired units. New hydraulic ram systems allow relining times to be greatly reduced as old worn linings can be quickly “pushed out” for easy replacement.

Better Working Environment: Induction furnaces are much quieter than gas furnaces, arc furnaces, or cupolas. No combustion gas is present and waste heat is minimized.

Energy Conservation: Overall energy efficiency in induction melting ranges from 55 to 75 percent, and is significantly better than combustion processes.

Disadvantages

(i) Initial cost is high.
(ii) Due to high speed of melting bath sampling cannot be carried out.
(iii) Refining process cannot be used due to the difficulties in maintaining hot fluid, and reactive slag on the metal surface.

SAQ 2

(a) How the iron content in the iron ores is increased before charging it to blast furnace?
(b) Why induction furnaces are popular for melting of non-ferrous metals?
(c) Explain the reason for more careful selection of charge in case of coreless induction furnaces.
(d) In induction furnaces slag cover is not must, why?

1.7 REVERBERATORY FURNACES

It is a furnace designed for operations in which it is not desirable to mix the material being heated with the fuel. The flame is directed at the roof of the furnace and the heat radiated downwards. This type of furnace used in smelting of copper and nickel ores. It is also used in melting of aluminium and other non-ferrous metals.

Reverberatory furnaces come in many different configurations but can be categorised in three main groups.
1.7.1 Standard Reverberatory
These are usually of a rectangular or square shape and can be either static or tilting. Scrap is normally charged in through the main furnace door in either a lose or baled format. Dross will float to the surface and, unless removed, can hinder heat transfer to the molten metal. The main furnace door has to be opened to charge material or to dross off, giving rise to a substantial heat loss from the furnace. If decoated material is to be fed into these types of furnaces the material is usually allowed to cool and then is baled prior to charging. This means that the heat energy contained in the scrap during decoating is lost. Characteristics of this type of furnace include:
- Batch type operation
- Low capital cost
- Low recoveries
- Exhaust gases may require treatment

1.7.2 Sidewell Reverberatory
The sidewell furnace is widely used in North America for recycling operations. The furnace consists of reverb chamber as described above, but with the addition of a side well. Scrap metal is charged into the sidewell and is submerged quickly. Any dross formed collects in the dross well and can be easily removed. This helps to keep the main furnace chamber clean. Some form of pumping system is usually employed to circulate the metal. The most common is the mechanical pumping system which have a low capital cost. These pumps do require some regular maintenance but this can normally be done without bringing the furnace out of service. Electro-Magnetic systems are now gaining popularity. These have a higher capital cost but reduced maintenance requirements. Depending upon design, the furnace may have to be taken out of service for maintenance to be performed. Sidewell furnaces are ideal for decoated product as they allow the scrap to be charged on a continuous basis from the decoating system. If charged quickly the scrap is still hot after decoating (typically 300 – 450°C) which means that the energy required to melt the scrap will be reduced markedly. This combined with the submerging action of the sidewell promotes melt time and the reduction of dross. As melting is on a continuous basis, there will often be a mechanical system for automatically feeding flux into the furnace. A hood can be sited above the sidewell to collect any fumes that may arise. If dirty scrap (coated) is charged, these fumes could be an environmental hazard and consideration should be given to treatment of these gases, normally by some form of after burning.
Characteristics of this type of furnace include:
- Continuous charging, ideal for use with decoating system.
- Moderate capital cost.
- Suitable for most scrap types.
- Clean exhaust gases if decoated scrap is used.
- High recoveries when used with good quality decoated scrap.
1.7.3 Dual Chamber Reverberatory

The dual chamber furnace consists, as the name suggests, of two separate sections within the main furnace. Scrap is normally charged onto a dry hearth section and left for a period of time for the Volatile organic compounds to evolve. During this time the scrap heats up to close to melting point. The gases are extracted to, and combusted in the rear chamber. As the next batch of scrap is charged, the previous load is pushed into the molten bath to finish melting.

These furnaces typically employ some form of pumping system that again can be either Mechanical or Electromagnetic, often with a separate sidewell. Some designs utilise the rear chamber of the furnace as an after burner while other may have a separate afterburner. These furnaces are normally fed with dirty scrap that has not been decoated.

Recoveries for heavy scrap types are claimed to be high but they appear to be unsuitable for lightweight scrap types. One disadvantage with this type of furnace is that as they try to combine the process of decoating and melting within one furnace, requiring very complex process control. As the Volatile organic compounds evolve in a batch then the combustion chamber must be sized for peak loading and there are periods when there may be excessive energy available and others when the burners must operate at a higher level to compensate for lower loadings.

Characteristics of this type of furnace can be summarised as:

- Batch type operation
- All in one solution for melting scrap
- High Capital Cost
- Good recoveries reported with heavy scrap types. May not be suitable for lightweight scrap types
- Combustion chamber has to be sized for peak loading

1.8 OTHER MELTING PRACTICES

The different types of furnaces used in melting outlined in the first section of this unit. But melting operations usually involve much more than simply adding enough heat to liquify solid metal. The furnace atmosphere must carefully be controlled to avoid unwanted impurities and loss of important elements. Unwanted impurities are removed by refining or degassing. Final solidification structure can be improved by inoculation. In this section, we are going to discuss these techniques in general which can be used after tapping in some cases and while melting of the metal in few other cases as well.

1.8.1 Degassing

When it is not possible to prevent gas absorption the hazards of dissolved gases may be reduced by

(i) removing the gas or gases or
(ii) removing or isolating one or more of the components of the gas.

Hydrogen is completely removed from the atmosphere around a melt, any hydrogen gas dissolved will tend to escape. Thus melting and pouring under a vacuum is one method but it is very expensive. Vacuum degassing is another attempt to combine the advantages of vacuum, letting with the economy of air melting. In this method metal is placed in an evacuated chamber (for degassing) before pouring; pouring takes place in the open atmosphere. Flushing with an inert gas like argon is the most common method of removing gas. In this method the inert gas is bubbled directly through the metal. The pressure of the dissolved gas within each inert gas bubble is zero. Therefore any dissolved gas migrates readily to the bubble where it collects and is flushed from the metal baths.
Inert gases such as chlorine, nitrogen or argon are used in practice for degassing metals especially aluminium and magnesium alloys. The gases are simply piped from storage tanks through graphite tubes directly into the metal baths. Sometimes solid degassers are also used as a source of the inert gas. Here a solid compound held beneath the melt surface decomposes to give the flushing action. In steel making practice the CO from the carbon boil acts as an inert gas to flush hydrogen from the metal (as discussed in the previous sections). Gas porosity is also minimized by removing or isolating one of the components of the gas. Thus in steel making after the carbon boil has progressed to the desired point it is blocked by adding silicon or aluminum to the bath to tie up one of the reagents of the CO gas. Another example is the addition of phosphor-copper to copper base alloys to tie up dissolved oxygen. The phosphorus combines with dissolved oxygen to form a solid P₂O₅ which floats out of the bath and prevents the oxygen from combining with any dissolved hydrogen to form water vapour.

1.8.2 Refining
Refining in the melting operation is the removal of unwanted impurities from the metal bath. The general types of impurities that may be present are

(i) dissolved gases (as discussed in sub-section 1.8.1),
(ii) dissolved non-gaseous elements, and
(iii) suspended oxides and inclusions.

In non-ferrous melting no attempt is made in the foundry to remove dissolved impurities. Dissolved gases are removed by one of the degassing techniques described above. A refining operation to remove entrapped oxides and inclusions is often necessary in non-ferrous metals-especially in aluminium and magnesium alloys. These alloys easily form solid oxides called dross which tend to remain suspended in the melt. Sufficient time must be allowed for the particles to float to the surface in the furnace and ladle or they must be fluxed from the metal by stirring a reactive salt flux into the bath.

In the case of steel two general types of melting practices – acid practice and basic practice – are used. Acid melting involves the use of acid refractories and acid slags in contact with the metal. Such slags and refractories are high in SiO₂ content and low in CaO and MgO. Basic melting involves slags and refractories of relatively high CaO and MgO content. In acid melting, dissolved gases and suspended non-metallics are removed, and carbon composition is adjusted. Phosphorus and sulphur contents are not however affected and since these impurities are deleterious to the mechanical and casting properties of steel, acid melting requires an initial charge low in these elements. Basic melting possesses the metallurgical advantages of acid melting, with the addition that sulphur and phosphorus may be reduced to any desired level by properly controlling the many melting variables involved, particularly the concentration of lime and iron oxide in the slag. Basic melting therefore can employ a lower and cheaper grade of scrap as charge material.

In the melting of ferrous metals phosphorus removal is promoted by slags which are both basic and oxidizing. Sulphur removal is promoted by slags which are basic and reducing. Thus melting conditions for optimum sulphur removal are not the same as those for optimum phosphorus removal. For example melting of steel in the basic open-hearth furnace takes place under oxidizing conditions. The basic open hearth reduces phosphorus contents of steel to very low values but is less efficient in regard to sulphur. In the basic cupola melting of cast iron takes place under reducing conditions. Sulphur is readily removed but under ordinary melting practices little reduction of phosphorus takes place. In electric furnace melting of steel both phosphorus and sulphur may be reduced to very low values by a double slag melting practice. The metal is melted under a highly oxidizing basic slag to accomplish phosphorus removal; this slag is then removed and replaced with a basic reducing slag to lower the sulphur content.

Until recently refining operations in cast iron were limited. Essentially all cast iron was melted in the acid cupola furnace which permits close control of carbon and silicon
contents but does not remove sulphur or phosphorus. Sulphur elimination in cast iron is now accomplished by:

(i) melting in a basic cupola,
(ii) melting in a basic electric furnace, or
(iii) melting in an acid cupola and adding desulphurizing compounds in the forehearth or ladle.

Since phosphorus removal is not ordinarily accomplished in the cupola it is necessary to avoid high phosphorus charge materials for the cupola melting practice; both phosphorus and sulphur may however be removed by a double slag electric furnace operation. Desulphurization in the ladle may be accomplished in a variety of ways; two of these being to pour over a sodium oxide slag or to inject powdered desulphurizers such as calcium carbide. Injections is accomplished by blowing the powders into the metal through a tube immersed in the melt.

### 1.8.3 Inoculation

Inoculation is the addition made to a melt that alters the solidification structure of gray iron. It involves the use of certain materials that, when added to molten iron before casting, make higher quality, more predictable, gray and ductile iron castings. Its primary purposes are to improve the mechanical properties and the machinability of iron castings. Inoculants most commonly are 70-90% ferrosilicon blended with calcium (0.50% minimum) and aluminum (1.0-1.4%). At times, the molten metal may be inocculated with graphite to adjust carbon content or treated with calcium carbide to reduce the sulphur content.

In grain-refining aluminium alloys less than 0.2 per cent, titanium or 0.02 per cent boron is sufficient to reduce the cast grain size of the alloy from as much as 0.10 in diameter to as little as 0.005 in diameter. Magnesium aluminium alloys are somewhat anomalous; most other cast metals tend to exhibit a coarser grain structure when they are superheated high above their melting point. Magnesium alloys which do not contain aluminium are usually grain refined with small additions of zirconium. Magnesium-aluminium alloys are grain refined by small additions of carbon to the melt, or by superheating the metal to about 165°F.

A slight different type of inoculation treatment is the graphitizing inoculation of gray cast iron. Here the inoculant promotes graphite formation and is used to prevent “chilling” (formation of white iron in thin sections) and to avoid the undesirable “interdendritic graphite” structure which sometimes forms on rapid cooling. Common graphitizers employed are ferrosilicon, nickelsilicon, silicon-manganese-zirconium and calcium-manganese-silicon. These inocculants must be added late in the melting operation or their effectiveness is diminished.

A most important and very new inoculation treatment is that of adding small quantities of magnesium to cast iron to produce ductile iron. The addition of as little as 0.04 per cent residual magnesium alters the graphite flakes to almost perfect spheroids with tremendous improvement in mechanical properties of the alloy. A metallurgically similar phenomenon to the magnesium treatment of ductile iron is the sodium inoculation of aluminium-silicon alloys. In this case minute quantities of sodium alter a needle like AlSi precipitate to a finely divided eutectic structure. This treatment has been in use for many years. It substantially improves the ductility of aluminium silicon alloys containing more than about 8 to 10 per cent silicon.

It is known that the action of these inoculants is due to more than a simple alloying effect. Two melts with analytically identical final chemical composition may produce very different microstructures depending on the time, temperature and type of inoculating additions. Typical of this is the graphitization inoculation of cast iron; a ferrosilicon addition made late in the melting operation is a far more effective graphitizer than a similar addition made earlier. The effects of inoculants seem to be due to more subtle causes than chemistry; for example, grain refiners and graphitizers probably promote nucleation in the melt by introducing "foreign" nuclei into the liquid metal.
Other inoculants such as those that produce ductile iron may change the surface tension of solidifying particles and thereby alter nucleation and/or growth.

### 1.8.4 Bessemer Process

It is an industrial process for the manufacture of steel from molten pig iron. The principle involved is that of oxidation of the impurities in the iron by the oxygen of air that is blown through the molten iron; the heat of oxidation raises the temperature of the mass and keeps it molten during operation. The process is carried on in a large container called the Bessemer converter as shown in Figure 1.6, which is made of steel and has a lining of silica and clay or of dolomite. The capacity is from 8 to 30 tons of molten iron; the usual charge is 15 or 18 tons. The converter is egg-shaped. At its narrow upper end it has an opening through which the iron to be treated is introduced and the finished product is poured out. The wide end, or bottom, has a number of perforations (tuyeres) through which the air is forced upward into the converter during operation. The container is set on pivots (trunnions) so that it can be tilted at an angle to receive the charge, turned upright during the blow, and inclined for pouring the molten steel after the operation is complete. As the air passes upward through the molten pig iron, impurities such as silicon, manganese, and carbon unite with the oxygen in the air to form oxides; the carbon monoxide burns off with a blue flame and the other impurities form slag. Dolomite is used as the converter lining when the phosphorus content is high; the process is then called basic Bessemer. The silica and clay lining is used in the acid Bessemer, in which phosphorus is not removed. In order to provide the elements necessary to give the steel the desired properties, another substance (an iron-carbon-manganese alloy) is usually added to the molten metal after the oxidation is completed. The converter is then emptied into ladles from which the steel is poured into molds; the slag is left behind. The whole process is completed in 15 to 20 min.

![Figure 1.6: The Bessemer Process](image)

### 1.8.5 Converters

Cast iron, containing the usual amounts of carbon, manganese and silicon can be converted into steel by blowing air through or over molten iron. In operation molten iron is transferred from the cupola by ladles to an oval vessel called a converter. The vessel is levelled and iron is poured into the open nose; as soon as the unit is tilted back into position air is blown through tuyeres in the bottom or side. The air oxidizes the silicon, manganese and carbon. High carbon cast iron is reduced to very low-carbon cast iron essentially free of silicon and manganese; the blow is continued until carbon is reduced to 0.10-0.20 percent to prevent undue oxidation of iron. The order of oxidation of elements and their rate of oxidation can be followed by the color and length of flame issuing from the converter nose. No fuel is required for converting; the oxidizing reactions are exothermic and more heat is added to the metal than is removed by passing...
air through or over the charge. Ferroalloys of carbon, manganese and silicon are added to the molten iron as it is tapped into a pouring ladle, to adjust the metal to required composition.

SAQ 3
(a) Reverberatory furnaces are recommended for what kind of operations?
(b) How the reverberatory furnaces are different from the other furnaces?
(c) What are two different types of melting practices? Explain the difference in the refining treatment in each case.
(d) Why are graphitizers so important in treating the cast iron?
(e) How are the impurities removed in Bessemer Converter?

1.9 SUMMARY
There are different kinds of furnaces available for melting in foundry. In general cast iron is melted mostly in cupolas. Steel for casting is commonly melted in arc furnaces. Induction furnaces can nearly melt all commercial metals and alloys. Aluminium and copper base alloys can be melted in reverberatory furnaces. All these types of furnaces have been dealt with in this unit.

The basic raw material for making steel is scrap whereas for cast iron scrap and pig iron, variety of other melting practices are also used in foundries for refining, inoculation etc. to achieve the desired properties of the molten metal. In the last part of this unit these practices have been discussed.

1.10 KEY WORDS

Alloy : Usually a mixture of metals but steel is an alloy that contains some non-metals, especially carbon.
Blowing : An operation in which a gas, often oxygen, is blown into the furnace.
Carbon Monoxide : A toxic flammable gas, formula CO. The gaseous reducing agent that reduces iron ore in the Blast Furnace.
Charging : An operation in which raw materials are added to a furnace.
Coke : An impure form of carbon that is made by baking coal in sealed ovens. Used as a reducing agent in blast furnaces.
Flux : A chemical substance, usually a base, which combines with impurities to make a molten slag.
Hearth : A heat-resistant basin at the bottom of a furnace, in which molten metal collects.
Ladle : A large bucket used as a carrier for molten metal.
Limestone : A Blast Furnace raw material that removes impurities such as silica from the ore. Mainly made from calcium carbonate, CaCO₃.
Ore : A substance in the Earth's crust that contains enough metal for it to be profitably mined.
Reducing Agent : A substance that brings about reduction.
Principle of Metal Casting

Sinter: A Blast Furnace raw material that is made by heating iron ore and coke together to make coarse lumps.

Slag: A waste product of iron and steel making, used to remove impurities. In particular, a by-product of the Blast Furnace that is formed when limestone combines with impurities in the ore.

Tapping: An operation in which molten metal is allowed to run out of a furnace.

Vacuum Degassing: A method used to remove impure gases from a molten metal by shaking it at very low pressures.

1.11 ANSWERS TO SAQs

Refer to the preceding text and the books given under “Further Reading”.
Manufacturing is the lifeline of an industrialized society. Without it, no nation can afford many of the amenities required to improve the life quality of its citizens. In this context, it is important to study the techniques to manufacture. Therefore in this course some of the basic concept of manufacturing have been discussed.

This course has been designed with a view to introduce the conventional methods of production to you. Non-conventional methods will be discussed later under the course “Advanced Manufacturing Technology”. Conventional methods such as casting, cold working, hot working and welding etc. have been dealt with in sufficient detail required for understanding of the fundamentals.

While developing this course, it is assumed that you have sufficient knowledge of engineering materials and machines, although most of the concepts are defined, however briefly, to aid recapitulate and self study.

This course is divided into four blocks.

The first block deals with essentials of metals and melting practices. It covers Moulding Materials. It also describes the conventional moulding processes.

In Block 2, we have considered the concepts of metal forming like Principle of Elastic and Plastic Deformation, Bulk Deformation Processes and Sheet Metal Forming Processes.

Block 3 starts with Geometry of the Tools. After this the concepts of force and power requirement and cutting conditions are explained in the next two units. In the end, machining economics has been covered in details.

In the last Block, i.e. Block 4, various welding processes are covered. After this Welding Defects have been discussed in detail. In the end, concepts of Thermal Cutting are explained.
PRINCIPLE OF METAL CASTING

Block 1, comprising three units, deals with some of the basics of metal casting. There are special techniques used for melting and casting of the metals to reduce the wastage. In this block melting practices and materials have been described.

Unit 1 deals with metals and melting practices. There are number of methods available for melting foundary alloys. In this unit, some of these methods have been described.

Unit 2, entitled “Moulding Materials”, deals with the different types of materials used in the moulding of metals. In this unit, sand which is the most widely used material with the modification in composition has been discussed in detail.

Finally, Unit 3 discusses the conventional moulding processes. Even today in most of the cases they are the first ones to be used in manufacturing. In this unit, various moulding processes based on the types of moulds, pouring techniques, types of pattern and material are described.