Pig Iron

Objectives: At the end of this lesson you shall be able to
- **name the commonly used ferrous metals**
- **state the main raw materials used for the smelting of pig-pron and their uses**
- **name the ores used for producing pig-iron**
- **state the constructional features of a blast furnace**
- **state the properties and uses of pig-iron.**

Metals which contain iron as a major content are called ferrous metals. Ferrous metals of different properties are used for various purposes.

The ferrous metals and alloys used commonly are:

- Pig-iron
- Cast iron
- Wrought iron
- Steels and alloy steels.

Different processes are used to produce iron and steel.

Pig-iron is obtained by the chemical reduction of iron ore. This process of reduction of the iron ore to pig-iron is known as SMELTING.

The main raw materials required for producing pig-iron are:

- Iron ore
- Coke
- Flux.

Iron ore

The types of iron ores

- Magnetite
- Hematite
- Limonite
- Carbonate.

These ores contain iron in different proportions and are 'naturally' available.

Coke

Coke is the fuel used to give the necessary heat to carry on the reducing action. The carbon from the coke in the form of carbon monoxide combines with the iron ore to reduce it to iron.

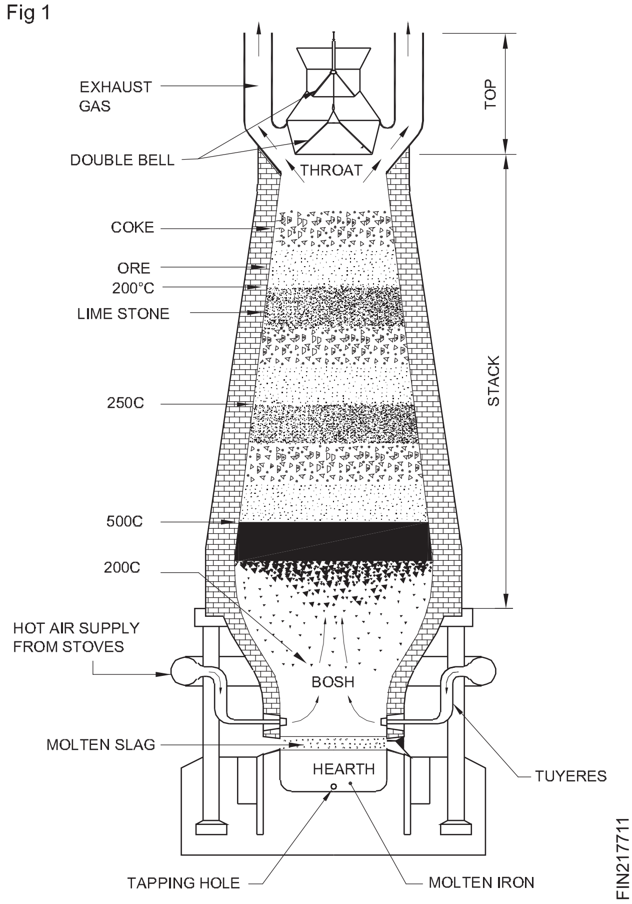
Flux

This is the mineral substance charged into a blast furnace to lower the melting point of the ore, and it combines with the non-metallic portion of the ore to form a molten slag.

Limestone is the most commonly used flux in the blast furnace.

Blast furnace (Fig 1)

Fig 1



The furnace used for smelting iron ore is the blast furnace. The product obtained from smelting in the blast furnace is pig-iron. The main parts of the blast furnace are:

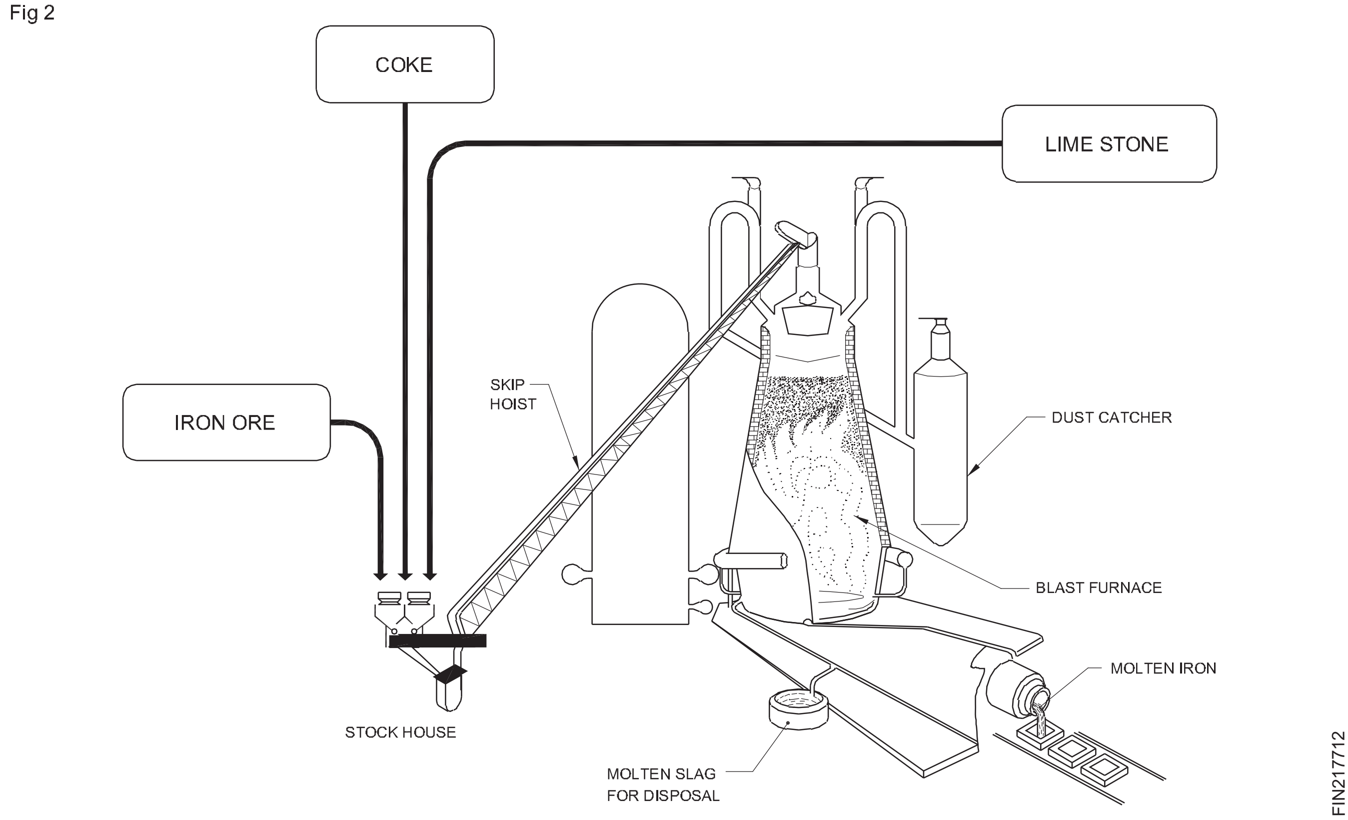
- Throat
- Stack
- Bosh

- Hearth
- Double bell charging mechanism
- Tuyeres.

Smelting in a blast furnace

The raw materials are charged in alternate layers of iron ore, coke and flux in the furnace by means of a double bell mechanism. (Figs 1 & 2)

Fig 2



The hot blast is forced into the furnace through a number of nozzles (Fig1) called tuyeres.

The temperature of the furnace just above the level of the tuyeres (melting zone) is between 1000° C to 1700° C when all the substances start melting.

The limestone, which serves as a flux, combines with the non-metalic substances in the ore to form a molten slag which floats on the top of the molten iron. The slag is tapped off through the slag hole.

The molten iron is tapped at intervals through a separate tapping hole.

The molten iron may be cast in pig beds or used in other processing plants for steel making.

Properties and use of pig-iron

Pig-iron absorbs varying amounts of carbon, silicon, sulphur, phosphorus and manganese during the smelting process. A high amount of carbon makes the pig-iron very hard and brittle, and unsuitable for making any useful article.

Pig-iron is, therefore, refined and remelted and used to produce other varieties of iron and steel.

Cast iron (types)

Objectives: At the end of this lesson you shall be able to
- **name the different types of cast iron**
- **state the properties of each type of cast iron**
- **state the uses of each type of cast iron.**

Cast iron is an alloy of iron, carbon and silicon. The carbon content ranges from 2 to 4%.

Types of cast iron

The following are the types of cast iron.

- Grey cast iron
- White cast iron
- Malleable cast iron
- Nodular cast iron

Grey cast iron

This is widely used for the casting of machinery parts and can be machined easily.

Machine bases, tables, slideways are made of cast iron because it is dimensionally stable after a period of aging.

Because of its graphite content, cast iron provides an excellent bearing and sliding surface.

The melting point is lower than that of steel and as grey cast iron possesses good fluidity, intricate casting can be made.

Grey cast iron is widely used for machine tools because of its ability to reduce vibration and minimize tool chatter.

Grey cast iron, when not alloyed, is quite brittle and has relatively low tensile strength. Due to this reason it is not used for making components subjected to high stress or impact loads.

Grey cast iron is often alloyed with nickel, chromium, vanadium or copper to make it tough.

Grey cast iron is weldable but the base metal needs pre-heating.

White cast iron

This is very hard and is very difficult to machine, and for this reason, it is used in components which should be abrasion-resistant.

White cast iron is produced by lowering the silicon content and by rapid cooling. When cooled in this manner,it is called chilled cast iron.

White cast iron cannot be welded.

Malleable cast iron

Malleable cast iron has increased ductility, tensile strength and toughness when compared with grey cast iron.

Malleable cast iron is produced from white cast iron by a prolonged heat-treatment process lasting for about 30 hours.

Nodular cast iron

This is very similar to malleable cast iron. But this is produced without any heat treatment. Nodular cast iron is also known as:

Nodular iron - ductile iron - spheroidal graphite iron

This has good machinability, castability, resistance to wear, low melting point and hardness.

Malleable and nodular castings are used for machine parts where there is a higher tensile stress and moderate impact loading. These castings are less expensive and are an alternative to steel casting.

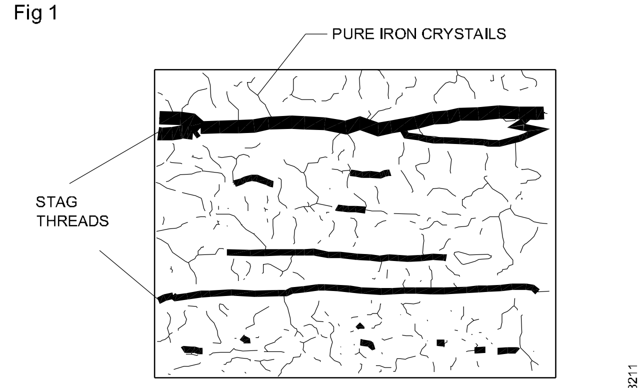
— — — — — —

Wrought iron and plain carbon steels

Objectives: At the end of this lesson you shall be able to
- **state the manufacturing process of wrought iron**
- **state the properties and uses of wrought iron.**

Wrought iron is the purest form of iron. The analysis of wrought iron shows as much as 99.9% of iron. (Fig 1)

Fig 1



MICROSTRUCTURE OF WROUGHT IRON

When heated, wrought iron does not melt, but only becomes pasty and in this form it can be forged to any shape.

Modern methods used to produce wrought iron in large quantities are the:

- Puddling process
- Aston or Byers process.

Puddling process

Wrought iron is manufactured by refining pig-iron.

By refining pig-iron silicon is removed completely, a greater amount of phosphorus is removed, and graphite is converted to combined carbon.

The above process is carried out in a puddling furnace.

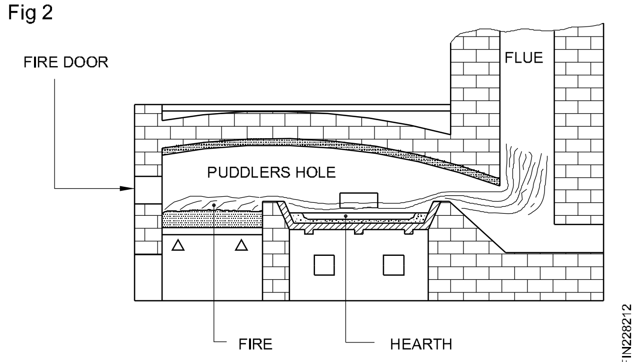
Puddling furnace

This furnace is a coal-fired reverberatory furnace. (Fig 2)

The term reverberatory is applied because the charge is not in actual contact with the fire, but receives its heat by reflection from the dome shaped furnace roof.

The product obtained is taken out from the furnace in the form of balls (or blooms) having a mass of about 50 kgs.

Fig 2



The hot metal is then passed through grooved rollers which convert blooms into bars called Muck bars or Puddle bars.

These bars are cut into short lengths, fastened together in piles, reheated to welding temperatures and again rolled into bars.

Aston process

In this process molten pig-iron and steel scrap are refined in a Bessemer converter.

The refined molten metal is poured into an open hearth furnace in the iron silicate stage. This removes most of the carbon.

The slag cools the molten metal to a pasty mass which is later squeezed in a hydraulic press to remove most of the slag. Rectangular blocks known as blooms are formed from this mass.

The hot bloom is immediately passed through rolling mills to produce products of wrought iron of different shapes and sizes.

COMPOSITION OF WROUGHT IRON

Carbon	-	0.02 to 0.03%
Silicon	-	0.1 to 0.2%
Manganese	-	0.02 to 0.1%
Sulphur	-	0.02 to 0.04%
Phosphorous	-	0.05 to 0.2%
Iron forms of the rest of the content.		

Properties and uses of Wrought Iron

Properties	Uses
Malleable and ductile. It can neither be hardened nor tempered.	Architectural works.
Tough, shock-resistant fibrous structure; easy for forge welding. Ultimate tensile strength of about 350 newtons per sq. mm.	Crane hooks, chain links, bolts and nuts & railway couplings.
No effect in salt water.	Marine works.
Will not retain the magnetism.	Temporary magnets. Core of dynamos.
Corrosion resistant.	Agricultural equipment.
Easy to forge - wide temperaturerange 850°C to 1350°C.	Pipes, flanges etc.

Steel (plain carbon steel)

Objective: At the end of this lesson you shall be able to
- **state the composition and properties of plain carbon steel.**

Steel is fundamentally an alloy of iron and carbon, with the carbon content varying up to 1.5%. The carbon present is in a combined state.

Plain carbon steels are classified according to their carbon content.

Classification and content of Plain Carbon Steel is given in Table 1.

TABLE 1

Classification and content of Plain Carbon Steel

Name of the plain carbon steel	Percentage of Carbon	Properties and uses
Dead mild steel	0.1 to 0.125 %	Highly ductile. Used for making wire rods, thin sheets & solid drawn tubes.
Mild steel	0.15 to 0.3%	Relatively soft and ductile. Used for general workshop purposes, boiler plates, bridge work, structural sections and drop forgings.
Medium carbon	0.3 to 0.5%	Used for making axles,drop forgings, high tensile tubes, wires and agricultural tools.
- do -	0.5 to 0.7%	Harder, tougher and less ductile. Used for making springs, locomotive tyres, large forging dies, wire ropes, hammers and snaps for riveters.
High carbon steel	0.7 to 0.9%	Harder,less ductile and slightly less tough. Used for making springs, small forging dies, shear blades and wood chisels.
- do -	0.9 to 1.1%	Used for making cold chisels, press dies, punches, wood-working tools, axes,etc.
- do -	1.1% to 1.4%	Used for making hand files, drills, gauges, metal-cutting tools & razors.

Non-ferrous metals - copper

Objectives: At the end of this lesson you shall be able to
- **name the commonly used copper alloys**
- **state the properties and uses of copper**
- **state the composition and uses of different types of brasses**
- **state the composition and uses of different types of bronze.**

Metals without iron are called non-ferrous metals. Eg. Copper, Aluminium, Zinc, Lead and Tin.

Copper

This is extracted from its ores 'MALACHITE' which contains about 55% copper and 'PYRITES' which contains about 32% copper.

Properties

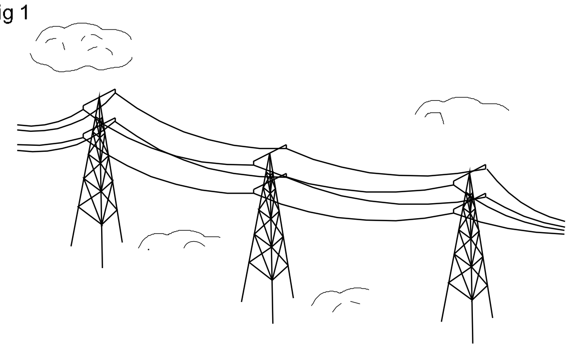
Reddish in colour. Copper is easily distinguishable because of its colour.

The structure when fractured is granular, but when forged or rolled it is fibrous.

It is very malleable and ductile and can be made into sheets or wires.

It is a conductor of electricity. Copper is extensively used as electrical cables and parts of electrical apparatus which conduct electric current. (Fig 1)

Fig 1

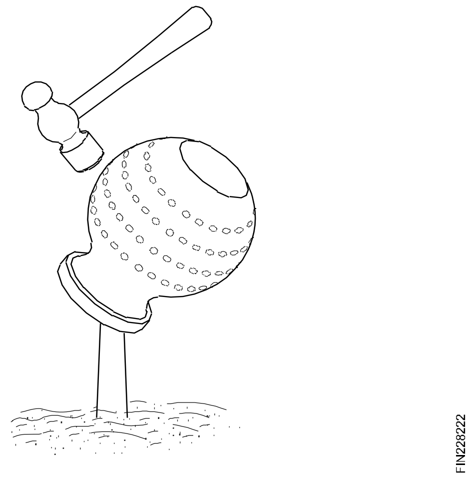


Copper is a good conductor of heat and also highly resistant to corrosion. For this reason it is used for boiler fire boxes, water heating apparatus, water pipes and vessels in brewery and chemical plants. Also used for making soldering iron.

The melting temperature of copper is 1083^o C.

The tensile strength of copper can be increased by hammering or rolling.(Fig 2)

Fig 2



Copper alloys

Brass

It is an alloy of copper and zinc. For certain types of brass small quantities of tin or lead are added. The colour of brass depends on the percentage of the alloying elements. The colour is yellow or light yellow, or nearly white. It can be easily machined. Brass is also corrosion-resistant.

Brass is widely used for making motor car radiator core and water taps etc. It is also used in gas welding for hard soldering/brazing. The melting point of brass ranges from 880 to 930^{o}C.

Brasses of different composition are made for various applications. The following table-1 gives the commonly used brass alloy compositions and their application.

Bronze

Bronze is basically an alloy of copper and tin. Sometimes zinc is also added for achieving certain special properties. Its colour ranges from red to yellow. The melting point of bronze is about 1005^{o}C. It is harder than brass. It can be easily machined with sharp tools. The chip produced is granular. Special bronze alloys are used as brazing rods. Bronze of different compositions are available for various applications. Table-2 gives the type compositions and applications of different bronzes.

TABLE 1 - Composition of different types of Brass

Name	Composition (%)			Applications
	Copper	Zinc	Other elements	
Cartridge brass	70	30	-	Most ductile of the copper/zinc alloys. Widely used in sheet metal pressing for severe deep drawing operations. Originally developed for making cartridge cases, hence its name.
Standard brass	65	35	-	Cheaper than cartridge brass and less ductile. Suitable for most engineering processes.
Basic brass	63	37	-	The cheapest of the cold working brasses. It lacks ductility and is only capable of withstanding simple forming operations.
Muntz metal	60	40	-	Not suitable for cold working, but suitable for hot-working. Relatively cheap due to its high zinc content. It is widely used for extrusion and hot-stamping processes.
Free-cutting brass	58	39	3% lead	Not suitable for cold working but excellent for hot working and high speed machining of low strength components.
Admirality brass	70	29	1% tin	This is virtually cartridge brass plus a little tin to prevent corrosion in the presence of salt water.
Naval brass	62	37	1% tin	This is virtually Muntz metal plus a little tin to prevent corrosion in the presence of salt water.
Gilding metal	95	5	-	Used for jewellery.

TABLE 2 - Composition of different types of bronze

Name	Composition (%)				Applications
	Copper	Zinc	Phosphorus	Tin	
Low tin bronze	96	-	0.1 to 0.25	3.9 to 3.75	This alloy can be severely cold-worked to harden it so that it can be used for springs where good elastic properties must be combined with corrosion resistance,fatigue-resistance and electrical conductivity. Eg.Contact blades
Drawn phosphor/ bronze	94	-	0.1 to 0.5	5.9 to 5.5	This alloy is used for turned components requiring strength and corrosion resistance, such as valve spindles.
Cast phosphor/ bronze	89.75 to 89.97		0.03 to 0.25	10	Usually cast into rods and tubes for making bearing bushes and worm wheels. It has excellent anti-friction properties.
Admirality gun-metal	88	2	-	10	This alloy is suitable for sand casting where fine-grained, pressure-tight components such as pump and valve bodies are required.
Leaded gun-metal (free cutting)	85	5 (5%lead)	-	5	Also known as 'red brass' this alloy is used for the same purposes as standard, admirality gun-metal. It is rather less strong but has improved toughness and machining properties.
Leaded (plastic) bronze	74	(24%lead)	-	2	This alloy is used for lightly loaded bearings where alignment is difficult. Due to its softness, bearings made from this alloy "bed in" easily.

Lead

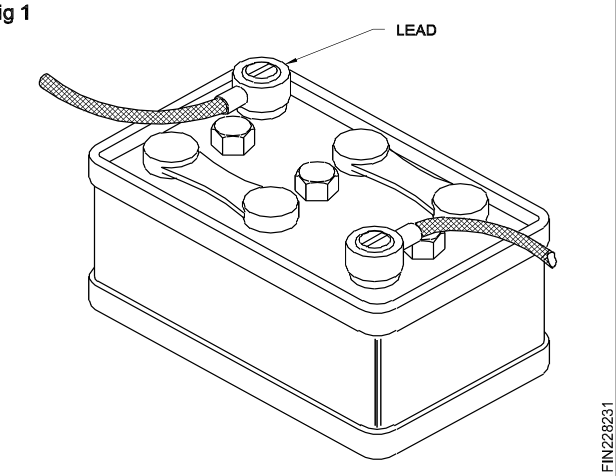
Objectives: At the end of this lesson you shall be able to
- **state the properties of lead**
- **state the various uses of lead**
- **state the uses of babbit metal.**

Lead is a very commonly used non-ferrous metal and has a variety of industrial applications.

Lead is produced from its ore 'GALENA'. Lead is a heavy metal that is silvery in colour when molten. It is soft and malleable and has good resistance to corrosion. It is a good insulator against nuclear radiation. Lead is resistant to many acids like sulphuric acid and hydrochloric acid.

It is used in car batteries, in the preparation of solders etc. It is also used in the preparation of paints. (Fig 1)

Fig 1



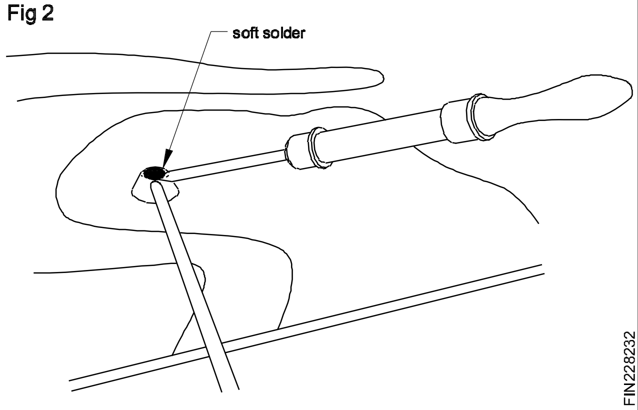
Lead Alloys

Babbit metal

Babbit metal is an alloy of lead, tin, copper and antimony. It is a soft, anti-friction alloy, often used as bearings.

An alloy of lead and tin is used as 'soft solder. (Fig 2)

Fig 2



Zinc

Objectives: At the end of this lesson you shall be able to
- **state the properties and uses of zinc**
- **state the uses of zinc alloys.**

Zinc is a commonly used metal for coating on steel to prevent corrosion. Examples are steel buckets, galvanized roofing sheets, etc.

Zinc is obtained from the ore-calamine or blende.

Its melting point is 420^{o} C.

It is brittle and softens on heating; it is also corrosion-resistant. Due to this reason it is used for battery containers and is coated on roofing sheets etc.

Galvanized iron sheets are coated with zinc.

Tin

Objectives: At the end of this lesson you shall be able to
- **state the properties and uses of tin**
- **name the common tin alloys and state their uses.**

Tin

Tin is produced from cassiterite or tinstone. It is silvery white in appearance, and the melting point is 231^{o} C. It is soft and highly corrosion-resistant.

It is mainly used as a coating on steel sheets for the production of food containers. It is also used with other metals, to form alloys.

Example: Tin with copper to form bronze. Tin with lead to form solder. Tin with copper, lead and antimony to form Babbit metal.

Aluminium

Objectives: At the end of this lesson you shall be able to

- **state the properties and uses of aluminium**
- **name the commonly used aluminium alloys and their uses**
- **name the ores from which aluminium is produced.**

Aluminium

Aluminium is a non-ferrous metal which is extracted from 'BAUXITE'. Aluminium is white or whitish grey in colour. It has a melting point of 660° C. Aluminium has high electrical and thermal conductivity. It is soft and ductile, and has low tensile strength. Aluminium is very widely used in aircraft industry and fabrication work because of its lightness. Its application in the electrical industry is also on the increase. It is also very much in use in household heating appliances. Some typical aluminium alloys, their composition and applications are given in the table that follows.

ALUMINIUM ALLOYS - COMPOSITION - USES

Composition(%) (Only the percentage of alloying elements is shown. The remaining is aluminium.)						**Category**	**Applications**
Copper	Silicon	Iron	Manganese	Magnesium	Other elements		
0.1 max.	0.5 max.	0.7 max.	0.1 max.	-	-	Wrought. Not heat treatable.	Fabricated assemblies, Electrical conductors. Food and brewing, processing plants. Architectural decorations.
0.15 max.	0.6 max.	0.75 max.	1.0 max.	4.5 to 5.5	0.5 Chromium	Wrought. Not heat treatable.	High strength ship building and engineering products. Good corrosion resistance.
1.6	10.0	-	-	-	-	Cast, not heat treatable.	General purpose alloy for moderately stressed pressure die-castings.
-	10.0 to 13.0	-	-	-	-	Cast, not heat treatable	One of the most widely used alloys. Suitable for sand,gravity and pressure die castings. Excellent foundry characteristics. Used for large marine, automotive and general engineering castings.
4.2	0.7	0.7	0.7	0.7	0.3 Titanium (option)	Wrought. Heat treatable.	Traditional'Duralumin'. General machining alloy. Widely used for stressed components in aircraft.
-	0.5	-	-	0.6	-	Wrought. Heat treatable.	Corrosion-resistant alloy for lightly stressed components such as glazing bars, window sections and automotive body components.
1.8	2.5	1.0	-	0.2	0.15 Titanium 1.2 Nickel	Cast. Heat treatable.	Suitable for sand and gravity die casting. High rigidity with moderate strength and shock resistance. A general purpose alloy
-	-	-	-	10.5	0.2 Titanium	Cast. Heat treatable.	A strong, ductile and highly corrosion-resistant alloy used for air craft and marine castings, both large and small.

— — — — — —