

UNIT-I Electric Heating

1. Electric Heating.
2. Methods of Electric Heating.
3. Resistance Heating.
4. Induction Heating.
5. Dielectric Heating.
6. Electric welding.
7. Resistance welding.
8. Electric Arc welding.
9. Comparison between Resistance and Arc Welding.
10. Comparison between A.C. and D.C. Welding

Heat plays a major role in everyday life. All heating requirements in domestic purposes such as cooking, room heater, immersion water heaters, and electric toasters and also in industrial purposes such as welding, melting of metals, tempering, hardening, and drying can be met easily by electric heating, over the other forms of conventional heating.

Heat and electricity are interchangeable. Heat also can be produced by passing the current through material to be heated. This is called electric heating; there are various methods of heating a material but electric heating is considered far superior compared to the heat produced by coal, oil, and natural gas.

Advantages of Electric Heating

The various advantages of electric heating over other the types of heating are:

1. Economical:

Electric heating equipment is **cheaper**; they do not require much skilled persons; therefore, maintenance cost is less.

2. Cleanliness:

Since **dust and ash** are completely eliminated in the electric heating, it keeps surroundings cleanly.

3. Pollution free:

As there are **no flue gases** in the electric heating, atmosphere around is pollution free; no need of providing space for their exit.

4. Ease of control:

In this heating, temperature can be controlled and regulated accurately either **manually** or **automatically**.

5. Uniform heating:

With electric heating, the **substance** can be **heated uniformly**, throughout whether it may be conducting or non-conducting material.

6. High efficiency:

In **non-electric heating**, only 40–60% of heat is utilized but in **electric heating** 75–100% of heat can be successfully utilized. So, overall efficiency of electric heating is very high.

7. Automatic protection:

Protection against over current and overheating can be provided by using **fast control devices**.

8. Heating of non-conducting materials:

The heat developed in the non-conducting materials such as **wood and porcelain is possible** only through the electric heating

9. Better working conditions:

No irritating noise is produced with electric heating and also radiating losses are low.

10. Less floor area:

Due to the compactness of electric furnace, floor area required is less.

11. High temperature:

High temperature can be obtained by the electric heating except the ability of the material to withstand the heat.

12. Safety:

The electric heating is quite safe.

Modes of Transfer of Heat

The transmission of the heat energy from one body to another because of the temperature gradient takes place by any of the following methods:

1. Conduction. 2. Convection. 3. Radiation.

1. Conduction:-

In this mode, the heat transfers from one part of substance to another part without the movement in the molecules of substance. The rate of the conduction of heat along the substance depends upon the temperature gradient.

2. Ex: Refractory heating, the heating of insulating materials, etc

In this mode, the heat transfer takes place from one part to another part of substance or fluid due to the actual motion of the molecules. The rate of convection of heat depends mainly on the difference in the fluid density at different temperatures.

Ex: Immersion water heater.

3. Radiation:-

In this mode, the heat transfers from source to the substance to be heated without heating the medium in between. It is dependent on surface.

Ex: Solar heaters.

Essential Requirements of Good Heating Element

The materials used for heating element should have the following properties:

- ✓ High-melting point.
- ✓ Low temperature coefficient of resistance.
- ✓ Free from oxidation.
- ✓ High-mechanical strength.
 - ✓ Non-corrosive.
 - ✓ Economical.
- ✓ High-specific resistance.

Material for Heating Elements

S. No.	Type of alloy	Composition	Commercial name	Max. operating temperature	Resistivity at 20°C	Specific gravity
1	Nickel chromium (Ni-Cr)	80% Ni 20% Cr	Nichrome	1,150°C	1.03 μΩ-m	8.35
2	Nickel chromium iron (Ni-Cr-Fe)	60% Ni 16% Cr 24% Fe	—	950°C	1.06 μΩ-m	8.27
3	Nickel Copper (Ni-Cu)	45% Ni 55% Cu	Eureka or constantan	400°C	0.49 μΩ-m	8.88
4	Iron chromium aluminum (Fe-Cr-Al)	70% Fe 25% Cr 5% Al	Kanthal	1,200°C	1.4 μΩ-m	7.20

Causes of Failure of Heating Elements

Heating element may fail due to any one of the following reasons.

1. Formation of hot spots.

2. Oxidation of the element and intermittency of operation.
3. Embrittlement caused by grain growth.
4. Contamination and corrosion.

2. **Methods of Electric Heating:**-Heat can be generated by passing the **current** through a **resistance** or **induced currents**. The initiation of an **arc** between two **electrodes** also develops heat. The **bombardment** by some heat **energy particles** such as α , γ , β , and x-rays or accelerating ion can produce heat on a surface.

2.1. Resistance Heating

When the electric current is made to pass through a high-resistive element, a **power loss**($P_L = I^2R$) takes place in it, which results in the form of heat energy.

Applications: This method of heating has wide applications such as drying, baking of potteries, commercial and domestic cooking, and the heat treatment of metals such as annealing and hardening. **In oven** where **wire resistances** are employed for heating, temperature up to **about 1,000°C** can be obtained.

The resistance heating is further classified as:

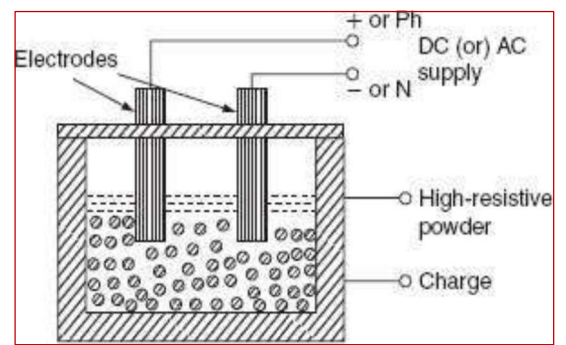
1. Direct Resistance heating.
2. Indirect Resistance heating.
3. Infrared (or) Radiant heating.

1. Direct Resistance heating:-

In this method, **electrodes** are immersed in a material or **charge** to be heated. The charge may be in the form of powder, pieces, or liquid. The electrodes are connected to **AC or DC supply**

as shown in Figure. In case of DC or 1- ϕ AC, **two electrodes** are immersed and **three electrodes** are immersed in the charge and connected to supply in case of availability of 3- ϕ supply.

The **current flows** through the **charge** and **heat** is produced in the charge itself. So, this method has high efficiency. As the current in this case is **not variable**, so that automatic temperature control is not possible. This method of heating is employed in **salt bath furnace and electrode boiler for heating water**. ($Q=I^2.R.t$)

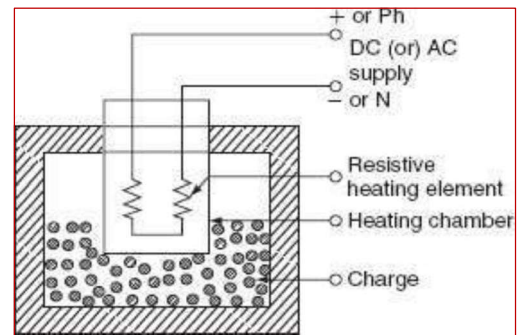


2. Indirect Resistance heating:-

In the indirect resistance heating method, high current is passed through the heating element. In case of industrial heating, sometimes the heating element is placed in a cylinder which is surrounded by the charge placed in a jacket is known as heating chamber is shown in Figure. The heat is proportional to power loss produced in the heating element is delivered to the charge by one or more of the modes of the transfer of heat viz. conduction, convection.

This arrangement provides uniform temperature and

automatic temperature control. Generally, this method of heating is used in immersion water heaters, room heaters, and the resistance ovens used in domestic and commercial cooling and salt bath furnace.



3. Infrared (or) Radiant heating:-

In this method of heating, the heat transfer takes place from the **source to the body** to be heated **through radiation**, for **low and medium temperature applications**. Whereas in resistance ovens, the heat transfers to the charge partly by **convection** and partly by **radiation**.

In the radiant heating, the **heating element** consists of **tungsten filament lamps together with reflector** and to direct all the heat on the charge. Tungsten filament lamps are operating at **2,300°C instead of 3,000°C** to give greater portion of infrared radiation and a longer life. The lamp ratings used are usually between **250 and 1,000 W** and are operating at voltage of **115 V** in order to ensure a **robust filament**.

The radiant heating is mainly used for **drying enamel or painted surfaces**. The **main advantage** of the radiant heating is that the **heat absorption** remains approximately **constant** whatever the charge temperature.

2.2. Induction Heating

The induction heating process makes use of the **currents induced by the electromagnetic action** in the material to be heated. To develop sufficient amount of heat, the resistance of the material must be low

$$\text{(Power drawn} = \frac{V^2}{R} \text{) ,}$$

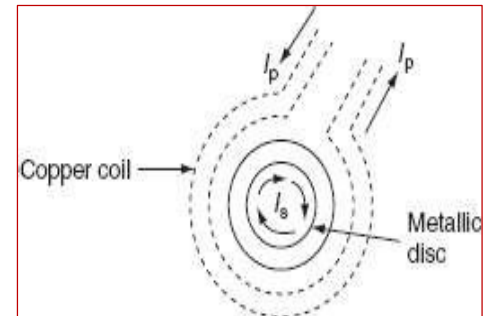
which is possible only with the metals, which can be obtained by employing **higher flux** and higher frequency. Therefore, the **magnetic materials** can be heated than non-magnetic materials due to their **high permeability**.

Heat developed in the disc is depending upon the following factors.

- ✓ Primary coil current.
- ✓ The number of the turns of the coil.
- ✓ Supply frequency.
- ✓ The magnetic coupling between the coil and the disc.

There are basically two types of **induction furnaces** and they are:

1. **Core type (or) Low-frequency induction furnace.**
2. **Coreless type (or) High-frequency induction furnace.**



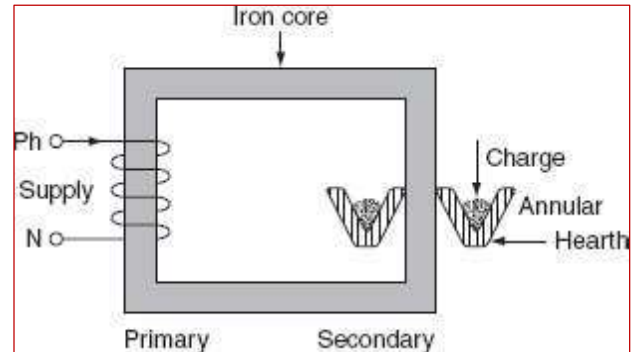
1. ore type Induction furnace:-

The operating **principle** of the core type furnace is the **electromagnetic induction**. This furnace is operating just like a **transformer**. It is further classified as:

- a) Direct core type.
- b) Vertical core type.
- c) Indirect core type.

a). Direct core type:

The core type furnace is essentially a **core type transformer** in which the charge to be heated forms **single- turn secondary circuit** and is magnetically coupled to the primary by an iron core as shown in Figure. The furnace consists of a **circular hearth** in which the charge to be melted in the form of an annular ring. Main Draw back is **pinch effect**.



b). Vertical core type:

It is an improvement (from **Pinch effect**) over the direct

core type furnace, This type of furnace consists of a **vertical core (shell type)** instead of **horizontal core** as shown in Figure.

It

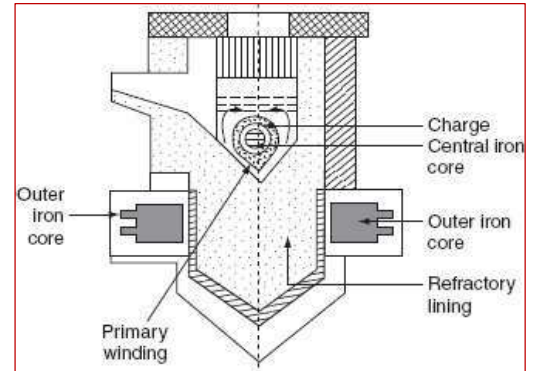
is also known as *Ajax-Wyatt induction furnace*.

The Primary winding is connected to **600V, 50Hz, AC supply**, then flux will generate in the V-shaped core, hence current will pass in secondary winding (molten metal) where **charge is melted**. Here heat transfer is done by **Convection method**.

The inside layer of furnace is **lined** depending upon the

type **charge used**. Clay lining is used for yellow brass and an alloy

of magnesia and alumina is used for red brass. The **top surface** of the furnace is covered with insulating material, which can be **removed for admitting the charge**.



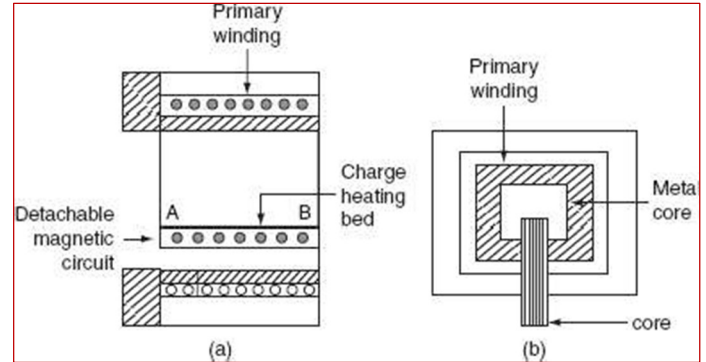
c). Indirect core type:

This type of furnace is used for providing heat treatment to metals. The secondary winding itself forms the walls of the container or furnace and an iron core links both primary and secondary windings.

secondary windings.

When primary is connected to AC supply currents are induced in the metal made furnace, and heat is transferred to charge to be heated by Radiation. The main advantage of such furnace is wide variation of temperature control is possible .?

When the furnace reaches to critical temperature, the reluctance of the magnetic circuit increases many times and the inductive effect decreases thereby cutting off the supply heat. Thus, the temperature of the furnace can be effectively controlled.



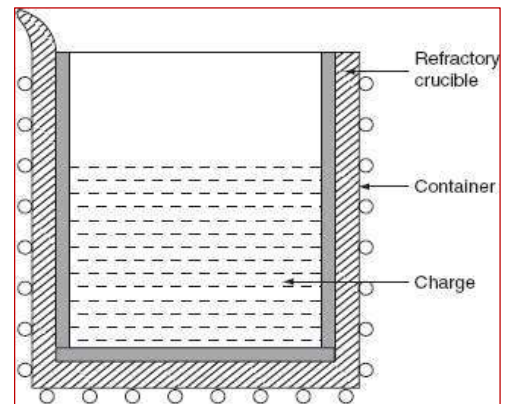
2. Core Less type Induction furnace:-

It is a simple furnace with the absence of core is shown in Figure. In this furnace, heat developed in the charge due to eddy currents flowing through it. The furnace consists of a refractory crucible cylindrical in shape enclosed within a coil that forms primary of the transformer. The furnace also contains a conducting or non-conducting container (charge to be placed) that acts as secondary. When primary coils are excited by an alternating source, the flux set up by these coils induces the eddy currents in the charge. The direction of the resultant eddy current is in a direction opposite to the current in the primary coil. These currents heat the charge to melting point. The eddy currents developed in any magnetic circuit gives Eddy current loss causes Heating of charge [H] (metal) given by :

$$W_e \propto B_m^2 f^2 \quad \& \quad H = [(w \times S \times \Delta T) + (w \times l)]$$

w=weight of charge, S=Specific heat, l=Latent Heat required

where B_m is the maximum flux density (tesla), f is the frequency in (Hz), and W_e is the eddy current loss (watts). The selection of a suitable frequency of the primary current can be given by penetration formula. According to this:



$$f = \frac{16 \times \rho \times 10^9}{\pi^2 \times \mu \times d^2}$$

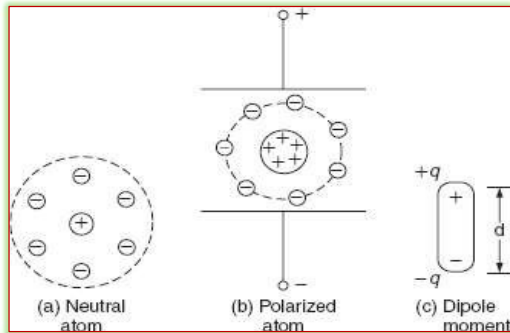
Where d =depth of charge, ρ =resistivity of the material.
 μ = the permeability of the material

Following are the advantages of coreless furnace over the other furnaces:

- ✓ Ease of control.
- ✓ Oxidation is reduced, as the **time taken** to reach the melting temperature is **less**.
- ✓ The **cost is less** for the erection and operation.
- ✓ It can be used for heating and melting.
- ✓ Any shape of crucible can be used.
- ✓ It is suitable for intermittent operation.

2.3. Dielectric Heating

When non-metallic materials i.e., **insulators** such as wood, plastics, and China glass are subjected to **high-voltage alternating electric field**, the atoms get stresses, and due to interatomic friction caused by the repeated deformation and the rotation of atomic structure (**polarization**), heat is produced. This is known as **dielectric loss**, causes dielectric heating.



Dielectric loss is $P_L = V \cdot I \cdot \cos\theta = VI_R$

We have $\tan\delta = \frac{I_R}{I_C}$

$$P_L = V \cdot I_R = V \cdot I_C \cdot \tan\delta$$

$$P_L = V \cdot \left(\frac{V}{X_C}\right) \cdot \tan\delta$$

$$P_L = V^2 \cdot \omega C \cdot \tan\delta$$

$$P_L = V^2 \cdot (2\pi f) \cdot \left(\frac{\epsilon_0 \cdot \epsilon_R \cdot A}{d}\right) \cdot \tan\delta$$

From the above Eq.....

$$P_L \propto V^2 \quad \& \quad P_L \propto f$$

