Electric Heating

I) <u>Advantages of Electrically produced heat</u>:

Some of the most important advantages of electrically produced heat are:

i. **Cleanliness**- The complete elimination of dust and ash keeps cleaning costs down to a minimum.
ii. **Absence of flue gases**: No space has to be used in providing flues and there is no risk of contamination of the atmosphere or of the objects being heated.
iii. **Ease of Control**-Simple and accurate control of temperature can be provided either by hand or by fully automatic devices, so that temperature can be maintained constant or made to vary in accordance with a predetermined plan. Further any particular temperature or temperature cycle can be accurately repeated at any time.
iv. **Low attention and maintenance costs**- Electric heating equipment in general requires no attention, while maintenance costs are negligibly small. This results in considerable savings in labour costs over alternative heating systems.
v. **Special heating requirements**- special heating requirements such as uniform heating or heating one particular portion of a job without affecting the other parts or heating with no oxidation is met only by electric heating.
vi. **Higher efficiency**- Heat produced electrically does not go away waste through the chimney or other products. Most of the heat produced is utilized for heating the material.

II) <u>Types and Applications of Electric Heating Equipments</u>:

Various methods of producing heat for general industrial work, heating of buildings and for welding may conveniently are classified as follows:

i. **Direct-resistance Heating**- Current is passed through the body to be heated. A few industrial processes, including resistance welding, employ this method. It is also used in electrode boiler for heating water.

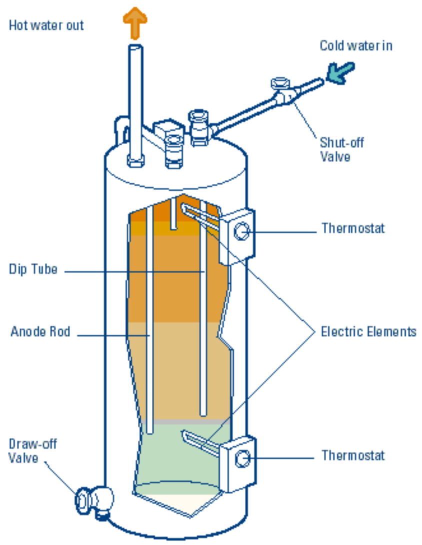
CAPACITY Gold	1 Kg.
WATTAGE	1.5 Kw
TEMPERATURE	0 to 1200° C
POWER SUPPLY	1Ø, 230V AC
DIMENSIONS	9.5"(L)X10.25"(D)X 16.5"
WEIGHT	3 Kgs.
REQUIREMENT	One Crusible & tong provided.

Features: Resistance Heating, Direct heating system, Long life heater, 'K' Type thermocouple, Digital Controller, Tong Holder hooks, Crucible Stand, Melting 30 minutes, Melts Gold, Silver, Brass .

ii. **Indirect-resistance Heating**- Current is passed through a wire or other high resistance material forming a heating element. The heat (I2R loss) so produced is transmitted by radiation or convection to the body to be heated. This method is used in ordinary domestic radiator, the immersion water heater and in various types of resistance ovens used for domestic and commercial cooking, heat treatment of metals and other purposes.

Electric Domestic Water Heaters

Electric Water Heater



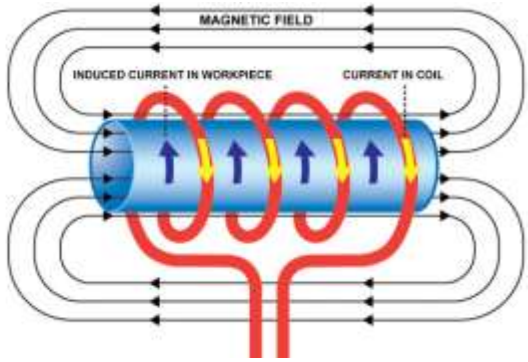
Electric water heaters supply hot water for household use in many homes. An electric water heater usually consists of a tank, thermostats, two electric resistance elements (which are submerged inside the tank), and inlet and outlet pipes for cold and hot water. Internal thermostats regulate the temperature of the water.

Tanks are typically covered with foam insulation and lined on the inside with a ceramic glass layer. When cold water replaces the water withdrawn from the tank and the temperature of the water falls below a certain level, the elements are activated, reheating the water to the correct temperature. Essentially, electric hot water heaters are large closed electric kettles.

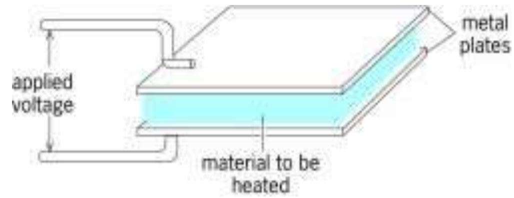
The submerged electric resistance heating elements in water heaters are very efficient, providing about 99 per cent of the available heat to the surrounding water. Even so, older water heaters lose heat as a result of standby losses.

iii. **Indirect-induction Heating**- Eddy currents are induced in the heating element by electro-magnetic action. The heat so produced is transmitted to the body to be heated by radiation and convection, as in the indirect-resistance method. Certain types of induction ovens used for heat treatment of metals operate on this principle.

iv. **Direct-induction Heating**- Currents are induced by electromagnetic action in the body to be heated, and, in the case of steel and other metals, produce a sufficiently high temperature to melt the metal. The equipment used for melting is known as induction furnace, whilst the process used for general heat treatment of metals is referred to as eddy-current heating.



v. **Dielectric heating**- Use is made of dielectric losses set up in non-metallic materials when subjected to an alternating electric field.



vi. **The Electric Arc**- An electric arc drawn between two electrodes has a temperature of between 3000 to 3500^{0}C depending on the electrode material. This is used in the arc furnaces for the melting of metals and also for arc welding.

III) <u>Transfer of heat (Conduction, Convection and Radiation)</u>-

Conduction- The rate at which the heat is conducted through a substance depends on the temperature gradient i.e. on the difference between the temperatures of the surfaces on each side of the body. This is expressed in watts per square centimeter per centimeter. Conduction of heat is important chiefly in connection with refractory and heat-insulating materials when these are used for preventing the escape of heat in direction in which it is not required.

Consider a solid material of cross section 'A 'm^2 and thickness 'x' metre (refer fig). If T_1 and T_2 are the temperatures of two sides of the slab in ^{0}K, then the heat conducted between the two opposite faces in time 't' seconds is given by :

$H = \frac{KA(T1-T2)t}{x}$, where K is the thermal conductivity of the material.

Convection- Heat is transmitted by convection in immersion type water heaters and in certain low temperature heating equipment for buildings, but not to any great extent in oven or furnace work, except in the heat dissipation from the outside walls. For vertical heating surfaces in air, natural convection takes place according to the law:

Heat Dissipation (H) =3.875 $(T1-T2)^{1.25}$ W/m^2

Where T1 and T2 are the temperatures (in Kelvin) of the heating surface and the air respectively.

Radiation: The Stephen's law of radiation may be written as:

Heat Dissipation $(H) = 5.72 * 10^4 * n\epsilon \left[\left(\frac{T1}{1000}\right)^4 - \left(\frac{T2}{1000}\right)^4\right]$ W/m^2

where T1=Absolute temperature(K) of radiating surface

T2=Absolute temperature (K) of absorbing surface

η=constant, commonly called the radiating efficiency, depending on the disposition of heating elements used and

=1 for single element

=0.5 to 0.8 for several elements side by side

Є=emissivity

=1 for black body

= 0.9 for resistance heating elements.

It can be seen that since radiation is proportional to the difference of fourth powers of the temperatures, it will have a pre-pondering effect in high-temperature heating.

(IV) Resistance Ovens

Electrically heated ovens are used for a wide variety of purposes, including the heat treatment of metals (annealing, hardening etc), stoving of enameled wires, drying and baking of pottery, and commercial and domestic heating. Ovens using wire resistance elements can be made to produce temperatures of up to about 1000^0C. If special elements of graphite are employed, temperatures of up to 3000^0C can be obtained, although such high temperatures are normally obtained by other means.

General construction: For heat treatment of metals and for other purposes, the oven itself is constructed of fire-bricks or other heat insulating material supported on a metal framework. The heating elements are mounted on the top, sides or bottom of the oven, according to circumstances.

Heating element material- a material for use as a heating element should have the following properties-

i. High specific resistance, so that only a small quantity of wire is required to produce a given amount of heat
ii. High melting point, so that high temperatures can be produced
iii. Freedom from oxidation at high temperatures to ensure a long life
iv. Small temperature coefficient, so that the resistance does not change with temperature.

The materials which most satisfactorily fulfill these requirements at a reasonable cost are either alloys of nickel and chromium containing about 80% nickel; or alloys of nickel (65%), chromium (15%) and iron (20%). Introduction of iron reduces cost but facilitates oxidation at lower temperatures. A more recent range of alloys containing iron, chromium, cobalt and aluminium can withstand temperatures up to 1300^0C.

Efficiency and losses- Typical efficiency of resistance furnace usually lie between 60 to 80%. Loss of heat in a resistance oven occurs due to:

A=Heat used in raising temperature of oven
B=Heat used in raising temperature of containers or carriers
C=Conduction of heat through walls
D=Escape of heat due to opening door.

If W is the heat required to raise the charge (material to be heated) to the required temperature, then the efficiency of oven is given by

$$Efficiency = \frac{W}{W + A + B + C + D}$$

Following table gives typical energy consumption for various processes using resistance ovens-

Approximate Energy Consumption of Resistance Oven Processes	
	kWh/tonne
Annealing steel	200-250
Annealing copper	100-200
Vitreous enamelling of sheet steel	400-700
Carburising	250-500
Baking of bread	50-100

(V) Induction heating (core and coreless type)

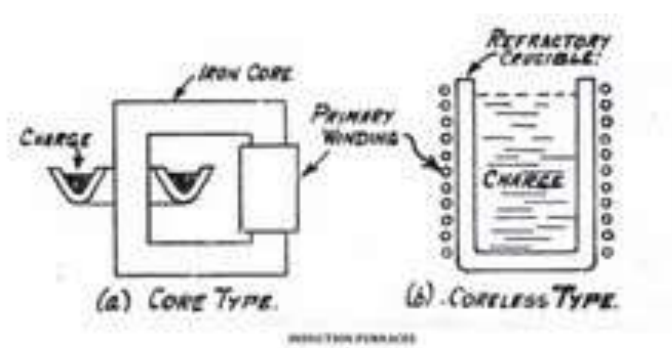
Induction heating processes make use of currents induced by electro-magnetic action in the material to be heated. It is suitable for materials with low resistivity (such as metals) in which high currents often at very high frequency can be induced for creating sufficient heat. Magnetic materials which are having high permeability and hence create greater flux with a given magnetizing force are more suitable, as compared to non magnetic material.

For melting or refining metals, various types of induction furnaces are available. For other applications such as case-hardening and soldering, high frequency eddy current heating is used at the appropriate stage of the manufacturing process.

Core type furnaces- The core type furnace is essentially a transformer in which the charge to be heated forms the secondary circuit, and is magnetically coupled to the primary by an iron core. (Refer diagram). It is evident from the diagram that the magnetic coupling between the primary and secondary is very poor, resulting in high leakage reactance and poor power factor. To overcome this difficulty, the furnaces can be designed for a low frequency (as low as 10 Hz). The electro-magnetic forces cause turbulence of the molten metal which, although useful up to a certain point, is liable to become too severe unless the frequency is kept low. If the current density is allowed to exceed about 5A/mm2, the 'pinch effect' due to these forces may cause complete interruption of secondary circuit.

Other disadvantage are-

i. A crucible of inconvenient shape from the metallurgical point of view needs to be used
ii. In order to start the furnace, a complete ring of metal must be present in the crucible; otherwise the secondary circuit is not complete.
iii. A special motor-generator set is required for low frequency electric supply.
iv. Cost is high.



Core-less induction furnace- the general construction of this type of furnace (refer fig) shows that a convenient shape of crucible can be used. The flux produced by the primary winding or inductor sets up eddy currents in the ‘charge’ which tends to flow concentrically with those in the inductor. These eddy currents are sufficient to heat the metal to melting point. The eddy currents also setup electro-magnetic forces which produce stirring action.

There are certain special features which require careful attention in coreless induction furnace. At the (high) frequencies generally employed, the skin effect in the inductor coil (of primary winding) causes high copper loss and artificial cooling of coils is required. The coil is generally made of (hollow) copper tube through which cooling water is circulated. Further, stray magnetic field outside the inductor coil may cause serious eddy-current losses in supporting (metallic) structure, unless care is taken in the design.

One of the major disadvantages is that the power factor is too low (of the order of 0.1 lag). In larger size furnaces, static capacitors are used in parallel with the furnace, for maintaining power factor near unity.

(VI)Dielectric heating-

For the heating of non-metallic materials such as wood, plastic or ceramics; use can be made of dielectric loss which occurs in such materials when subjected to an alternating electrostatic field. The material to be heated is placed between two metallic electrodes across which a voltage is applied. To ensure sufficient loss to give an adequate amount of heating, frequencies between 10 MHz and 30 MHz must be used. The voltage may be as high as 20 kV.

Comparing oven heating Vs dielectric heating of materials of poor thermal conductivity- it should be understood that in dielectric heating, the heat is produced in the material itself; whereas in the oven heating the heat must be conducted from outside to inside of the material, which takes long time and also results in non uniform temperature distribution. Process which would take several hours for oven heating of materials with low thermal conductivity (such as wood, plastic or ceramics), can be carried out in minutes by dielectric heating.

Dielectric heating is only employed where other methods are impracticable or too slow, due to high cost of equipment. Such applications may include bonding of laminated wood and plastic materials, dehydration of food and tobacco, and sterilization of cereals.

References-

1. Utilization of Electric Energy- E. Openshaw Taylor.
2. A Text Book of Electrical Technology by B.L. Theraja