

UTILIZATION OF ELECTRICAL ENERGY

UNIT I

ELECTRIC HEATING AND WELDING

- Electric heating is extensively used both for domestic and industrial applications.
Domestic applications include
 - (i) room heaters
 - (ii) immersion heaters for water heating
 - (iii) hot plates for cooking
 - (iv) electric kettles
 - (v) electric irons
 - (vi) pop-corn plants
 - (vii) electric ovens for bakeries
 - (viii) electric toasters etc
- Industrial applications of electric heating include
 - (i) melting of metals
 - (ii) heat treatment of metals like annealing, tempering, soldering and brazing etc.
 - (iii) moulding of glass
 - (iv) baking of insulators
 - (v) enamelling of copper wires etc

Advantages of Electrical heating

- Some of the most important advantages of electrically produced heat are:
 - Economical: Electric heating equipment is cheaper; they do not require much skilled persons; therefore, maintenance cost is less.

UTILIZATION OF ELECTRICAL ENERGY

- Cleanliness: Since dust and ash are completely eliminated in the electric heating, it keeps surroundings clean.
 - 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.
 - Ease of control: In this heating, temperature can be controlled and regulated accurately either manually or automatically.
 - Uniform heating: The substance can be heated uniformly throughout whether it may be conducting or non-conducting material.
 - 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.
 - Automatic protection: Protection against over current and overheating can be provided by using control devices.
 - 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.
 - Better working conditions: No irritating noise is produced with electric heating and also radiating losses are low.
 - Less floor area: Due to the compactness of electric furnace, floor area required is less.
 - High temperature: High temperature can be obtained by the electric heating except the ability of the material to withstand the heat.
 - Lower Attention and Maintenance Cost: Electric heating equipment generally will not require much attention and supervision and their maintenance cost is almost negligible.
- Hence, labour charges are negligibly small as compared to other forms of heating.

Disadvantages

- The cost of electricity makes it expensive to use as a heating fuel.

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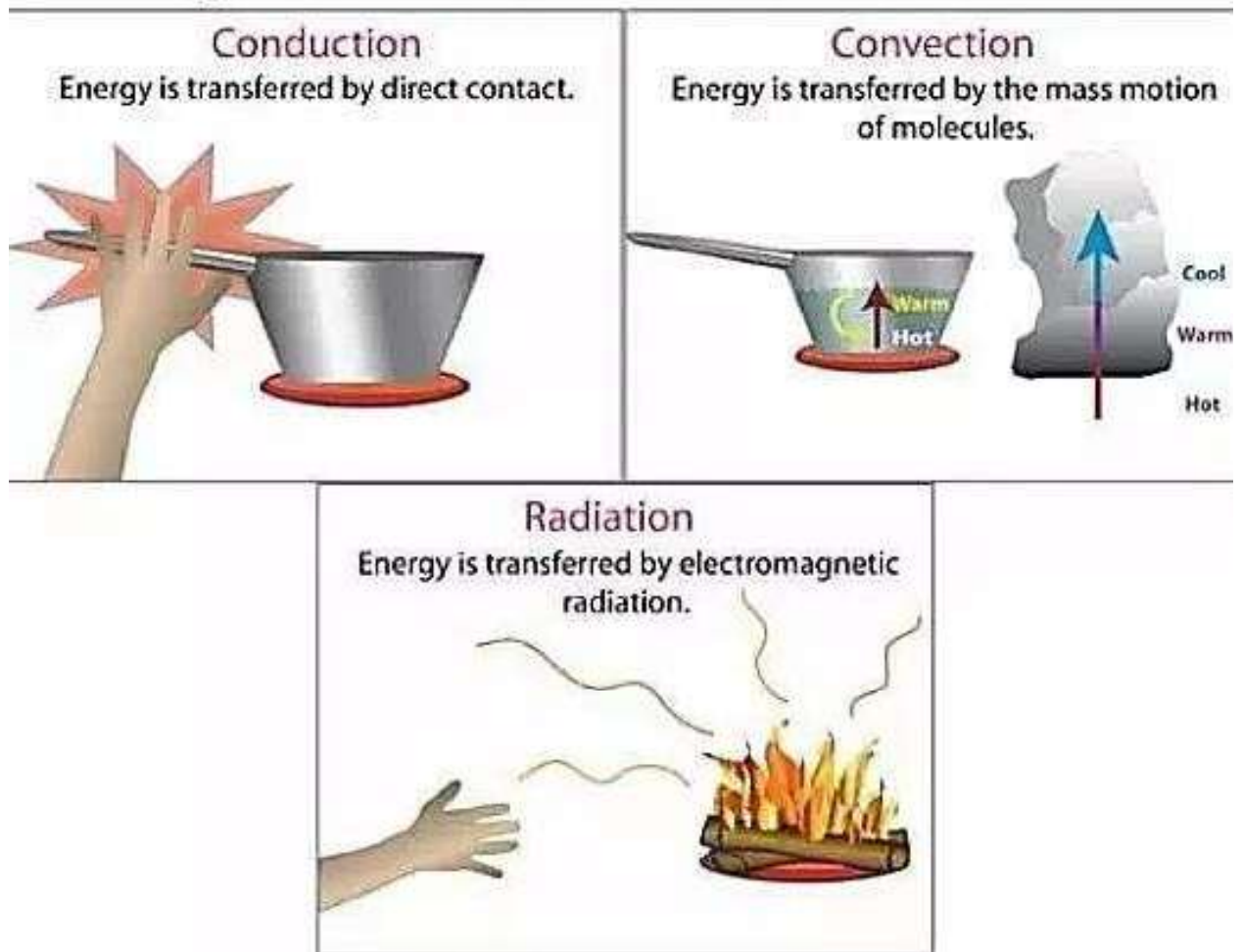
- With space heaters, we can't easily provide central filtration, humidification or cooling.
- The electrical hazard of shock and fire caused by electricity is an issue.
- There are a cost associated with Electric heat requires a larger electrical service than normal.

Different Methods of Heat Transfer

- 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.

UTILIZATION OF ELECTRICAL ENERGY

Figure 2--Conduction, Convection, and Radiation



1. Conduction

In this mode of heat transfer, one molecule of the body gets heated and transfers some of the heat to the adjacent molecule and so on.

There is a temperature gradient between the two ends of the body being heated.

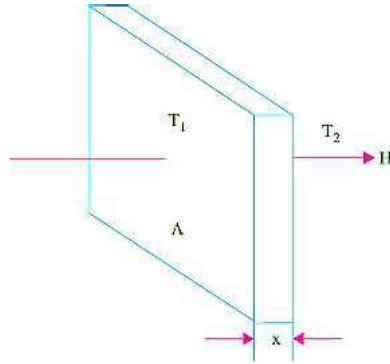
Consider a solid material of cross-section A sq.m. and thickness x metre as shown in Fig.

If T_1 and T_2 are the temperatures of the two sides of the slab in $^{\circ}K$, then heat conducted between the two opposite faces in time t seconds is given by:

$$H = \frac{KA(T_1 - T_2)t}{x}$$

UTILIZATION OF ELECTRICAL ENERGY

where K is thermal conductivity of the material.



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

2. Convection

- In this process, heat is transferred by the flow of hot and cold air currents.
- This process is applied in the heating of water by immersion heater or heating of buildings.
- The quantity of heat absorbed by the body by convection process depends mainly on the temperature of the heating element above the surroundings and upon the size of the surface of the heater.
- It also depends, to some extent, on the position of the heater.
- The amount of heat dissipated is given by
- where a and b are constants and T_1 and T_2 are the temperatures of the heating surface and the fluid in $^{\circ}\text{K}$ respectively.
- In electric furnaces, heat transferred by convection is negligible.
- Ex: Immersion water heater.

$$H = a(T_1 - T_2)$$

3. Radiation

- It is the transfer of heat from a hot body to a cold body in a straight line without affecting

UTILIZATION OF ELECTRICAL ENERGY

the intervening medium.

- The rate of heat emission is given by Stefan's law according to which
- where K is radiating efficiency and e is known as emissivity of the heating element.

$$H = 5.72 eK \left[\left(\frac{T_1}{100} \right)^4 - \left(\frac{T_2}{100} \right)^4 \right] \text{ W m}^2$$

- If d is the diameter of the heating wire and l its total length, then its surface area from which heat is radiated = $\pi \times d \times l$.
- If H is the power radiated per m² of the heating surface,
- then total power radiated as heat = $H \times \pi d l$.
- If P is the electrical power input to the heating element, then $P = \pi d l H$
- Ex: Solar heaters

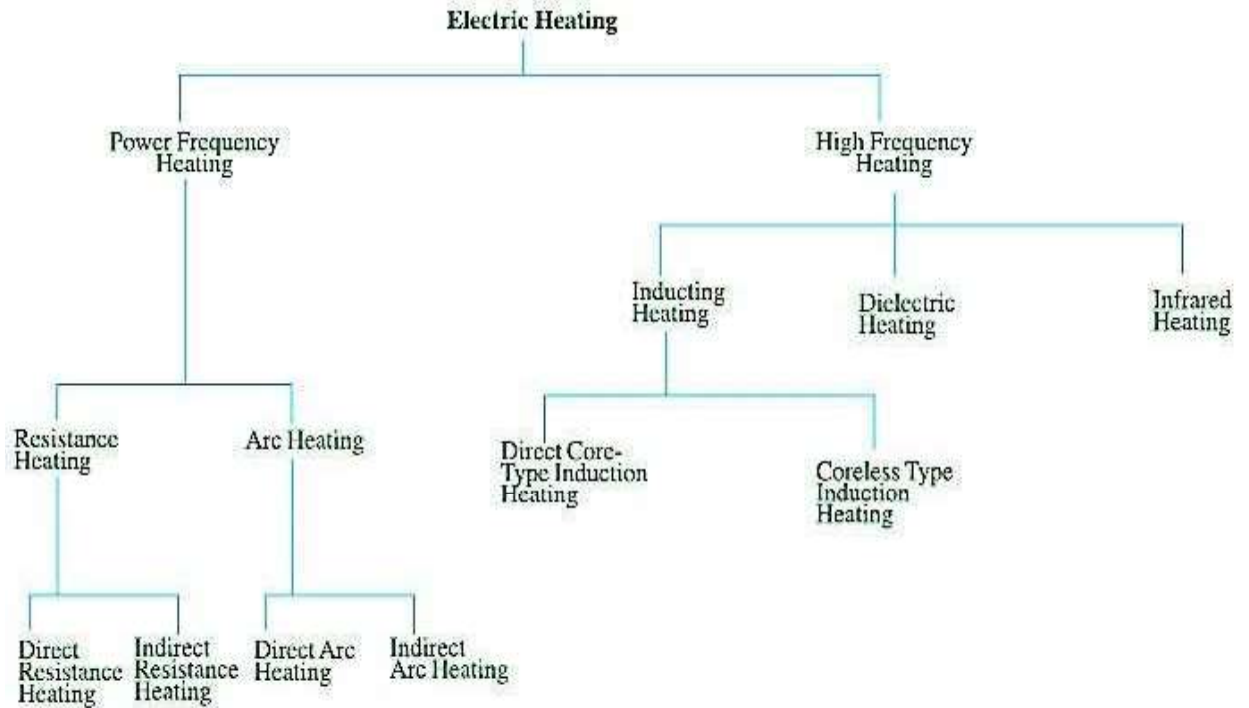
Methods of Electric Heating

- Basically, heat is produced due to the circulation of current through a resistance.
- The current may circulate directly due to the application of potential difference or it may be due to induced eddy currents.
- Similarly, in magnetic materials, hysteresis losses are used to create heat.
- In dielectric heating, molecular friction is employed for heating the substance.
- An arc established between an electrode and the material to be heated can be made a source of heat.
- Bombarding the surface of material by high energy particles can be used to heat the body.
- Room heater is a familiar appliance where electric heating is employed

Different methods of producing heat for general industrial and domestic purposes may be

UTILIZATION OF ELECTRICAL ENERGY

classified below :



Resistance Heating

- It is based on the I^2R effect.
- When current is passed through a resistance element I^2R loss takes place which produces heat.
- There are two methods of resistance heating.
 - Direct Resistance Heating
 - Indirect Resistance Heating

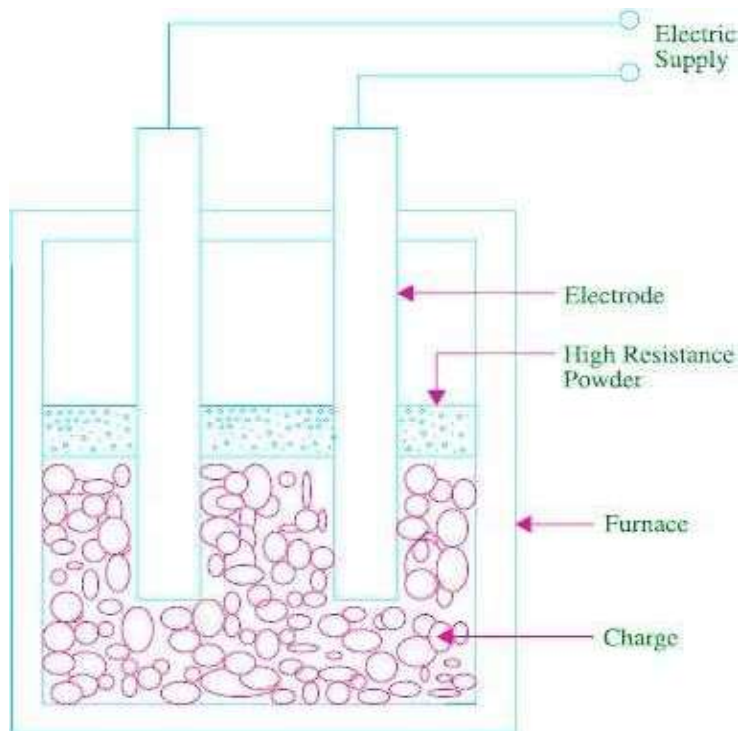
1. Direct Resistance Heating

- In this method the material (or charge) to be heated is treated as a resistance and current is passed through it.
- The charge may be in the form of powder, small solid pieces or liquid.
- The two electrodes are inserted in the charge and connected to either a.c. or d.c. supply

UTILIZATION OF ELECTRICAL ENERGY

(Fig. next slide).

- Obviously, two electrodes will be required in the case of d.c. or single-phase a.c. supply but there would be three electrodes in the case of 3-phase supply.
- When the charge is in the form of small pieces, a powder of high resistivity material is sprinkled over the surface of the charge to avoid direct short circuit.
- Heat is produced when current passes through it.
- This method of heating has high efficiency because the heat is produced in the charge itself.



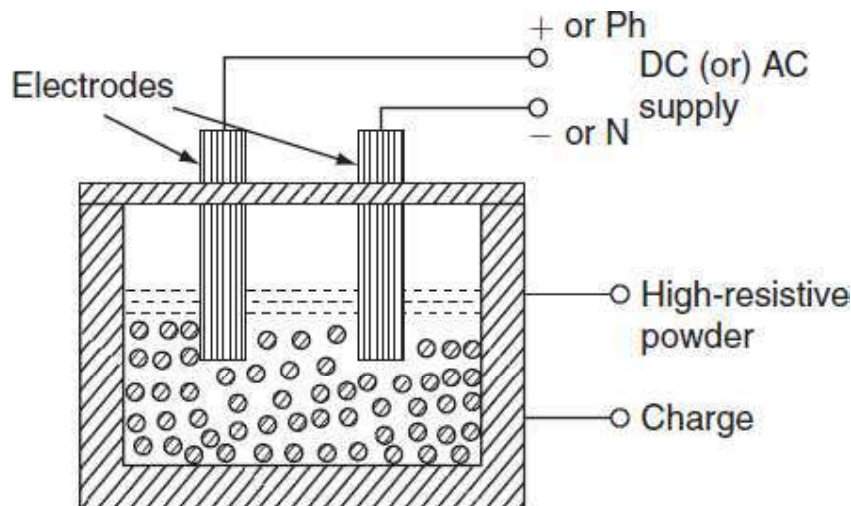
Example : (i) Salt bath furnace

- This type of furnace consists of a bath and containing some salt such as molten sodium chloride and two electrodes immersed in it.
- Such salt have a fusing point of about 1,000- 1,500 deg C depending upon the type of salt used.
- When the current is passed between the electrodes immersed in the salt, heat is developed

UTILIZATION OF ELECTRICAL ENERGY

and the temperature of the salt bath may be increased.

- Such an arrangement is known as a salt bath furnace.
- In this bath, the material or job to be heated is dipped.
- The electrodes should be carefully immersed in the bath in such a way that the current flows through the salt and not through the job being heated.
- As DC will cause electrolysis so, low-voltage AC up to 20 V and current up to 3,000 A is adopted depending upon the type of furnaces.
- The resistance of the salt decreases with increase in the temperature of the salt, therefore, in order to maintain the constant power input, the voltage can be controlled by providing a tap changing transformer.
- The control of power input is also affected by varying the depth of immersion and the distance between the electrodes.

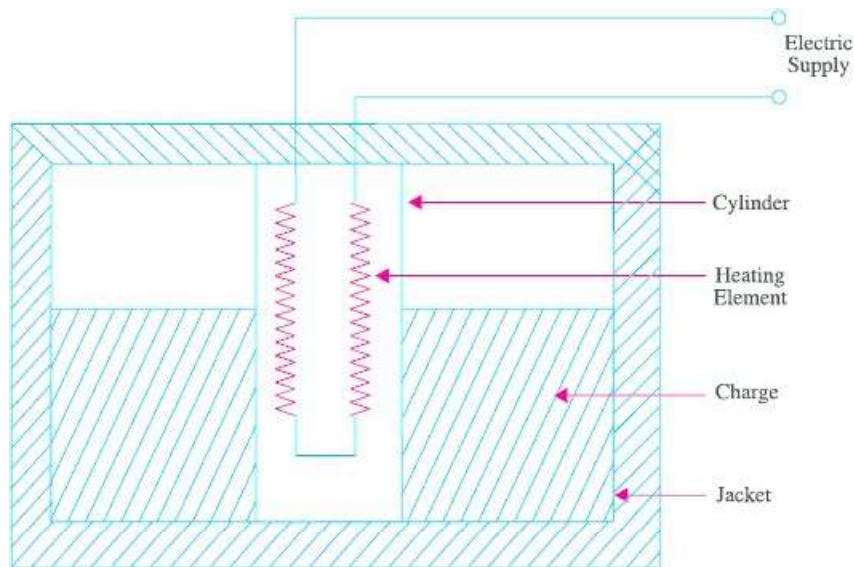


Indirect Resistance Heating.

- In this method of heating, electric current is passed through a resistance element which is placed in an electric oven.
- Heat produced is proportional to I^2R losses in the heating element.

UTILIZATION OF ELECTRICAL ENERGY

- The heat so produced is delivered to the charge either by radiation or convection or by a combination of the two.
- Sometimes, resistance is placed in a cylinder which is surrounded by the charge placed in the jacket as shown in the Fig next slide.
- This arrangement provides uniform temperature. Moreover, automatic temperature control can also be provided.

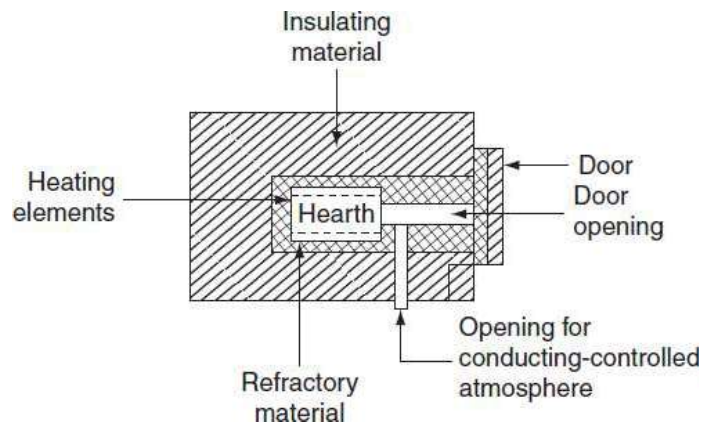


Example : Resistance ovens

- According to the operating temperatures, the resistance furnaces may be classified into various types.
- Low-temperature heating chamber with the provision for ventilation is called as oven.
- For drying varnish coating, the hardening of synthetic materials, and commercial and domestic heating, etc., the resistance ovens are employed.
- The operating temperature of medium temperature furnaces is between 300 deg C and 1,050 degC.
- These are employed for the melting of non-ferrous metals, stove (annealing), etc.
- Furnaces operating at temperature between 1,050deg C and 1,350deg C are known as high-temperature furnaces.

UTILIZATION OF ELECTRICAL ENERGY

- These furnaces are employed for hardening applications. A simple resistance oven is shown in Fig below .



Essential requirements of good heating element

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

- High-specific resistance
 - Material should have high-specific resistance so that small length of wire may be required to provide given amount of heat.
- High-melting point
 - It should have high-melting point so that it can withstand for high temperature, a small increase in temperature will not destroy the element.
- Low temperature coefficient of resistance
 - From Equation (Radiation topic H) , the radiant heat is proportional to fourth powers of the temperatures, it is very efficient heating at high temperature.
 - For accurate temperature control, the variation of resistance with the operating temperature should be very low. This can be obtained only if the material has low temperature coefficient of resistance.
- Free from oxidation
 - The element material should not be oxidized when it is subjected to high

UTILIZATION OF ELECTRICAL ENERGY

temperatures; otherwise the formation of oxidized layers will shorten its life.

- Positive Temperature Coefficient of Resistance.
 - If the temperature coefficient of the resistance of heating element is negative, its resistance will decrease with rise in temperature and it will draw more current which will produce more wattage and hence heat.
 - With more heat, the resistance will decrease further resulting in instability of operation.
- Ductile.
 - Since the material of the heating elements has to have convenient shapes and sizes, it should have high ductility and flexibility.
- High-mechanical strength
 - The material should have high-mechanical strength and should withstand for mechanical vibrations.
- Non-corrosive
 - The element should not corrode when exposed to atmosphere or any other chemical fumes.
- Economical
 - The cost of material should not be so high.

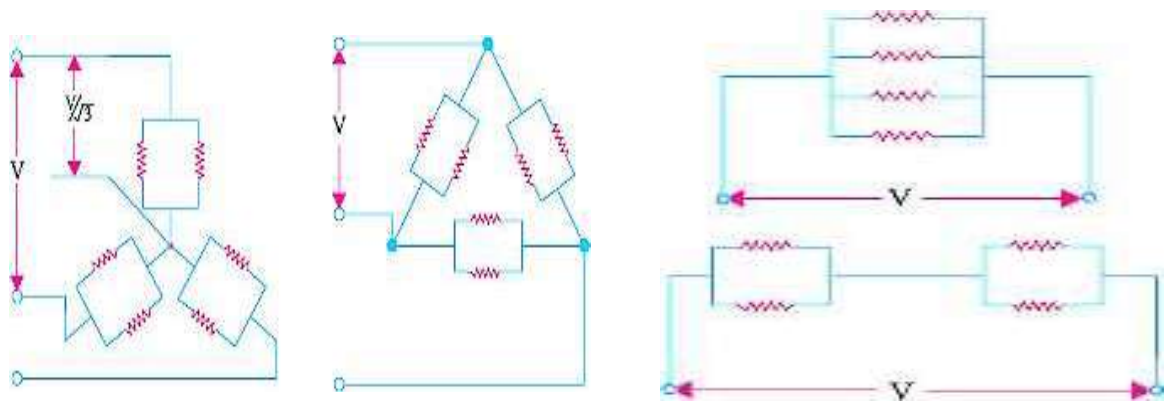
Temperature Control of Resistance Furnaces

- The temperature of a resistance furnace can be changed by controlling the I^2R or V^2/R losses.
- Following different methods are used for the above purpose
- (1) Intermittent Switching.
 - In this case, the furnace voltage is switched ON and OFF intermittently.
 - When the voltage supply is switched off, heat production within the surface is stalled and

UTILIZATION OF ELECTRICAL ENERGY

hence its temperature is reduced.

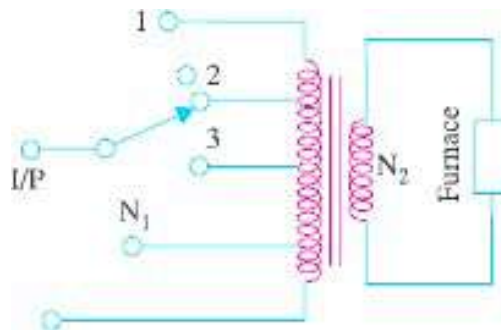
- When the supply is restored, heat production starts and the furnace temperature begins to increase.
- Hence, by this simple method, the furnace temperature can be limited between two limits.
- (2) By Changing the Number of Heating Elements.
- In this case, the number of heating elements is changed without cutting off the supply to the entire furnace.
- Smaller the number of heating elements, lesser the heat produced.
- In the case of a 3-phase circuit, equal number of heating elements is switched off from each phase in order to maintain a balanced load condition.
- (3) Variation in Circuit Configuration.
- In the case of 3-phase secondary load, the heating elements give less heat when connected in a star than when connected in delta because in the two cases, voltages across the elements is different (Fig. 1).
- In single-phase circuits, series and parallel grouping of the heating elements causes change in power dissipation resulting in change of furnace temperature.
- As shown in Fig. 2 heat produced is more when all these elements are connected in parallel than when they are connected in series or series-parallel.



- **(4) Change of Applied Voltage.**

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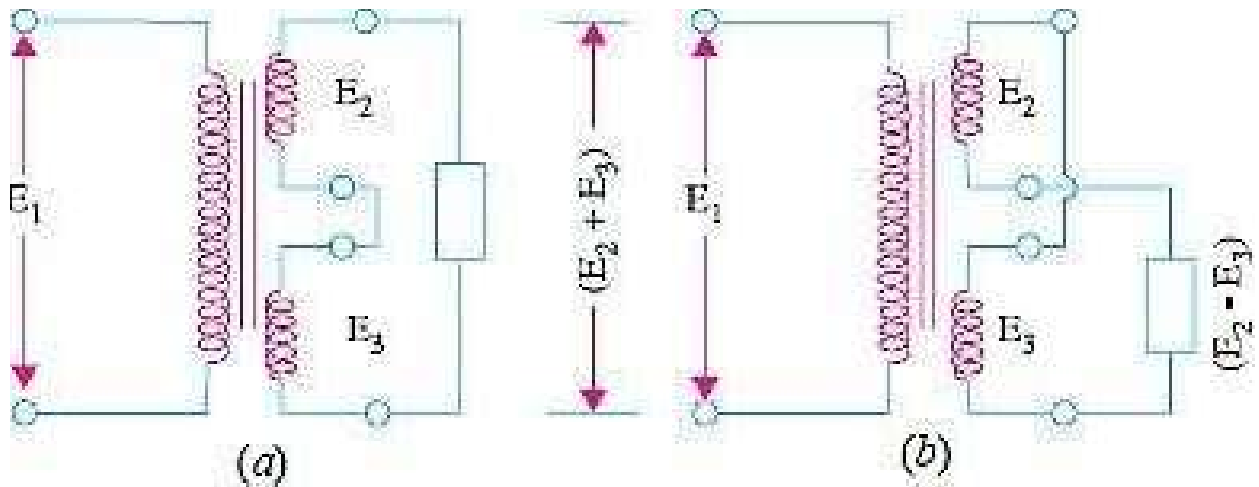
- Obviously, lesser the magnitude of the voltage applied to the load, lesser the power dissipated and hence, lesser the temperature produced.
- In the case of a furnace transformer having high voltage primary, the tapping control is kept in the primary winding because the magnitude of the primary current is less.
- Consider the multi-tap step-down transformer shown in Fig. 3.
- Let the four tapings on the primary winding have 100%, 80%, 60% and 50%.
- When 100% primary turns are used, secondary voltage is given by $V_2 = (N_2/N_1)V_i$ where V_i is the input voltage.
- When 50% tapping is used, the number of primary turns involved is $N_1/2$.
- Hence, available secondary voltage $V_2 = (2N_2/N_1)V_i$.
- By selecting a suitable primary tapping, secondary voltage can be increased or decreased causing a change of temperature in the furnace.



- **(b) Bucking-Boosting the Secondary Voltage.**
- In this method, the transformer secondary is wound in two sections having unequal number of turns.
- If the two sections are connected in series aiding, the secondary voltage is boosted *i.e.*, increased to $(E_2 + E_3)$ as shown in Fig. 4 (a).
- When the two sections are connected in series-opposing [Fig. 4 (b)] the secondary voltage is reduced *i.e.*, there is bucking effect.
- Consequently, furnace voltage becomes $(E_2 - E_3)$ and, hence, furnace temperature is

UTILIZATION OF ELECTRICAL ENERGY

reduced.



- **(c) Autotransformer Control.**
- Fig. 5 shows the use of tapped autotransformer used for decreasing the furnace voltage and, hence, temperature of small electric furnaces.
- The required voltage can be selected with the help of a voltage selector.
- **(d) Series Reactor Voltage.**
- In this case, a heavy-duty core-wound coil is placed in series with the furnace as and when desired.
- Due to drop in voltage across the impedance of the coil, the voltage available across the furnace is reduced. With the help of D.P.D.T. switch, high/low, two mode temperature control can be obtained as shown in the Fig. 6.
- Since the addition of series coil reduces the power factor, a power capacitor is simultaneously introduced in the circuit for keeping the p.f. nearly unity.
- As seen, the inductor is connected in series, whereas the capacitor is in parallel with the furnace.