CMR INSTITUTE OF TECHNOLOGY	USN	

Internal Assesment Test I – NOV 2021

Sub:	UTILIZATION OF ELECTRICAL POWER					Code:	17EE742/18EE742
Date:	13/11/2021	Duration:	90 mins	Max Marks:	50	Sem: VII	Section: A & B

Note: Answer any **five FULL** Questions

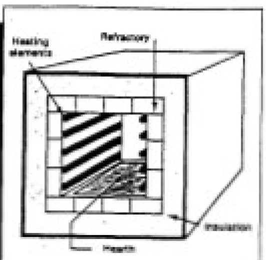
Sketch neat figures wherever necessary. Answer to the point. **Good luck!**

		Marks	OBE CO	OBE RBT
1.	With a neat sketch explain the working of Indirect Resistance Heating	[10]	CO1	L1

Clean, Controlled Heating

Electric resistance furnaces offer a safe, efficient, reliable and clean method for heat treating, melting, heating prior to forming, and brazing metals. Electric furnaces are also easy to control, and operate over a wide temperature range. In addition to heating metals, they are used for melting glass, sintering ceramics, and curing coatings. And the number of applications continues to grow as technological developments broaden the operating temperature range of electric furnaces, and the demand for automatic process control increases.

Resistance heating is based on the principle that, when a current is passed through an electrical resistor, electrical energy is converted to thermal energy. The thermal energy then is transferred to the part by convection, radiation and/or conduction. This issue of *TechCommentary* describes indirect resistance heating and discusses the technical and economic factors to consider when deciding if the process could benefit a particular application or product. Direct resistance heating and encased resistance heaters are discussed in *TechCommentary*, Vol. 3, No. 6.



Schematic diagram of an indirect resistance heating furnace showing the arrangement of the heating elements on the walls. Below about 1250 F, heat transfer to the workpiece is primarily by convection, sometimes with the aid of fans, as in "forced" convection furnaces. Radiation is the major mode of heat transfer at temperatures above about 1250 F and in vacuum furnaces where there is no atmosphere to support convection.

Advantages

Often, an electric resistance furnace and a gas-fired furnace are equally appropriate for a particular application, and the choice is based on economics. However, several characteristics of electric resistance furnaces may make them the better choice for your application. The advantages of electric resistance furnaces include:

- Flexibility. Both operating temperature and furnace atmosphere can be varied. Resistance heating elements are available for all temperatures of importance in industrial processing, whereas the maximum temperature of gas-fired furnaces is limited to approximately 2400 F. Heating in a controlled atmosphere or a vacuum is easily achieved with an electric furnace. Such control is more difficult in a gas furnace unless radiant tubes or protective muffles are used.
- Automatic temperature control. Microprocessors and solid-state switches can control furnace temperature automatically. Because the location and configuration of electric elements can be easily tailored to a given application, temperature is more uniform than with other types of furnaces.
- Improved working conditions. Electric furnaces are quiet because there is no combustion or blower noise (except in forced air furnaces, where there is some fan noise). The absence of smoke and hot flue gases makes the plant both cleaner and cooler, thus minimizing concerns for worker safety and environmental pollution.
- Cost savings. For some applications resistance furnaces are more energy efficient and save space. Resistance furnace efficiency is relatively independent of temperature, whereas the efficiency of gas-fired furnaces drops sharply with increasing temperature. Waste heat is minimized since there are no hot flue gases in an electric furnace. Space is saved because there is no need to store or pipe in flammable fuel or remove exhaust gases.
- Safety. There is little explosion hazard connected with the heating system with an electric resistance furnace.
- Serviceability. Every industrial company is likely to have an electrician with the skills to repair an electric heating system. Burner experts are less common, but are necessary to maintain the efficiency of a gas-fired system.

Applications

Indirect resistance heating is used primarily in the metals, ceramics, electronics and glass industries. The more frequently used processes that incorporate this heating technique include:

- Heat treatment of metals
- Metal melting
- Heating prior to forming
- Brazing
- Sintering ceramics
- Curing coatings
- Glass tempering

		Marks	CO	RBT
2.	A 16KW resistance oven employing nichrome wire is to be operated from a 220V, single phase power supply. If the temperature of the element is to be limited to 1170 ^{o} C and average temperature of the charge is 500 ^{o} C, find the diameter and length of the wire. Radiating efficiency is 0.57,emissivity is 0.9, and specific resistance of nichrome is 109x 10^{-8} ohm-m	[10]	CO1	L3

<table>
<tr>
<td></td>
<td>

Example 2.1. *A resistance oven employing nichrome wire is to be operated from 220 V single-phase supply and is to be rated at 16 kW. If the temperature of the element is to be limited to 1170°C and average temperature of the charge is 500°C find the diameter and length of the element wire.*

Radiating efficiency = 0.57, Emissivity = 0.9, Specific resistance of nichrome = 109 × 10⁻⁸ Ωm.

(Panjab University)

Solution. *Given* : $V = 220$ V ; $P = 16$ kW ; $T_1 = 273 + 1170 = 1443$ K ;
$T_2 = 273 + 500 = 773$ K ; $\eta_{rad} = 0.57$; $e = 0.9$; $\rho = 109 \times 10^{-8}$ Ωm.
l, d :

We know that, $$\frac{l}{d^2} = \frac{\pi V^2}{4\rho P} = \frac{\pi \times 220^2}{4 \times 109 \times 10^{-8} \times (16 \times 10^3)} = 2179660 \qquad ...(i)$$

Now, $$H = 5.67\, \eta_{rad}\, e \left[\left(\frac{T_1}{100}\right)^4 - \left(\frac{T_2}{100}\right)^4 \right] \text{ W/m}^2$$

$$= 5.67 \times 0.57 \times 0.9 \left[\left(\frac{1443}{100}\right)^4 - \left(\frac{773}{100}\right)^4 \right] = 115729 \text{ W/m}^2$$

Now, total heat dissipated/sec. =Electrical power input

$\therefore \quad (\pi d) \times l \times 115729 = 16000 \qquad \therefore \quad dl = 0.044$

or, $$d^2 l^2 = 0.001936 \qquad ...(ii)$$

Multiplying (*i*) and (*ii*), we have

$$l^3 = 2179660 \times 0.001936 = 4219.8$$

$$\therefore \quad \mathbf{l = 16.16\ m.} \quad \textbf{(Ans.)}$$

and, $$\mathbf{d} = \frac{0.044}{16.16} = 2.723 \times 10^{-3} \text{ m} = \mathbf{2.723\ mm.} \quad \textbf{(Ans.)}$$

</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td>

Explain high Frequency Heating

2.1.8. Dielectric Heating

- Dielectric heating (also sometimes called *High frequency capacitive heating*) is employed for heating insulators like wood, plastics and ceramics etc. which cannot be heated easily and uniformly by other methods.
- The supply frequency required of dielectric heating is between 10-50 MHz and applied voltage is 20 kV.
- The overall efficiency of dielectric heating is about 50 percent.

Principle of dielectric heating. When a capacitor is subjected to a sinusoidal voltage, the current drawn by it is never leading the voltage by exactly 90°. The angle between the current and voltage is *slightly less* with the result that there is a small in-phase component of the current which produces power loss in the dielectric of the capacitor.

At ordinary frequency of 50 Hz such loss may be small enough to be negligible but at high frequencies the loss becomes large enough to heat the dielectric. It *is this loss that is utilised in heating the dielectric.*

The insulating material to be heated is placed between two conducting plates in order to form a *parallel-plate capacitor* as shown in Fig. 2.16. The vector diagram of the capacitor is shown in Fig. 2.17.

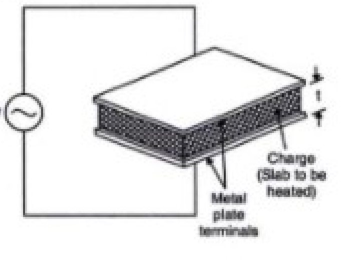


Fig. 2.16. Parallel-plate capacitor -Dielectric heating.

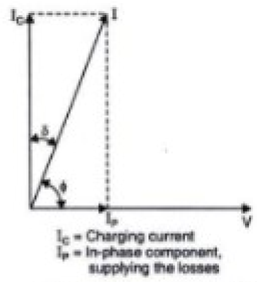


Fig. 2.17. Vector diagram of the parallel-plate capacitor

Power drawn from supply = $VI \cos \phi$

Now, $$I_C = I = \frac{V}{X_C} = \frac{V}{1/2\pi fC} = 2\pi fCV.$$

$$\therefore \quad P = V(2\pi fCV) \cos\phi = 2\pi fCV^2 \cos\phi \qquad ...(2.19)$$

Now, $\phi = (90° - \delta)$, $\cos\phi = \cos(90° - \delta) = \sin\delta = \tan\delta = \delta$

</td>
<td>[10]</td>
<td>CO1</td>
<td>L2</td>
</tr>
</table>

<table>
<tr>
<td></td>
<td>

Power drawn or heat produced will be maximum when resistance of secondary circuit will be equal to reactance of secondary circuit

i.e., $$\frac{0.8568 \times 10^{-4}}{x} = 1.1424 \times 10^{-4}$$

or, $$x = \frac{0.8568 \times 10^{-4}}{1.1424} = \mathbf{0.75.}\quad \textbf{(Ans.)}$$

(*i.e.*, Maximum heat will be obtained with the height of charge as $\frac{3}{4}$th of height of hearth).

2.1.7.3. High frequency eddy current heating

In order to heat an article by eddy currents, it is placed inside a high frequency A.C. current-carrying coil (Fig. 2.14). The alternating magnetic field produced by the coil sets up eddy currents in the article, which consequently, gets heated up. Such a coil is known as *heater coil* or *work coil* and the material to be heated is known as *charge* or *load*.

Primarily, it is the eddy-current loss which is responsible for the production of heat although hysteresis loss also contributes to some extent in the case of magnetic materials.

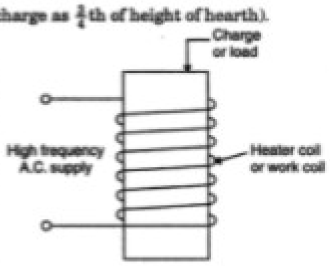


Fig. 2.14. High frequency eddy current heating.

As the eddy current loss $P_e \propto B^2 f^2$, this loss can be controlled by controlling flux density B and the supply frequency f. This loss is greatest on the surface of the material but decreases as we so deep inside. The depth of penetration (d) of eddy currents into the charge is given by :

$$d = \frac{1}{2\pi}\sqrt{\frac{\rho \times 10^9}{\mu_r . f}}\ \text{cm} \qquad ...(2.18)$$

where, ρ = Resistivity of the molten metal,
f = Supply frequency, and
μ_r = Relative permeability.

Thus, since $d \propto \frac{1}{\sqrt{f}}$, therefore, eddy current heating can be restricted to any desired depth of the material to be heated by judicious selection of frequency of the heating. The supply frequency is usually employed between 10000 and 40000 Hz.

Advantages of eddy current heating :

(*i*) Temperature control is very easy.
(*ii*) The heat can be made to penetrate into the metal surface to any desired depth.
(*iii*) This heating method is quick, clean and convenient.

</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td>

Estimate the efficiency of high frequency induction furnace which takes 10 minutes to melt 1.8kg of aluminium. The input to the furnace being 5KW and initial temperature is 15^{o} C. Given specific heat of aluminium =880J/Kg/^{o}C;Melting point of aluminium =660^{o}C,Latent Heat of fusion of aluminium=32KJ/Kg,1J=2.78X10^{-7} KWh

Sample problem based on this steps we get Efficiency is 36%

Example. 47.6. *Determine the efficiency of a high-frequency induction furnace which takes 10 minutes to melt 2 kg of a aluminium initially at a temperature of 20°C. The power drawn by the furnace is 5 kW, specific heat of aluminium = 0.212, melting point of alumimium = 660° C and latent heat of fusion of alumimium. = 77 kcal/kg.*

Solution. Heat required to melt aluminium = 2 × 77 = 154 kcal

Heat required to raise the temperature of aluminium from 20°C to 660°C
= 2 × 0.212 × (660 – 20) = 2 × 0.212 × 640 = 271.4 kcal

Total heat required = 154 + 271.4 = 425.4 kcal

Heat required per hour = 425.4 × 60/10 = 2552.4 kcal

Power delivered to aluminium = 2552.4/860 = 2.96 kW

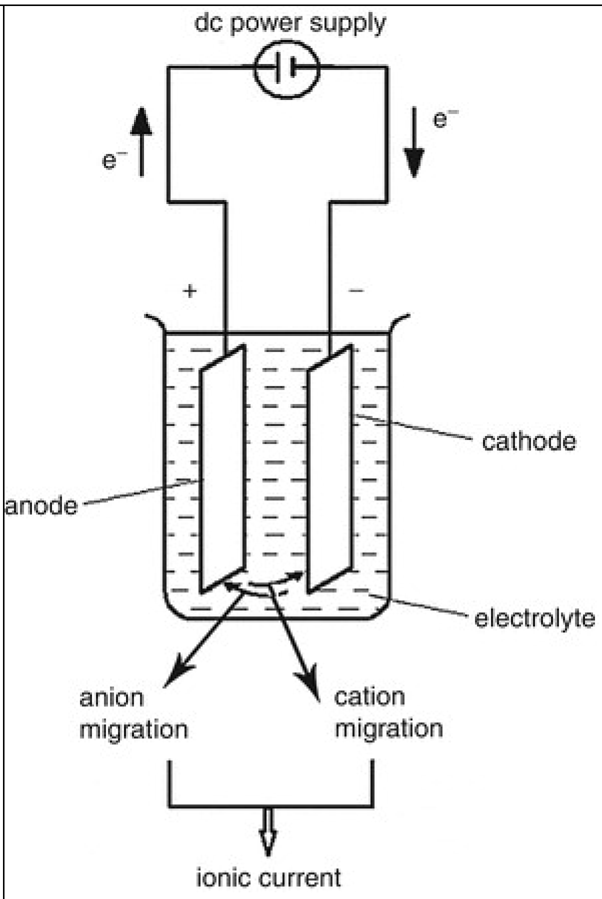
∴ efficiency = output/input = 2.97/5 = **0.594 or 59.4%**

</td>
<td>[10]</td>
<td>CO1</td>
<td>L3</td>
</tr>
<tr>
<td>5.</td>
<td>

What is electro deposition? Discuss the factors that affects the quality of electro deposition

Electrochemical deposition, or electro deposition (also known as electroplating), is a process of depositing conducting/semiconducting materials onto a substrate (often conducting) using an electric field and redox reaction.

</td>
<td>[10]</td>
<td>CO2</td>
<td>L2</td>
</tr>
</table>



The factors, on which the quality of electrodeposition depends, are given below:

Factor # 1. Nature of Electrolyte:

The formation of smooth deposit largely depends upon the nature of electrolyte employed. The electrolyte from which complex ions can be obtained, such as cyanides, provides a smooth deposit.

Factor # 2. Current Density:

Electrodeposition depends upon the rate at which crystals grow and the rate at which fresh nuclei are formed, therefore, at low current densities the deposits are coarse and crystalline in nature. The deposit of metal will be uniform and fine-grained if the current density is used at rate higher than that at which the nuclei are formed. In case the rate of formation of nuclei is very high due to very high current density, there is a chance that the limiting value of the electrolyte is exceeded. At such instances, the deposit will be spongy and porous.

Factor # 3. Temperature:

A low temperature of the solution favours formation of small crystals of metal; and a high temperature, large crystals. In some cases this is very marked, a difference of only 15°C resulting in a 50% decrease in strength of the metal deposited. On the other hand, high temperature may give beneficial results due to (a) increased solubility of the salts, permitting greater metal concentration and higher current densities; (b) increased conductivity, which also permits higher current densities and reduces the tendency to form trees; (c) decreased occlusion of hydrogen in the deposited metal, which in many cases is the case of bad deposits. Since both (a) and (b) tend to decrease crystal size, they may in some cases counteract the tendency of temperature alone to increase the crystal size.

Factor # 4. Conductivity:

The use of a solution of good conductivity is important from the standpoint of view of economy in power consumption and also because it reduces the tendency to form trees and rough deposits.

Factor # 5. Electrolytic Concentration:

Higher current density, which is necessary to obtain uniform and fine-grain deposit, can be achieved by increasing the concentration of the electrolyte.

Factor # 6. Additional Agents:

The addition of acids or other substances to the electrolyte reduces its resistance, as already mentioned. There is another class of additional agents which takes little or no direct part in the chemical reactions but influences the nature of deposit, sometimes even making an otherwise unworkable process into one of practical importance. Such additional agents are glue, gums, dextrose, dextrin, gelatin, agar, alkaloids, albumen, phenol, glycerin, sugar, glucose, rubber etc. The crystal nuclei absorb the additional agent added in the electrolyte. This prevents it to have large growth and thus deposition will be fine-grained. For obtaining satisfactory deposit of zinc from zinc sulphate solution addition of glucose or certain types of sugar is necessary.

Factor # 7. Throwing Power:

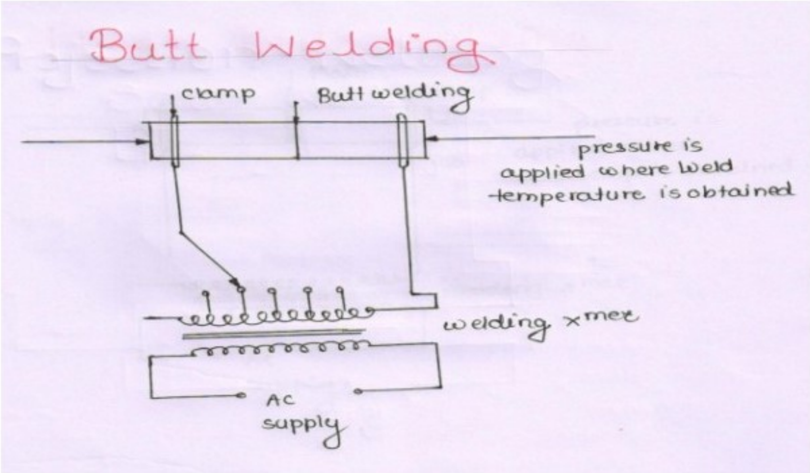
This is the ability of electrolyte to produce uniform deposit on an article of irregular shape and is one of the most important characteristics of plating or deposition bath. The distance between the various portions of cathode and anode will be different due to irregular shape of the cathode. Due to unequal distance, the resistance of the current path through the electrolyte for various portions of the cathode will be different but the potential difference between the anode and any point on the article to be plated (cathode) will, of course be the same and the result will be that the current density will be more on the portion nearer to anode and it will cause uneven deposit of the metal.

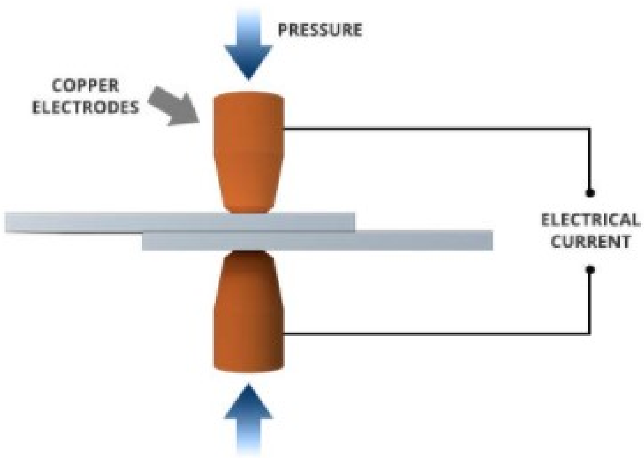
Throwing power can be improved in two ways—firstly by increasing the distance between the anode and cathode and secondly by reducing the voltage drop at the cathode surface. In some cases decrease of current density causes a decrease in voltage drop at cathode, leaving more voltage available for overcoming the resistance of the electrolyte, thus tending to counteract any change in current concentration. This is the reason that solutions of the cyanides of metals usually have a better throwing power than solutions of the sulphates.

Factor # 8. Polarization:

The rate of deposition of metal increases with the increase in electroplating current density up to a certain limit after which electrolyte surrounding the base metal becomes so much depleted of metal ions that the increase in current density does not cause increase in rate of deposition. Use of current density beyond this limit causes electrolysis of water and hydrogen liberation on the cathode. This hydrogen evolved on the cathode blankets the base metal which reduces the rate of metal deposition.

This phenomenon is called the polarization. Blanketing effect can be reduced by agitating the electrolyte. With reverse current electroplating, in which at regular intervals plating current is reversed for a second or so, sufficient electron concentration is established around the base metal and the polarization effect becomes negligible even

	with very high overall speed of plating. **The other advantages of reverse current plating are:** (i) unsound and inferior metal is depleted during reverse current period and flat level surfaces are produced,			
6.	Discuss the types of welding and state i) Spott welding ii)Butt welding **Diagram butt welding:-**  **Explanation:** Transformer used for welding is designed for low voltage and high current secondary. Transformer is oil cooled The job is clamped as shown in fig. two parts which are to be welded are brought together Sufficiently heavy current is passed through joints by welding transformer, which creates necessary heat at joints due to I2R When welding temperature is reached supply is cut down. And external pressure is applied simultaneously across the job to complete weld **Application Butt Welding:** 1) For welding rod, wire, pipe etc 2) For joining thick metal plates or bars at end	[10]	CO2	L2

	A form of resistance welding, spot welding is one of the oldest welding processes whereby two or more sheets of metal are welded together without the use of any filler material. The process involves applying pressure and heat to the weld area using shaped alloy copper electrodes which convey an electrical current through the weld pieces. The material melts, fusing the parts together at which point the current is turned off, pressure from the electrodes is maintained and the molten "nugget" solidifies to form the joint.  *Schematic diagram of resistance spot welding* The welding heat is generated by the electric current, which is transferred to the workpiece through copper alloy electrodes. Copper is used for the electrodes as it has a high thermal conductivity and low			
7.	The power required for dielectric heating of slab resin 150cm^2 in area and 2cm thick is 200W, frequency 30MHz.Material has a relative permittivity of 5 and power factor of 0.05.Determine the voltage necessary and current flowing through the material. If the voltage is limited to 600V, what will be the value of the frequency to obtain the same heating? Assume absolute permittivity = 8.854x10-12F/m. Determine the necessary voltage. **Example. 47.10.** *A slab of insulating material 150 cm^2 in area and 1 cm thick is to be heated by dielectric heating. The power required is 400 W at 30 MHz. Material has relative permittivity of 5 and p.f. of 0.05. Determine the necessary voltage. Absolute permittivity = 8.854 × 10^{-12} F/m.* **(Utilisation of Elect. Energy, Punjab Univ.)** **Solution.** $P = 400$ W, p.f. = 0.05, $f = 30 \times 10^6$ Hz $C = \in_0 \in_r\ A/d = 8.854 \times 10^{-12} \times 5 \times 150 \times 10^{-4}/1 \times 10^{-2} = 66.4 \times 10^{-12}$ F Now, $P = 2\pi f C V^2 \cos\phi$ or $400 = 2\pi \times 30 \times 10^6 \times 66.4 \times 10^{-12} \times V^2 \times 0.05$ or V = **800 V** I= 5 A, When voltage is 600V f= 53.2MHz	[10]	CO2	L3