Classroom slides: For reference only

Refer Video Sessions & Short Notes for detailed study

Classroom Slides Set-2

Utilization of Electrical Power

Electric Heating & Welding
Part-2

Electric Heating: Syllabus

Utilization of Electrical Power

Electrical Heating

Electric heating and welding- advantages and types of electric heating- properties of resistance heating materials- design of heating elements- Resistance ovens- methods of temperature controls.

Induction heating- Principle- factors affecting induction heating- induction furnace- core type and core less type- high frequency eddy current heating- dielectric heating- equivalent circuit loss angle application of dielectric heating- Arc furnace- direct and indirect types.

Arc Heating

Classroom Slides Set-2

- Heating the materials by means of electric arc
- Industrial arc furnaces working under arc heating
- Electrical arc furnace means an extremely hot enclosed space where heat is produced by means of electric arcing for melting certain metals such as scrap steel without changing electro chemical properties of the metals
- It is desirable to operate the arc furnace at 0.7 power factor
- The arc furnace have conical shapes
- Two type of arc heating direct and indirect

Electrode used in Arc Heating

- Carbon electrodes
- Graphite electrodes
- Self - baking electrodes

#Note
Dielectric Strength of air : 30 kV/cm (max.)
Dielectric Strength of air : 21.1 kV/cm (R.M.S)

Additional exam specific points is session ***SE-2-Part-1_Video: 21.2***

Carbon electrodes

- They are made of anthracite coal and coke
- Uniform heating can be obtained with large area of carbon electrodes
- Oxidation starts at about 400°C
- Used in small furnaces
- Used in manufacturing of Ferro-alloys, aluminium, calcium carbide, phosphorus

Graphite electrodes

- They are obtained by heating carbon electrodes to a very high temperature
- Owing to lower resistivity of graphite (one fourth of the carbon), graphite is required half in size for the same current resulting is easy replacement
- Oxidation starts at about 600°C

Self - baking electrodes

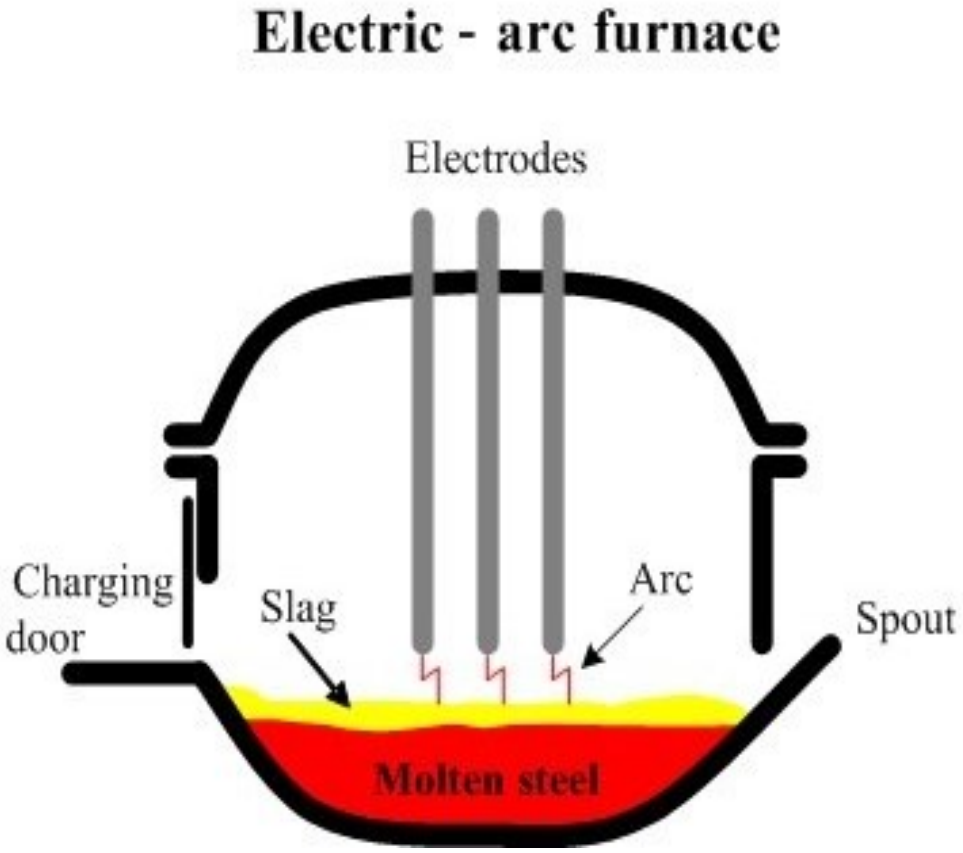
- They are made of a special paste, the composition of the paste depends upon the type of process for which it is employed
- When current is passed, heat is produced that bakes the paste to form an electrode
- Used production of Ferro-alloys, electro- chemical furnaces and in production of aluminium by electrolytic process

Direct Arc Heating

Additional exam specific points is session ***SE-2-Part-1_Video: 21.2***

Classroom Slides Set-2

- An arc is made to strike between electrodes and charge itself
- The heat energy of arc is absorbed by the charge and thus heating is done



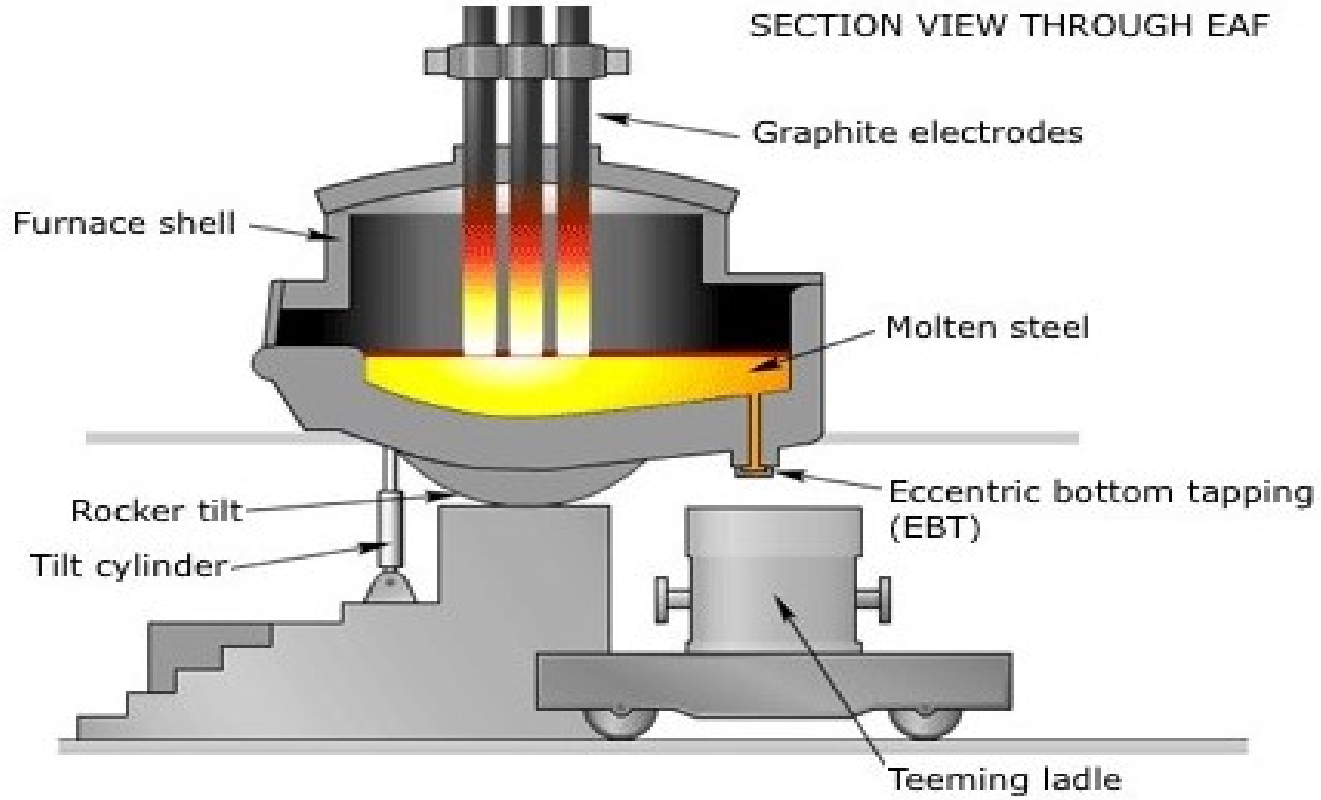


Fig: Electric Arc Heating

Working of Direct ARC heating furnaces: (for understanding purpose only)

Classroom Slides Set-2

- The space between the charge and electrode get ionized by Appling electric voltage in electrodes
- The ionized space become a conducting medium and form arc
- The arc direct contact with the charge
- To increase or decrease the arc length by moving the electrode upward and downward by a motor
- To control the voltage of arc a transformer is used with tapping in primary winding
- If the available supply is DC or 1-Φ AC, two electrodes are sufficient, if the supply is 3-Φ AC; three electrodes are placed at three vertices of an equilateral triangle
- The most important feature of the direct arc furnace is that the current flows through the charge, the stirring action is inherent due to the electromagnetic force setup by the current and such furnace is used for manufacturing alloy steel and gives purer product

Additional exam specific points is session ***SE-2-Part-1_Video: 21.2***

Advantages

Classroom Slides Set-2

- It produces purer products, when compared with other methods.
- It is very simple and easy to control the composition of the final product during refining process

Application

- This type of furnace is to produce steel, alloy steel such as stainless steel etc.
- Used for the manufacture of grey iron casting

Indirect Arc heating

Classroom Slides Set-2

- Electric arc is produced between the electrodes
- The heat of arc is then passed on to the charge through radiation
- This electric arc is used for melting the metal

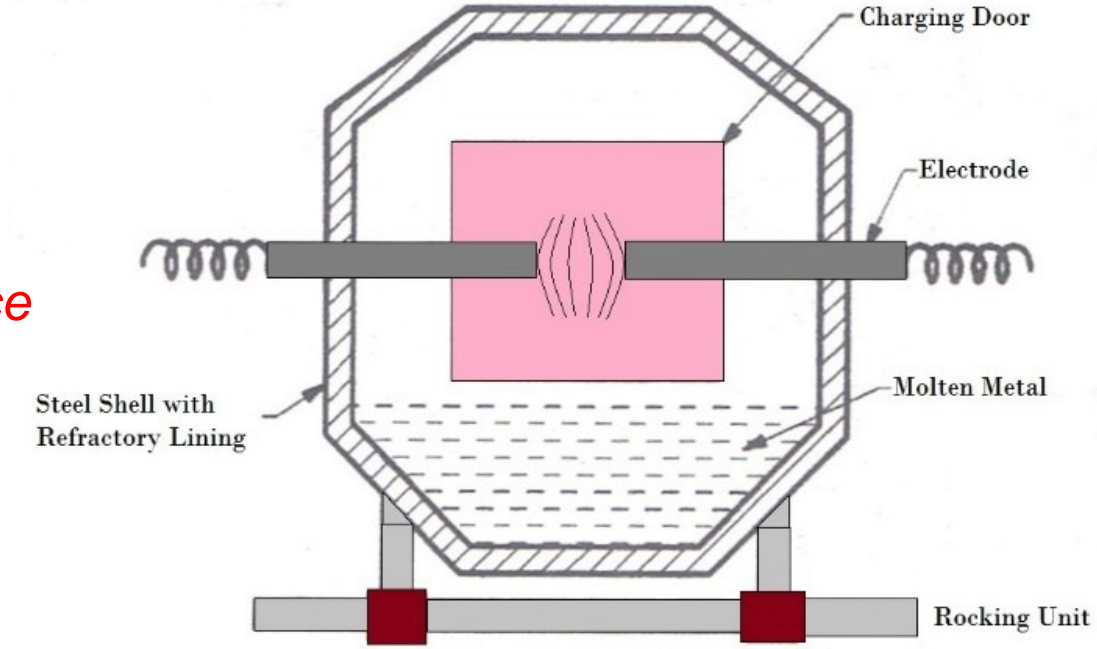


Fig: Rocking Arc Furnace

Working of Indirect ARC heating furnaces: (for understanding purpose only)

Classroom Slides Set-2

- In indirect arc furnace, the arc strikes between two electrodes by bringing momentarily in contact and then with drawing them heat so developed, due to the striking of arc across air gap is transferred to charge is purely by radiation
- These furnaces are usually single phase (1-Φ) and hence their size is limited by the amount of one-phase load which can be taken from one point
- Since on this furnace current does not flow through the charge, there is no stirring action and the furnace is required to be rocked mechanically
- The electrodes are projected through this chamber at each end along the horizontal axis. This furnace is also sometimes called as Rocking Arc Furnace

Additional exam specific points is session ***SE-2-Part-1_Video: 21.2***

Working of Indirect ARC heating furnaces: (for understanding purpose only)

Classroom Slides Set-2

- The charge in this furnace is heated not only by radiation from the arc between electrode tips but also by conduction from the heated refractory during rocking action; so the efficiency of such furnace is high
- Power input to the furnace is regulated by adjusting the arc length by moving the electrodes
- Even though it can be used in iron foundries where small quantities of iron are required frequently, the main application of this furnace is the melting of **non-ferrous metals**

Additional exam specific points is session ***SE-2-Part-1_Video: 21.2***

Classroom Slides Set-2

Advantages

- Lower overall production cost per tonne of molten material
- Sound casting in thin and intricate design can be produced
- Metal losses due to oxidation and volatilization are quite low
- Flexible in operation

Disadvantage

- No inherent stirring action as there is no current flow through the charge
- Continuous rocking should be done to distribute heat uniformly

Application

- The arc furnaces are used to produce mini steel structural bars and steel rods
- The main application of this type furnace is melting of non-ferrous metals

C) Electron bombardment heating

Classroom Slides Set-2

- The electrical heating process used is electron bombardment of a refractory metal heat exchange by ac celebration of electrons from an emitter to collecting surface heating occurs at the heat exchanger surface by impingement of electron

- Bombardment of electron causes heating

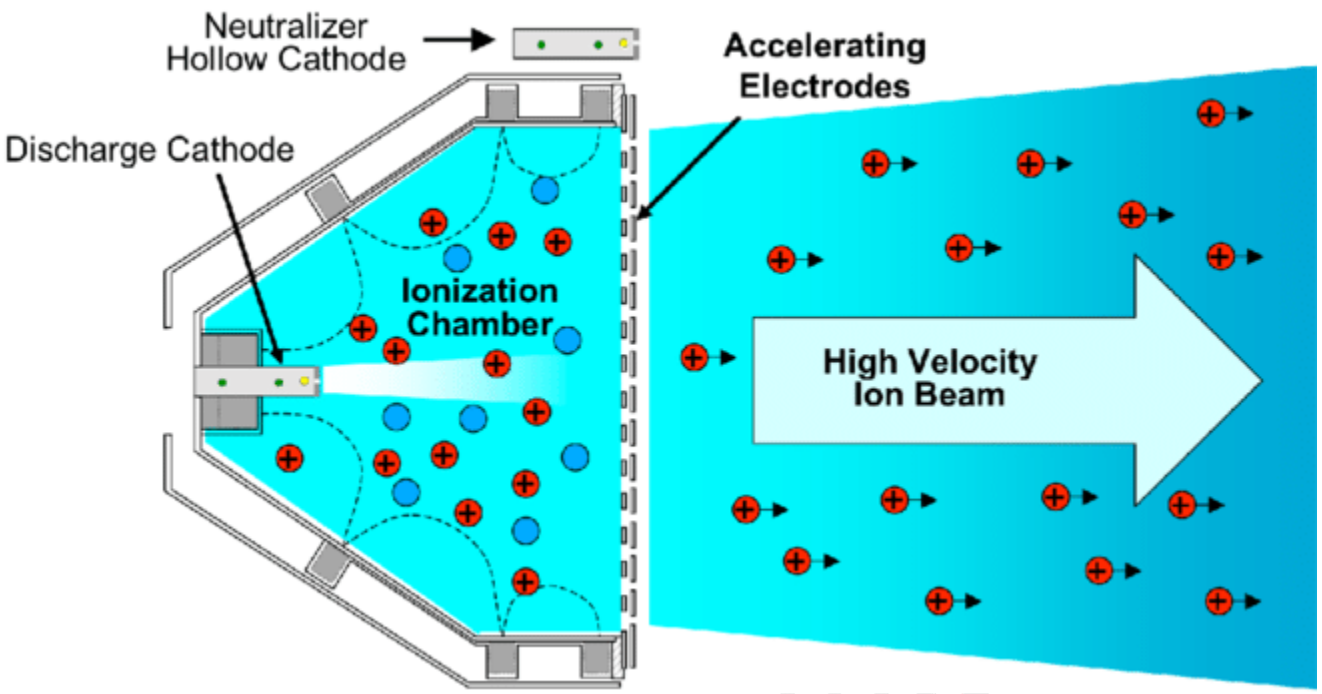


Fig: An Illustration of electron bombardment

Types: High Frequency Heating

Classroom Slides Set-2

1. Induction Heating or Eddy Current Heating
   (Electrically **conducting Materials**)

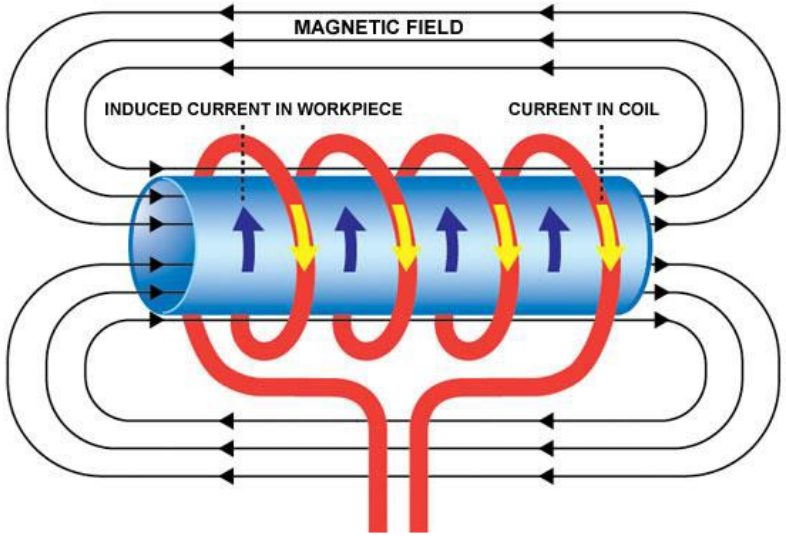
2. Dielectric Heating (or Electronic Heating or Radio Frequency Heating)
   (Electrically **insulating Materials**)

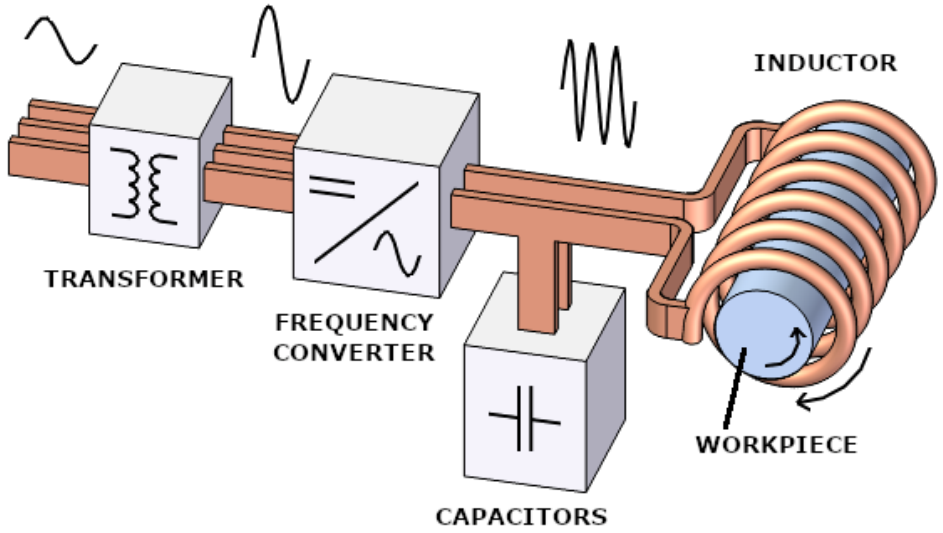
1. Induction Heating or eddy current heating

Classroom Slides Set-2

Induction heating is the process of heating an electrically conducting object (usually a metal) by electromagnetic induction, through heat generated in the object by eddy currents

Fig: An Illustration of eddy current heating





Classroom Slides Set-2

- An induction heater consists of an electromagnet and an electronic oscillator that passes a high frequency alternating current (AC) through the electromagnet
- The rapidly alternating magnetic field penetrates the object, generating electric currents inside the conductor, called eddy currents
- The eddy currents flowing through the resistance of the material heat it by Joule heating
- An important feature of the induction heating process **is that the heat is generated inside the object itself**

To develop sufficient amount of heat the resistance of material must be low and the voltage must be higher*, which can be obtained by employing higher flux and higher frequency*

Additional exam specific points is session ***SE-2-Part-1_Video: 21.2***

- If the charge is non magnetic, then the heat developed due to eddy current loss

Classroom Slides Set-2

- If the charge is magnetic material there will be hysteresis loss in addition to eddy current loss

- Both the hysteresis and eddy current loss depends upon frequency ,but in high frequency hysteresis loss is very small as compeered to eddy current

The depth of penetration of the eddy currents is given by,

$$\text{depth of penetration} = \frac{1}{2\pi}\sqrt{\frac{\rho \times 10^9}{\mu f}}\ \text{cm}$$

where ρ = specific resistance of charge in Ω cm

f = frequency in Hz

μ = permeability of the charge

Additional exam specific points is session ***SE-2-Part-1_Video: 21.2***

Skin depth, frequency, eddy current loss **

KPSC Question

Additional exam specific points is session ***SE-2-Part-1_Video: 21.2***

Applications of Induction Heating

Classroom Slides Set-2

1. Heat treatment in metallurgy
2. Zone refining used in the semiconductor industry *(Kerala PSC, SSC JE**)*
3. To melt refractory metals that require very high temperatures
4. It is also used in induction cook-tops for heating containers of food; called ***Induction Cooking***
5. Plastic processing: Induction heating is used in plastic injection moulding machines

Type of Induction Furnaces

Classroom Slides Set-2

There are basically two type of induction furnaces they are

1. Core type or low frequency induction furnace
2. Coreless type or high frequency induction furnace

Core Type Furnace

The operation principle of core type furnace is the electromagnetic induction. This furnace is operating just like a transformer

It further classified as

1. Direct core type
2. Vertical core type
3. Indirect core type

Direct Core Type

Classroom Slides Set-2

The core type furnace is essentially a transformer in which the charge to be heated forms single turn secondary Circuit and is magnetically coupled to the primary by an iron core

- The magnetic coupling between primary and secondary is very weak, it results in high leakage reactance and low pf
- To over come the increase in leakage reactance the furnace should be operated at low frequency of order of 10Hz

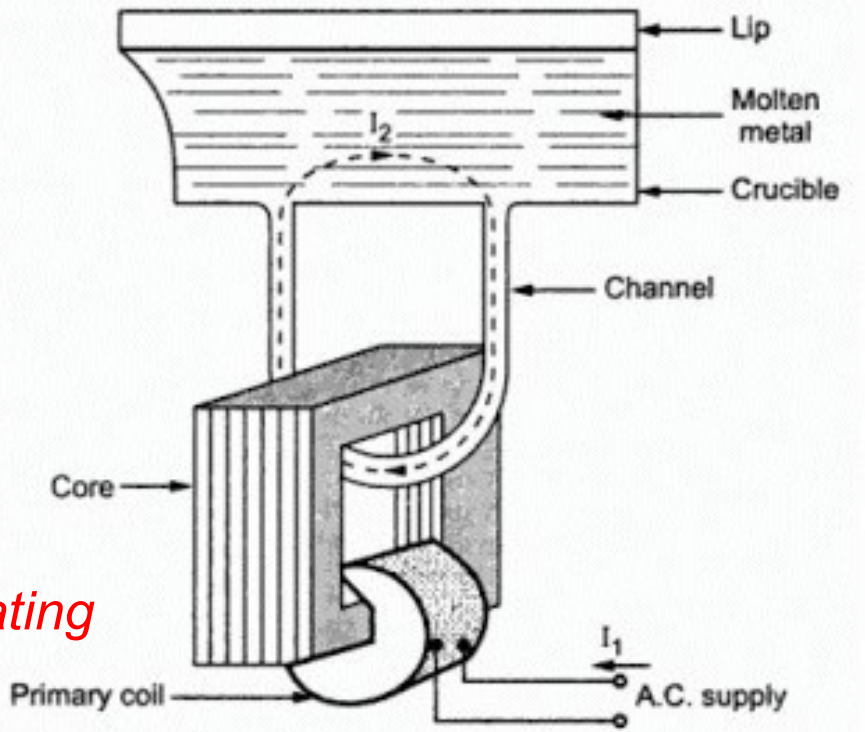


Fig: Direct core type Induction heating

Additional exam specific points is session

SE-2-Part-1_Video: 21.2
Disadvantages, Pinch effect ** KPSC question

Vertical Core Type furnace

Classroom Slides Set-2

- It is an improved form of direct core type, this furnace consists of a **vertical core instead of horizontal core** it is also called **Ajax-Wyatt induction** furnace
- This furnace is very suitable for continuous operation
- Vertical core avoids the pinch effect due to the weight of the charge in main body of the crucible
- The leakage reactance is comparatively low and the power factor is high as the magnetic coupling is high compared to direct core type
- It is suitable for continues operation and widely used for melting and refining of brass and other heavy non ferrous metals

Additional exam specific points is session ***SE-2-Part-1_Video: 21.2***

- The power factor of the arrangement is about 0.8
- Ajax Wyatt Vertical Core Furnace is used for melting and refining of non-ferrous metals like brass, copper, and zinc
- Its efficiency is about 75 percent

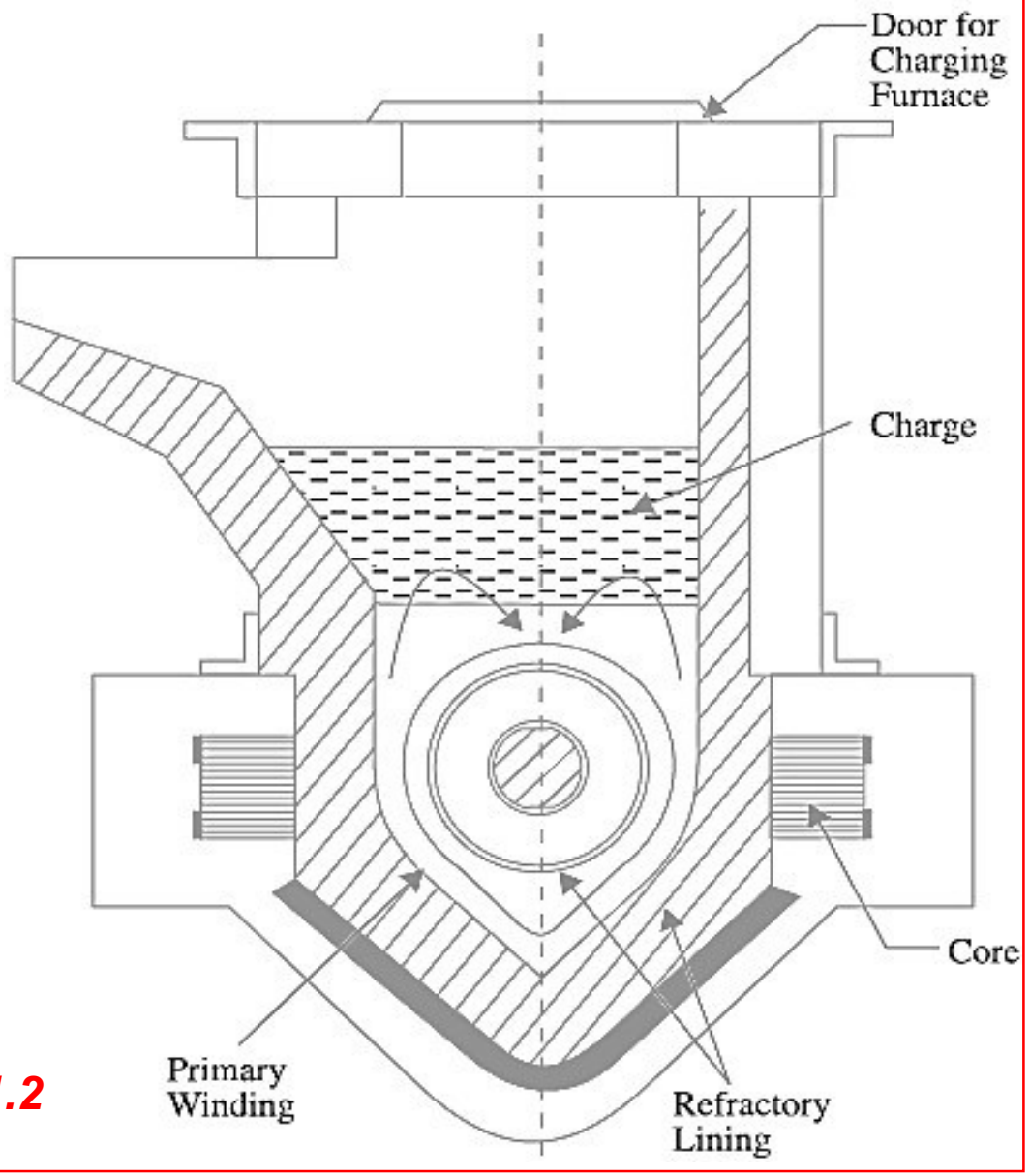


Fig: Vertical core type furnace

Important: Previous Year Question (Kerala PSC, SSC JE**)

Additional exam specific points is session ***SE-2-Part-1_Video: 21.2***

Indirect Core Type Furnace

Classroom Slides Set-2

- This type of furnace is used for providing heat treatment to metal
- The secondary winding itself forms the walls of the container or furnace and an iron core links both primary and secondary windings.
- The heat produced in the secondary winding is transmitted to charge by radiation

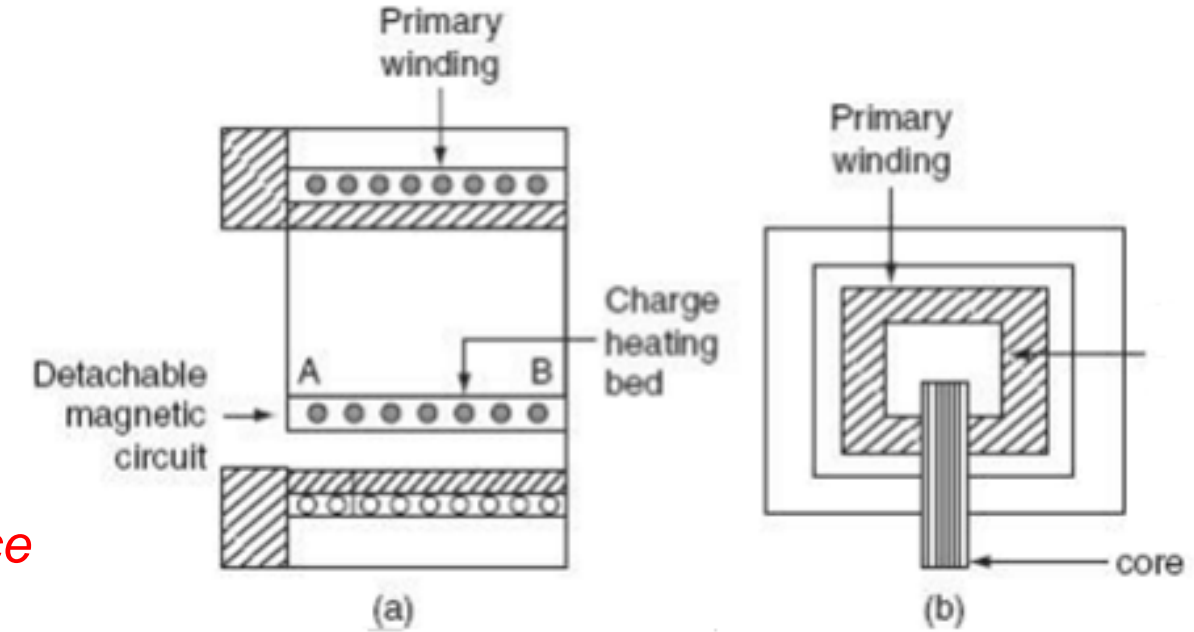


Fig: Indirect core type furnace

Indirect Core Type Furnace : Principle of working

Refer session: 21.2

Classroom Slides Set-2

- It consists of magnetic circuit AB is made up of a special alloy and is kept inside the chamber of the furnace.
- This magnetic circuit loses its magnetic properties at certain temperature and regains them again when it is cooled to the same temperature
- When the oven reaches to critical temperature, the reluctance of the magnetic circuit increases many times and the inductive effect decreases thereby cutting off the supply heat
- The magnetic circuit is detachable type that can be replaced by the other magnetic circuits having critical temperatures ranging between 400°C and 1,000°C
- The furnace operates at a pf of around 0.8

Additional exam specific points is session ***SE-2-Part-1_Video: 21.2***

Coreless Type Induction Furnace

Classroom Slides Set-2

- It is simple furnace with the absence core
- In this furnace heat developed in the charge due to eddy current
- The furnace consist of refractory or ceramic crucible cylindrical in shape enclosed within a coil that forms primary of the transformer
- The furnace also contains a conducting or non contacting container that acts as secondary

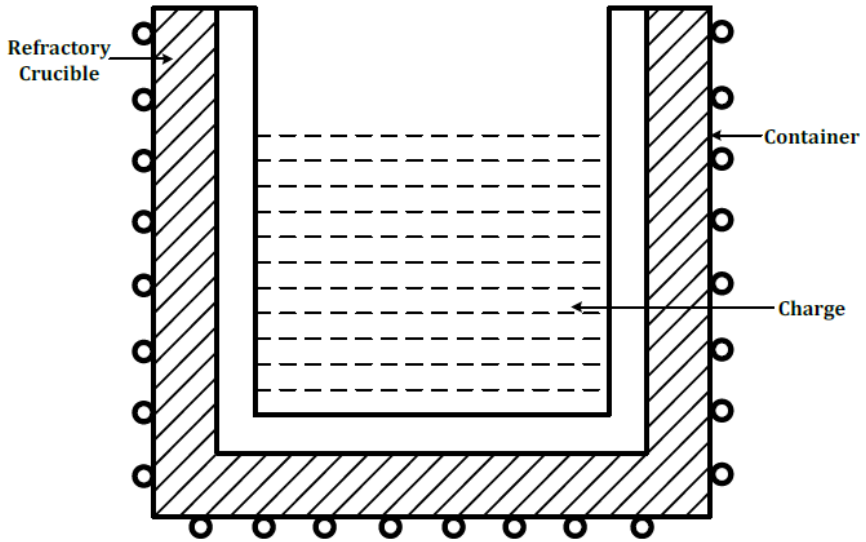


Fig: Coreless type Induction furnace

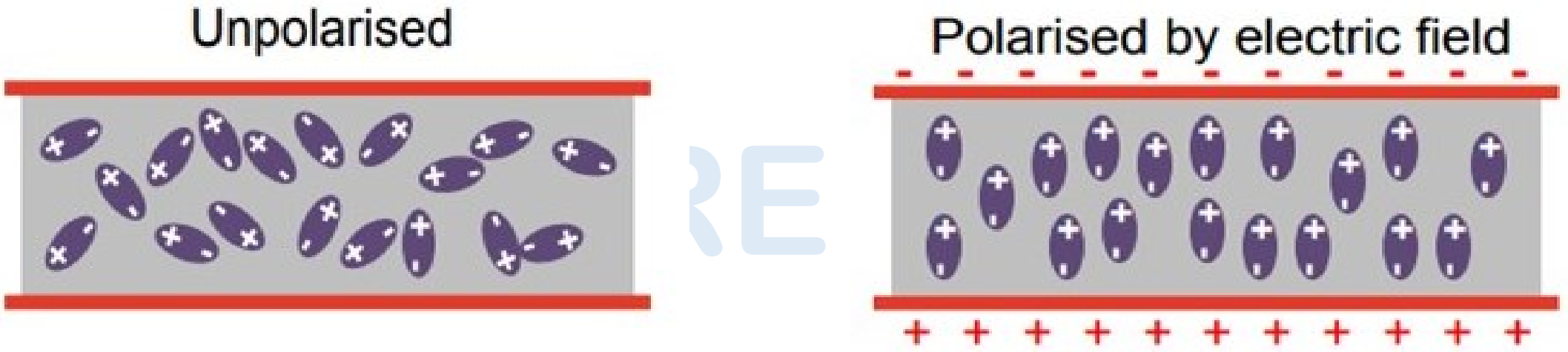
Classroom Slides Set-2

- If the container is made up of conducting material charge can be conducting or non conducting
- If the container is made up of non contacting material charge taken should have conducting properties
- When primary coils are excited by an alternating source, the flux set up by these coils induce the eddy currents in the charge
- These currents heat the charge to melting point and they also set up electromagnetic forces that produce a stirring action to the charge
- In coreless furnace, the flux density will be low as there is no core. Hence, the primary supply should have high frequency for compensating the low flux density
- If it is operating at high frequency, due to the skin effect, it results in copper loss, thereby increasing the temperature of the primary winding
- All this necessitates artificial cooling. The coil, therefore, is made of hollow copper tube through which cold water is circulated

2. Dielectric Heating (or Electronic Heating or Radio Frequency Heating)

Classroom Slides Set-2

- A dielectric material is an electrical insulator that can be polarized by applied electric field



- An important property of a dielectric is its ability to support an electrostatic field
- A dielectric material is a substance that is poor conductor of electricity but an efficient supporter of electrostatic field

*Additional exam specific points is session**

SE-2-Part-1_Video: 21.2

Dielectric Heating (or Electronic Heating or Radio Frequency Heating)

Classroom Slides Set-2

Dielectric heating is the process in which a radio frequency (RF) alternating electric field, or radio wave or microwave electromagnetic radiation heats a dielectric material. At higher frequencies, this heating is caused by molecular dipole rotation within the dielectric

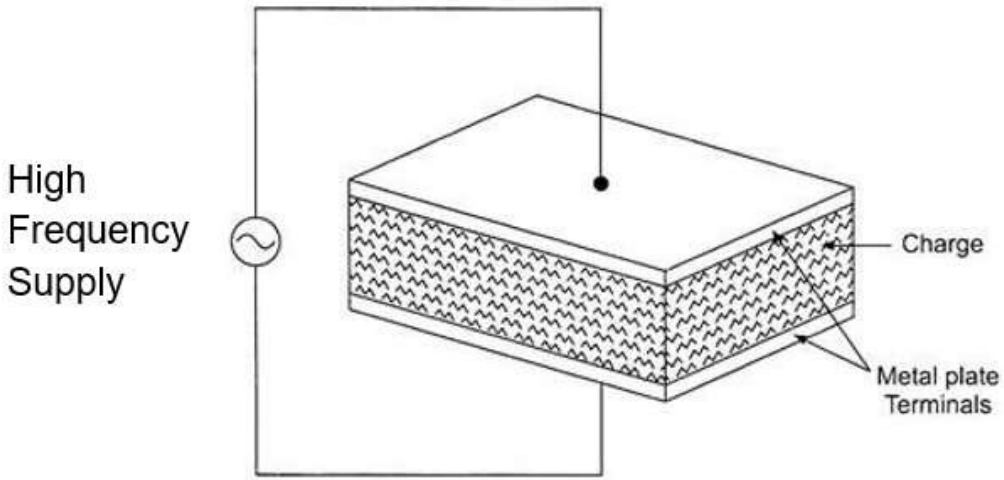


Fig: An Illustration of Dielectric heating

Classroom Slides Set-2

- In dielectric heating, it is desirable to use HIGH FREQUENCY than high voltage
- Dielectric heating involves the heating of electrically insulating materials by dielectric loss Frequencies in the range of **10–100 MHz** are necessary to cause dielectric heating
- In dielectric heating the heat is produced within the material itself. This results in uniform heat generation and thus dielectric material is heated uniformly
- This is the important property of dielectric heating
- Dielectric Heating is the only heating technique which operates at leading power factor

***** KPSC,SSC***

*Additional exam specific points is session***

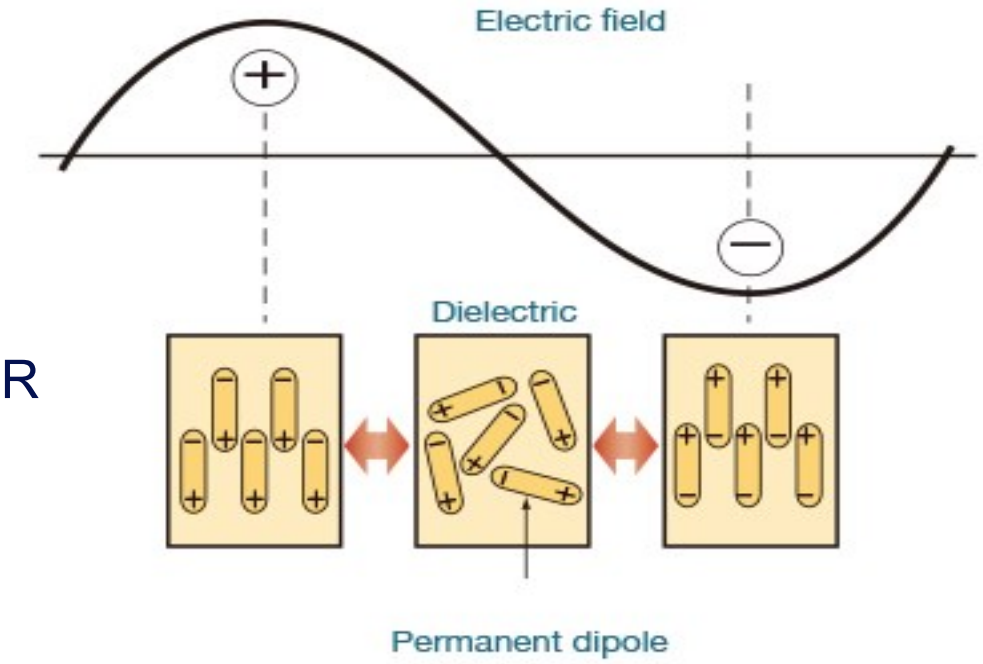
SE-2-Part-1_Video: 21.2

Dielectric Losses

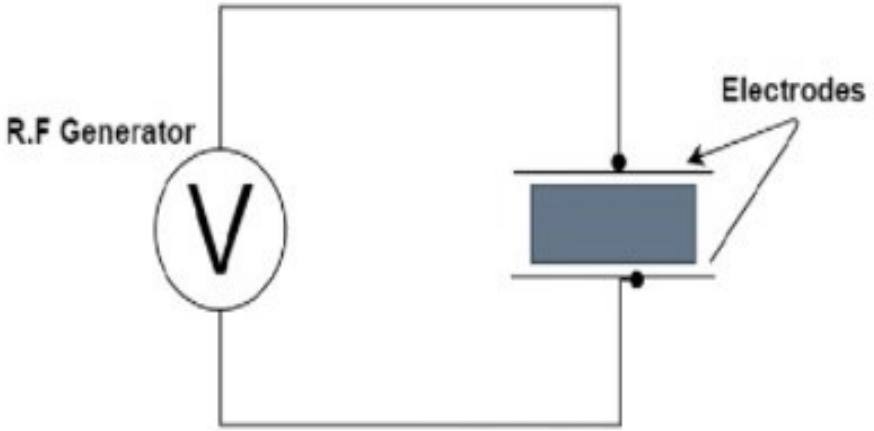
Classroom Slides Set-2

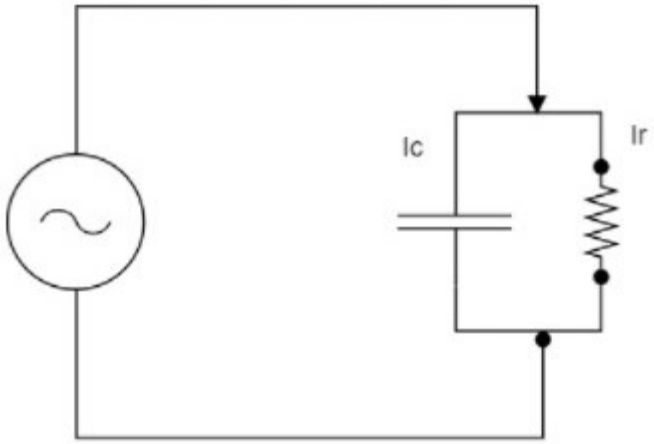
- When insulating material is subjected to an alternating field the atom gets stresses due to the inner atomic friction hence heat is produced

- In dielectric material, it has high value of reactance



- All the dielectric material are consider to be imperfect capacitor and can be represented in form of Resistance R and Capacitor C in parallel

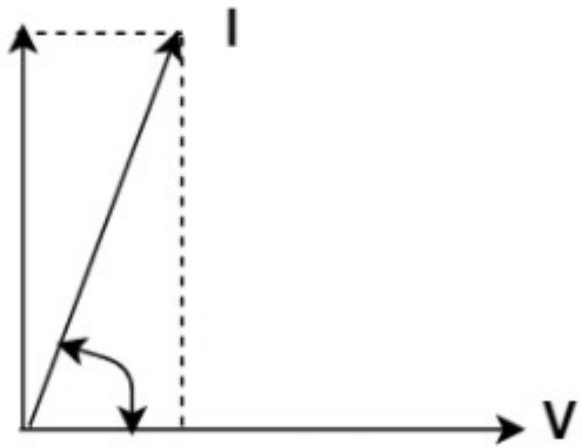




Classroom Slides Set-2

Dissipated power loss is proportional to

frequency **f** and
square of voltage V^2



- All the dielectric material are consider to be imperfect capacitor and can be represented in the form of
Resistance R and Capacitor C in parallel

*Additional exam specific points is session***

SE-2-Part-1_Video: 21.2
Module SE-3 : detailed session on loss tangent

$$\tan\delta = \frac{I_R}{Ic}$$

$$\tan\delta = \frac{v}{R} \Big/ \frac{V}{\omega c}$$

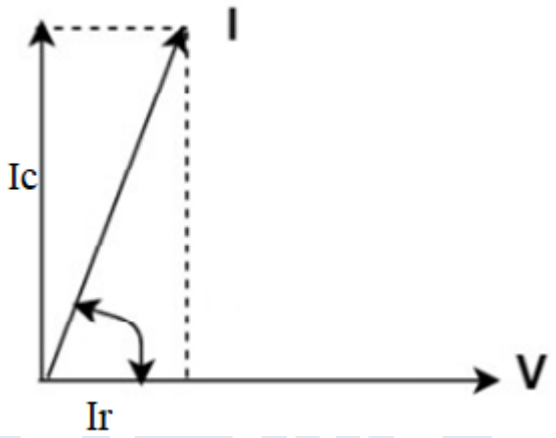
$$\tan\delta = \frac{1}{\omega RC}$$

$$R = \frac{1}{\omega C \tan\delta}$$

$$\text{Power} = \frac{V^2}{R}$$

$$\text{Power} = \frac{V^2}{\frac{1}{\omega C \tan\delta}}$$

$$I_c = \frac{V}{\omega c}$$



$$I_r = \frac{V}{R}$$

Power = $V^2 \tan\delta\, C\omega$

Power = $V^2 \tan\delta\, C 2\pi f$

Dissipated power loss is proportional to frequency **(f)** and square of voltage **(V^2)**

Advantages of dielectric heating

Classroom Slides Set-2

- No necked flame appears
- By increasing frequency heating become faster
- Heating can stopped by immediately
- Uniform Heating
- Plastic and wooden product can be safely heated

Application of dielectric heating

- Preparation of chocolates and popcorn
- Rubber vulcanizing
- Surgical instrument
- Removal of moisture from oil
- Diathermy
- Sterilization
- Textile industry

*** very important for all exams*

*Additional exam specific points is session***

SE-2-Part-1_Video: 21.2

Classroom Slides Set-2

Previous Year Questions : Relevant for Kerala PSC, SSC, RRB

Relevant Questions for Kerala PSC, SSC, RRB

Classroom Slides Set-2

1. For a arc heating , the electrodes are made of
   a) Copper b) Aluminium
   c) Graphite d) ACSR conductor

2. The power factor will be leading in case of
   a) Dielectric heating b) Resistance heating
   c) Inductive heating d) All the above

3. Which of the following is high importance in case of induction heating
   a) Voltage b) Frequency
   c) current d) All the above

4. Radiation from a black body are proportional to
   a) T^2 b) T^3
   c) T^4 d) T/2

*Detailed exam specific points and explanation to these questions in session***

SE-2-Part-1

Video: 21.1
Video: 21.2

Classroom Slides Set-2

5. Ni-Cr-Fe alloy wire can be safely used for temperature up to
   a) 2500C b) 2000C
   c) 1150C d) 850C

6. Which of the following heating element will have the least temperature range?
   a) Copper b) Aluminium
   c) Nichrome d) Eureka

7. Radiant heat is used for ?
   a) melting ferrous metals b) annealing of metals
   c) drying of paint and varnishes d) all the above

*Detailed exam specific points and explanation to these questions in session***

SE-2-Part-1

Video: 21.1
Video: 21.2

8. Direct resistive heat is used for ?
   a) electric boiler b) Salt-bath furnace
   c) resistance welding d) all the above

9. In direct arc furnace which of the following is of high value ?
   a) current b) voltage
   c) frequency d) all the above

10. It is desirable to operate the arc furnace at a power factor of ?
   a) zero b) unity
   c) .707 lag d) .707 lead

11. For radiant heat around 2000c° the heating element used is?
   a) Tungsten alloy b) Copper alloy
   c) Carbon d) Nichrome

12. The arc furnace of conical shapes have the advantages of ?
   a) Large surface area b) low power consumption
   c) Reduced radiation losses d) All the above

13. The main application of indirect arc furnace is to melt?
   a) Iron b) Steel
   c) Non-ferrous metals d) non of the above

*Detailed exam specific points and explanation to these questions in session***

Classroom Slides Set-2

SE-2-Part-1

Video: 21.1 ,Video: 21.2

Answer Key

1	a
2	a
3	b
4	c
5	d
6	d
7	c
8	d
9	a
10	c

14. In induction heating which of the following is high value ?
a) Frequency b) Current
c) voltage d) Power factor

Classroom Slides Set-2

15. Induction heating take place in?
a) insulating material b) conducting magnetic material
c) Non magnetic material d) Conducting material may be magnetic or non magnetic

16. A perfect black body is one which ?
a) Absorb all incident radiation b) Reflect all incident radiation
c) Transmits all incident radiation d) All the above

17. For the transmission of heat from one body to another it is essential that?
a) Both body are solid b) the two body are different temp
c) Both body are in contact d) Non of the above

18. The highest value of thermal conductivity is for ?
a) Steam b) Water
c) Melting ice d) Solid ice

*Detailed exam specific points and explanation to these questions in session***

SE-2-Part-1
Video: 21.1 ,Video: 21.2

19. Fourier's Law deals about ?
a) conduction b) Convection
c) Radiation d) All the above

20. Stephan's law deals about rate of heat transfer by ?
a) conduction b) Convection
c) Radiation d) All the above

21. Dielectric heating is also called ?
a) Volume heating b) Infrared heating
c) Surface heating d) Eddy current heating

22. Furnaces used for cremation ?
a) Dielectric heating b) Arc heating
c) Resistance heating d) Eddy current heating

Classroom Slides Set-2

Answer Key

11	a
12	d
13	c
14	a
15	d
16	a
17	b
18	d
19	a
20	c

*Detailed exam specific points and explanation to these questions in session***

SE-2-Part-1
Video: 21.1 ,Video: 21.2

23. Hysteresis loss and eddy current loss are used in?
a) Dielectric heating b) Resistance heating
c) Inductive heating d) Arc heating

24. In an electric heating the metal case is connected to?
a) Phase wire b) Earth wire
c) Neutral wire d) Non of the above

25. The ideal method of heating plastic is?
a) Dielectric heating b) Coal/oil heating
c) Resistance heating d) Eddy current heating

26. Which of the following is an advantage of heating by electricity ?
a) Quicker operation b) Absence of flue gases
c) Higher efficiency d) All of the above

Answer Key

Classroom Slides Set-2

21	a
22	c
23	c
24	b
25	a
26	d
27	c
28	d
29	c
30	d

*Detailed exam specific points and explanation to these questions in session***

SE-2-Part-1
Video: 21.1 ,Video: 21.2

27. Which of the following heating methods has maximum power factor? ** key as per SSCJE

Classroom Slides Set-2

a) Dielectric heating b) Arc heating
c) Resistance heating d) Eddy current heating

28. Which of the following will happen if the thickness of refractory wall of furnace is increased?
a) Heat loss through furnace wall will increase b) Temperature inside the furnace will fall
c) Temperature on the outer surface of furnace walls will drop d) Energy consumption will increase

29. The material of the heating element for a furnace should have?
a) temperature co-efficient b) High specific resistance
c) Lower melting point d) All of the above

30. By which of the following methods the temperature inside a resistance furnace can be varied?
a) By varying the operating voltages b) By varying the current through heating elements
c) By disconnecting some of the heating elements d) By any of the above method

31. The material to be used for heating element should be of high resistivity so as to?
a) Increase the life of heating element b) Reduce the length of the heating element
c) Reduce the effect of oxidation d) Produce large amount of heat

32. Which of the heating element can give highest temperature in resistance heating?
a) Nichrome b) Silicon carbide
c) Copper d) Ni,Cr,Fe

33. For temperature control in resistance furnaces resistance variation can be affected by connecting resistance element in?
a) series or parallel b) series-parallel
c) Star or Delta d) Any of the above

34. The simplest and most commonly used method for temperature control is ?
a) External resistance in heating circuit b) Changing the connection of heating circuit
c) Use variable number of heating element d) Transformer tapping

35. The device necessarily used for automatic temperature control in a furnace is ?
a) Thermostat b) Auto-transformer
c) Thermocouple d) Any of the above

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36. The temperature inside of a furnace is measured by ?
a) Mercury thermometer b) Optical pyrometer
c) Alcohol thermometer d) Any of the above

37. The control of salt-bath furnace is affected by ?
a) Varying the depth of immersion of electrode
b) Varying the distance between the electrode
c) Both a & b d) None of the above

38. Resistance oven used for ?
a) Domestic & commercial heating b) Electrical oven
c) Drying the varnishing d) All the above

39. It is desired to keep the arc length short in order to ?
a) Have better heating b) Reduce the oxidation
c) Increase the life of roof refractory d) All the above

Answer Key

31	d
32	b
33	d
34	b
35	a
36	b
37	c
38	d
39	d
40	c

40. Low frequency is necessary for direct core type induction furnace because ?
a) magnetic coupling is poor b) Pinch of effect occur
c)) Both a & b d) None of the above

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41. Induction furnace are used ?
a) Heat treatment of casting b) Heating of insulator
c) Melting of aluminium d) All the above

42. In induction heating the depth up to which current will penetrate is proportional to ?
a) $1/f^{.5}$ b) 1/F
c) F d) f^2

43. High frequency induction heating is used for ?
a) Ferrous metals only b) Non ferrous metals only
c) Both ferrous and non ferrous d) None of the above

*Detailed exam specific points and explanation to these questions in session***

SE-2-Part-1
Video: 21.1 ,Video: 21.2

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44. The dielectric loss in a dielectric material is proportional to ?

a) $Voltage^2$ b) Voltage

c) 1/ Voltage d) $\sqrt{voltage}$

45. Electric room heater is a ?

a) Induction heater b) Resistance heater

c)) Arc heater d) Dielectric heater

46. Hysteresis loss and eddy current loss are used in?

a) Resistance heating b) Dielectric heating

c) Induction heating of steel d) Induction heating of brass

47. Method of heating used for non-conducting metals ?

a) Induction heater b) Resistance heater

c)) Arc heater d) Dielectric heating

*Detailed exam specific points and explanation to these questions in session***

SE-2-Part-1

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48. Method of heating used for non-ferrous metals ?
a) Induction heater b) Resistance heater
c)) Indirect arc heater d) Dielectric heating

49. Most modern method for food processing ?
a) Induction heater b) Resistance heater
c)) Arc heater d) Dielectric heating

50. Which furnace is know as Ajax wyatt furnace ?
a) Vertical core type b) Direct core type
c)) coreless type d) Indirect induction

Answer Key

41	a
42	a
43	c
44	a
45	b
46	c
47	d
48	c
49	d
50	a

*Detailed exam specific points and explanation to these questions in session***

SE-2-Part-1
Video: 21.1 ,Video: 21.2

Heating	Type	Application	Electrodes used	Working principle	Power factor
Resistance Heating	Direct Resistance	1. Salt bath furnaces 2. Resistance welding 3. Electrode boiler	**N**ichrome **M**olybdenum **S**ilicon carbide Alloy of **T**ungsten	Ohmic Losses I^2R	High
	Indirect resistance	1. Room heater 2. Immersion water heater 3. Various type of resistance oven	**N**ichrome **M**olybdenum **S**ilicon carbide Alloy of **T**ungsten	Ohmic Losses I^2R	High
	Radiant	1. In paint drying industries for drying paints 2. De-hydration at low temperatures. 3. Heating of plastics at low temperatures	Tungsten		High

Heating	Type	Application	Electrodes used	Working principle	Power factor
Arc Heating	Direct Arc Heating	Melting steel, alloy steel such as stainless steel	Carbon electrodes Graphite electrodes Self – baking electrode	Electrical Arc	Low pf (lagging)
	Indirect Arc Heating	Melting of non-ferrous metals	Carbon electrodes Graphite electrodes Self – baking electrode	Electrical Arc	Low pf (lagging)

Heating	Type		Application	Working principle	Power factor
Induction Heating	Core type	Direct	Heat treatment in metallurgy Zone refining used in the semiconductor industry To melt refractory metals that require very high temperatures induction cooking	Electromagnetic Induction Heat formation due to Eddy current Heating Proportional to f^2 & Voltage	**Low pf (Lagging)**
		Vertical or Ajax-wyatt			
		Indirect			
	Coreless				
Dielectric Heating			• Preparation of chocolates and popcorn • Rubber vulcanizing • Surgical instrument • Removal of moisture from oil • Diathermy • Sterilization • Textile industry	Dielectric losses Heating Proportional to $Voltage^2$ & Frequency	**Leading pf**

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