UTILIZATION AND CONSERVATION OF ELECTRICAL ENERGY (UCEE)

- INDUSTRIAL APPLICATIONS OF ELECTRICAL ENERGY
- STORAGE, MANAGEMENT AND AUDIT OF ELECTRICAL ENERGY

Syllabus(UCEE)(EE1818PE71)

MODULE 1: Electric Heating:

Advantages, Classification, Resistance Heating, Furnaces, Requirements and Design of heating elements, Temperature control, Electric arc furnaces, Direct & Indirect, Construction & Operation, Electrodes & Power Supply, High Frequency Heating, Induction Heating, Working principle, Power & High frequency Heating, Choice of Frequency, Core type & Coreless Furnaces, Skin Effect & Pinch effect, High Frequency Supply, Advantages & Disadvantages, Dielectric Heating, Working principle, Choice of Voltage and Frequency, Advantages & Applications.

Syllabus….

MODULE 2: Electric Welding:

Classifications, Resistance Welding: Spot, Butt, Seam. Arc welding: types, electrode used, power sources and control circuits. Atomic hydrogen welding. Modern development.

Syllabus….

MODULE3:ElectricTraction:

Advantages. Systems of electric traction. Choice of system voltage and frequency. The Indian scenario. Types of train services. Train movements and energy consumption. Speed-time, distance-time and energy consumption curves. Tractive effort, Adhesion, Train resistance. Power supply arrangements. Substation equipment. D.C AND A.C. traction motors, their disposition and operation on tramcars, motor coaches and locomotives. Control systems; Rheostatic, field control and series parallel using shunt and bridge transition methods. Multiple unit control. Metadyne control. Controllers for dc & ac traction motors. Tram Cars, Motor coaches, &Trolley Buses. Auxiliary Electrical Equipments for Tramcars, Motor Coaches & Locomotives. Braking mechanical, vacuum & electrical.

Syllabus…

MODULE 4: Energy Storage

Size & Duration of storage. Modes of energy storage: mechanical, electrical, magnetic, thermal & chemical. Comparison of the different systems

MODULE 5: Electrical Losses & Energy Conversion: Electrical transmission, distribution & utilization losses. Classification. Reduction of losses. Benefits of electrical energy conservation. Energy conservation in lighting, electric furnaces, electric drive, traction systems. Use of energy –efficient equipment.

Syllabus….

MODULE6: Electrical Energy Audit:

Introduction, benefits, procedure for energy audit. Instruments for energy audit. Methodology. Case study.

Books

1. Electrical Energy Utilization & Conservation, by Tripathy, S.C ; TMG
2. Utilization of Electric power ; by Suryanarayan, N.V. : Wiley Eastern Ltd. Art and Science of Utilization of Electrical Energy'by H Partab: Dhanpat Rai and Sons.
3. Utilization of Electric Power and Electric Traction By J B Gupta: S K Kataria and Sons.
4. Generation, Distribution and Utilization of Electrical Energy By C L Wadhwa: New Age International (P) limited Publishers

Course Outcomes

CO1: Apply electrical energy for industrial heating and welding.

CO2: Analyze operation and control of electric traction.

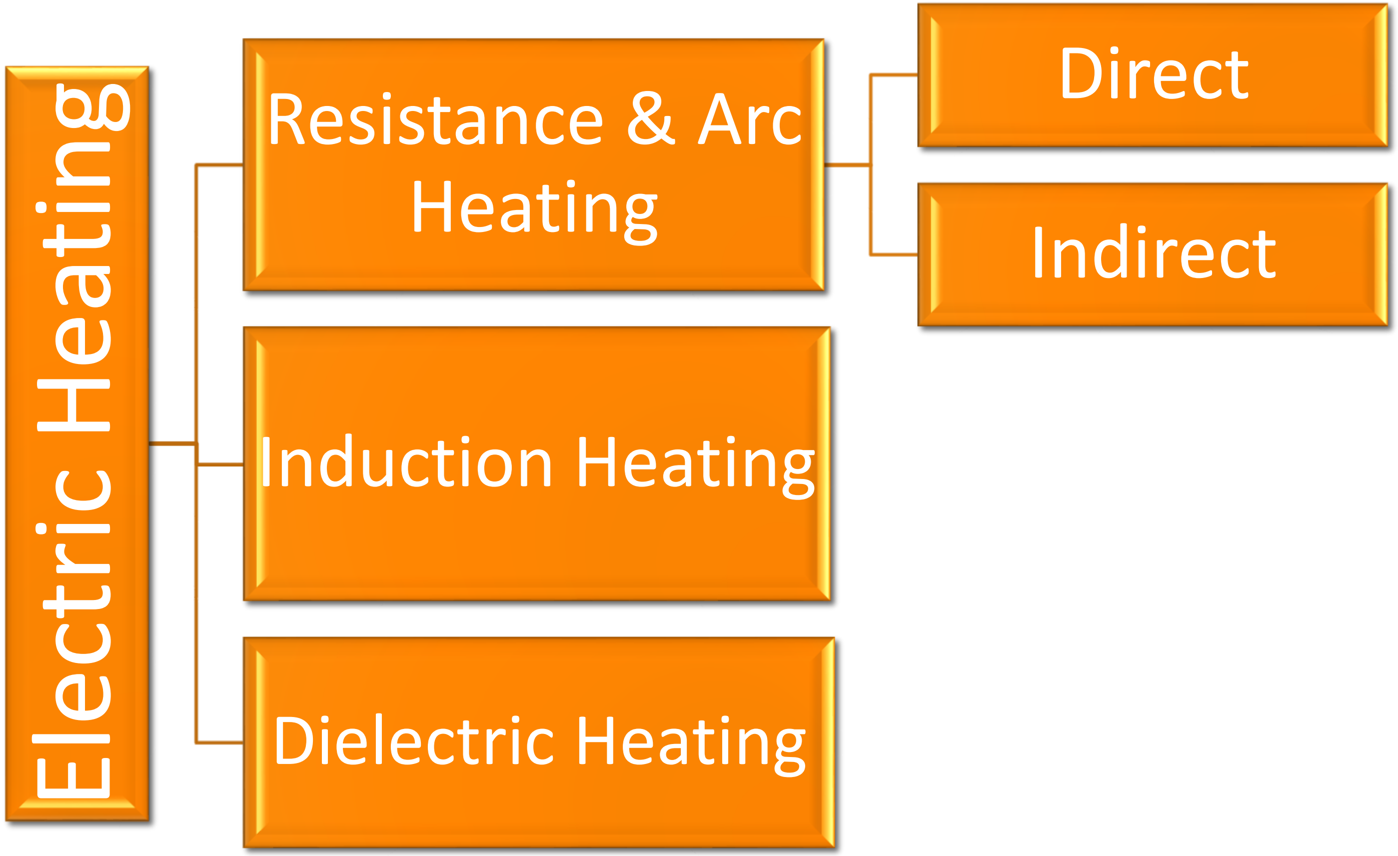
CO3: Analyze different methods of storing, conserving and auditing electrical energy.

HEATING

Utilisation of heating:

- Heating is an essential process.
- Extract ores.
- Water to steam.
- Move from one place to another.
- Move turbines of a generator.

Heating...


Electric Heating
Resistance & Arc Heating
Direct
Indirect
Induction Heating
Dielectric Heating

Electric Heating

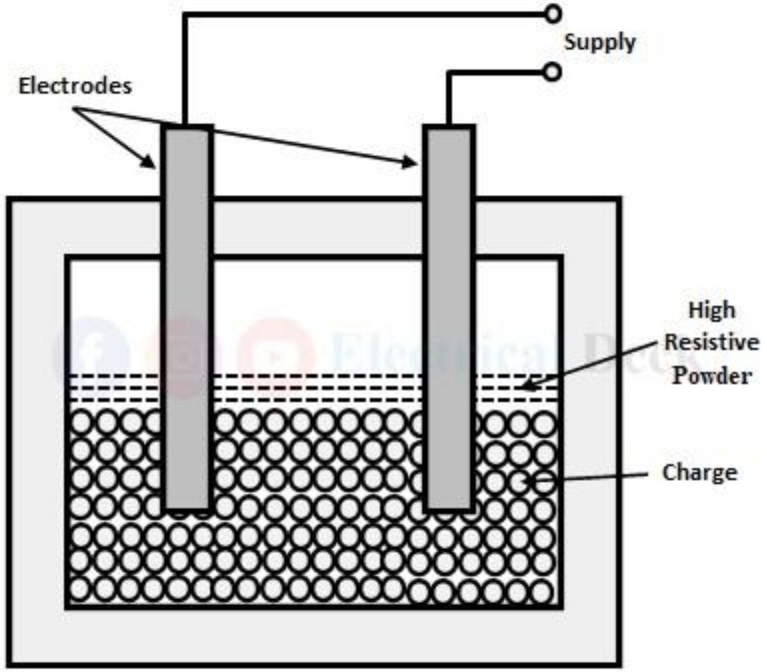
Advantages:

- Cleanliness : Elimination of dust and ash.
- Ease of Control: Use of manual and automatic devices.
- Uniform of heating:
- Low attention and maintenance cost:

Electric…..

1. Direct Resistance Heating:

- Current passes through the **Charge**.
- Efficient.
- Used in resistance welding, Electrode boiler for heating water, in **Salt Bath Furnaces.**



Direct Resistance Heating

Electric…

Salt Bath Furnace:

- Two electrodes immersed in salt like NaCl.
- Electrodes have **fusion point** of 1000ºC
- Current should pass through the salt not through the metal to be heated.
- Supply must be ac not dc.
- Step down transformer with tapping is used.

Source: Trymax

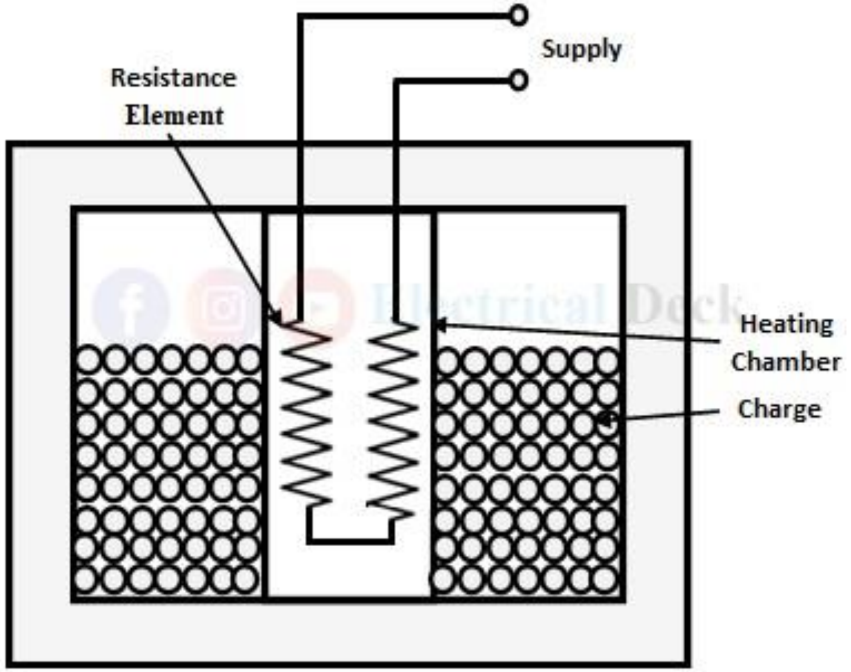
Salt Bath.....

- Secondary voltage of X'mer is of order of 20 V.
- Current is of order of 3 kA.
- Bath has negative temperature coefficient.
- Taps are helpful in maintaining constant power during heating.
- Used for hardening steel tools and prevents oxidation.

Electric…

2. Indirect Resistance Heating

- Current is passed through high resistance heating element.
- Heat is transferred by radiation or convection.
- Room heater, Immersion water heater, domestic or Commercial cooking by resistance ovens.



Indirect Resistance Heating

Heating Element

Requirements:

- Specific resistance: High
- Melting Point: High
- Free from oxidation
- Temperature Coefficient: Low

Note: Current will vary from cold to hot condition if not low coefficient. Materials made of Ni-Cr, Ni-Cr-Fe, Ni-Cu or Fe-Cr-Al. Fe is added to make alloy cheap but life of alloy gets reduced. Alloys can withstand temperature of 1300ºC.

Heating Element…

Properties of commercial heating elements:

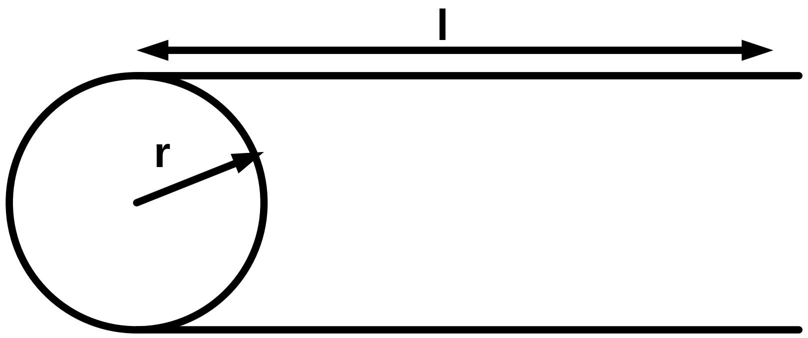
Type of Alloy Properties	**Ni-Cr**	**Ni-Cr-Fe**	**Ni-Cu**	**Fe-Cr-Al**
Composition	80+20	60+16+24	45+55	70+25+5
Commercial Name	Nichrome	NA	Eureka/Constantan	Kanthal
Max. Working Temp. in ºC	1150	950	400	1200
Sp. Resist. @20ºC in $\mu\Omega/cm^3$	109	110	49	140
Sp. Gravity	8.36	8.28	8.88	7.2

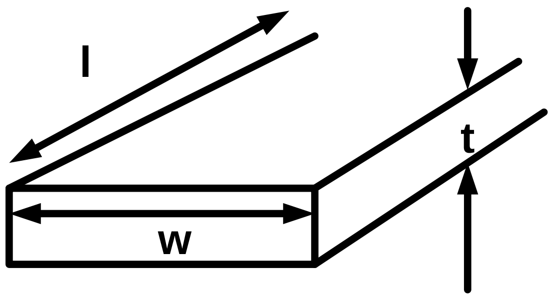
Design of Heating Element

- Circular or rectangular x-section wires are used as heating element.
- Dimensions of it can be calculated if P, V and T are known.
- $H = 5.72\ K\ e\left[\left(\frac{T_1}{100}\right)^4 - \left(\frac{T_2}{100}\right)^4\right]$ Watts/sq.m. (K = radiating efficiency = 1 for single element, 0.5 to 0.8 for more than one elements.
- P = H.2.π.r.l

Heating Element..

Let P = wattage of heating element
V = operating voltage
T_1 = Temperature of the radiating surface
T_2 = Temperature of the absorbing surface
a = x-sectional area of the heating element





Numerical

1. A 20 kW single phase , 220 V resistance oven employs circular Nichrome wire for it's heating element. If the wire temperature is not to exceed 1127º C and the temperature of the charge is to be 427 º C. calculate the size and length of the wire required. Assume e = 0.9 and radiation efficiency K = 0.6. Compute the temperature of the wire when the charge is cold.

2. A cubic water tank has surface area of 5.4 m^2 and is filled to 92% capacity five times daily. The water is heated from 15º C to 60 º C. The losses per sq. meter of tank surface per 1º C temperature difference are 5.9 W. Calculate loading in kW and efficiency of the tank. Assume specific heat of water = 4.186 kJ/kgºC.

TEMPERATURE CONTROL OF RESISTANCE FURNACE

- As $H = I^2 * R * t$

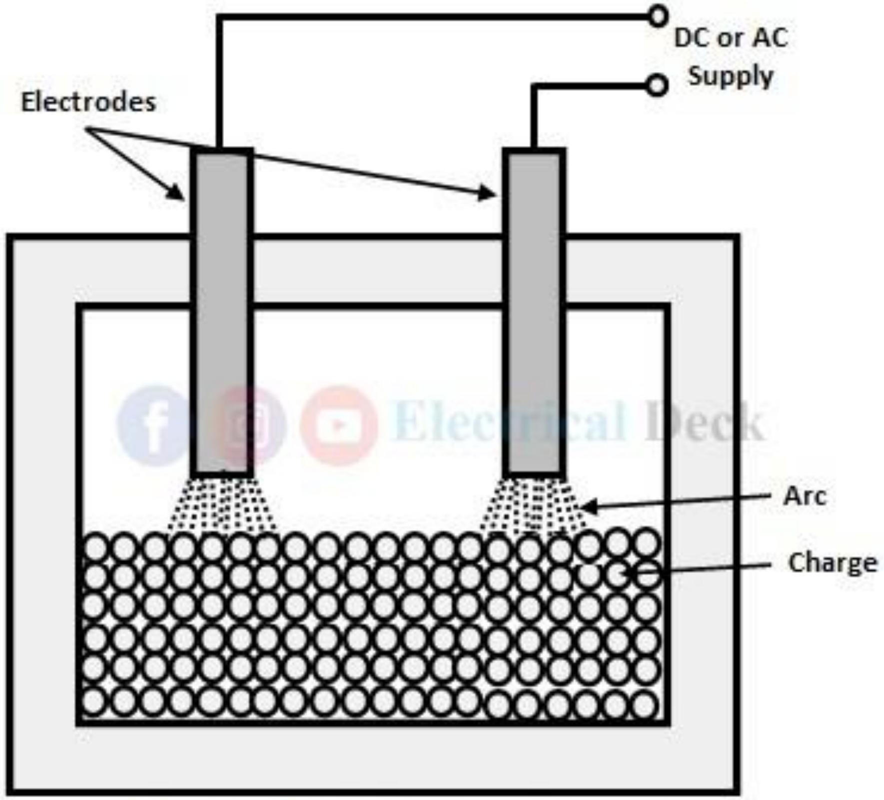
Heat can be controlled by varying

- Voltage or current: using X'mer taps, by adding resistance
- Resistance: By adding resistances in series or parallel or Y-Δ cpnnections.
- Time: by varying duty cycle

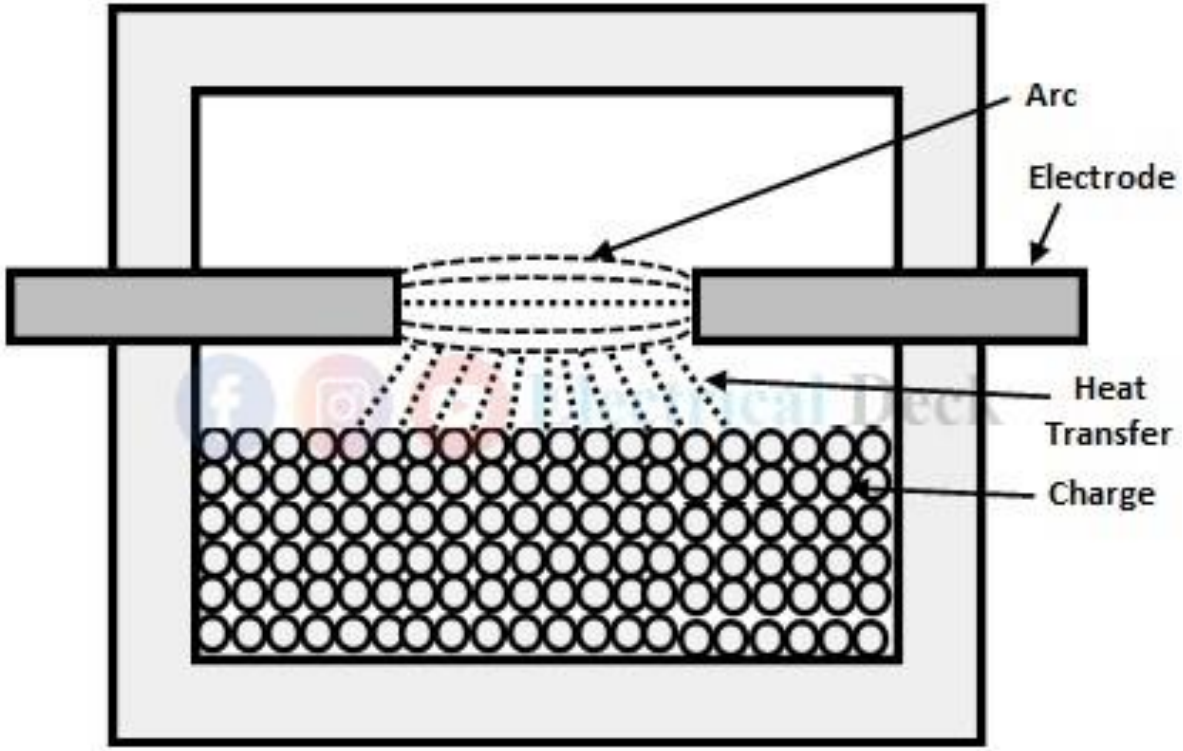
ANALYSIS

1. The resistance elements of each phase of delta connected resistance oven consists of two groups of elements in parallel. If the operating temperature of the elements is when supplied under normal voltage under these conditions is 1125 ºC. What other possible temperature could be obtained by reconnecting the elements, the supply voltage being kept same.

ELECTRIC ARC FURNACE



Direct Electric Arc Furnace



Indirect Electric Arc Furnace

SOURCE : ELECTRICAL DECK

ELECTRIC ARC FURNACE

Direct Arc furnace	**Indirect Arc Furnace**
Arc is between electrode and charge.	Arc is between two electrodes.
Heated through conduction and radiation.	Radiation only.
230 V 1-Φ or 400 V 3-Φ.	Same
Electrodes are made of Carbon or Graphite.	Same
Temperature is 3500ºC.	Temperature is 1500-2000 ºC.
Acid refractories are used e.g. ground ganister or basic magnesite mix.	Same.

Electric Arc Furnace

Direct Arc furnace	Indirect Arc Furnace
Low resistance.	High resistance.
Can operate at high temperature.	Operate at low temperature.
Electrodes are placed in equilateral triangle corners and charge at star point in a three phase supply system.	Electrodes are cylindrical in shape and only single phase supply is given.
Arc is controlled by varying arc length, resistance or voltage.	Size of the furnace is restricted by the maximum amount of load can be taken from single phase point.
Inherent stirring and hence uniform heating due to electromagnetic force.	Mechanical rocking is done.

Electric Arc Furnace

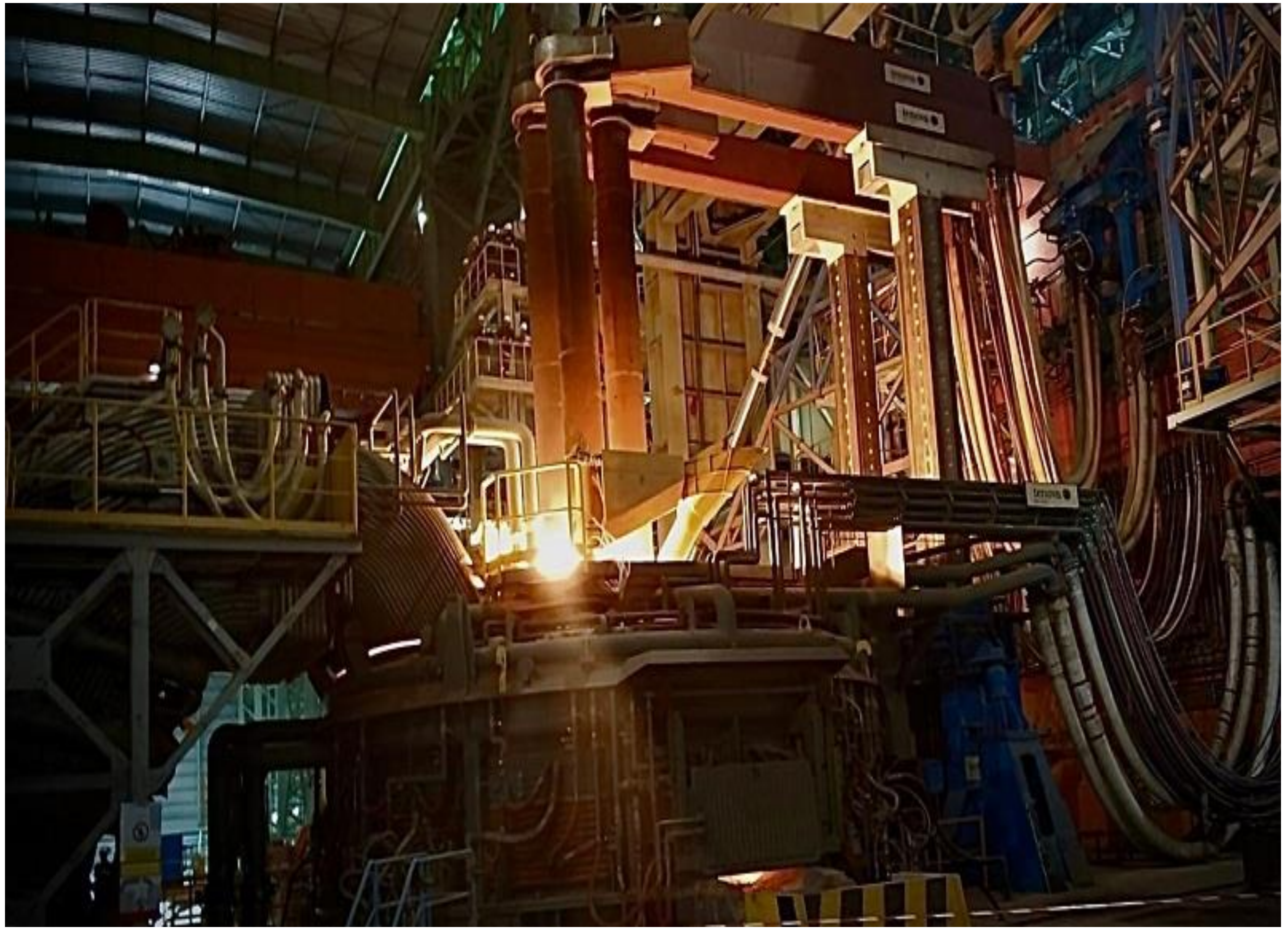
Direct Arc furnace

- Used in production of steel.
- Better than cupola method.
- Simple and easy to control.
- Used for melting and refining of materials.
- Expensive.

Indirect Arc Furnace

- Used in melting of non-ferrous metal.
- Rocking is done by grinder and roller run by electric motor.
- Rocking is given at an angle of 15-20 $^{\circ}$ initially and 200 $^{\circ}$ later @ 2 cycles per minute.
- Rocking results in proper mixing of charge.

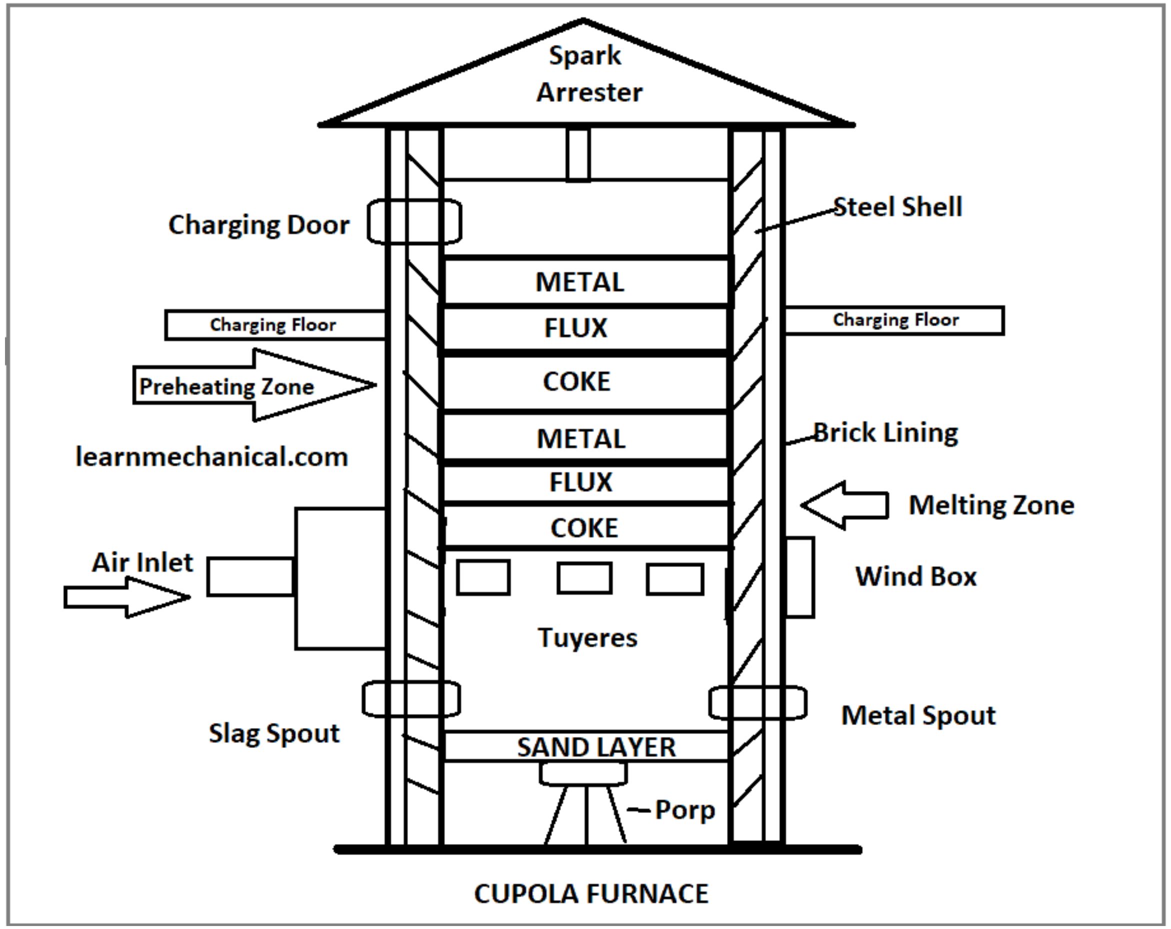
Electric Arc Furnace



- Rocking increases efficiency and increases life of refractory.
- Hammer transmits heat through conduction as well.

Source: HAN Tech.

Cupola Method



Electrodes of Arc Furnace

- Carbon and Graphite.
- Diameter : 18 -27 CM.
- Electrical conductivity.
- Insolubility.
- Infusibility.
- Chemical inertness.
- Mechanical strength.
- Resistance to thermal shock.

Electrodes of Arc Furnace

CARBON

- Amorphous in nature.
- Sp. Resistance: 0.0046 Ω-cm.
- Size halves for same Resistance.
- Easy replacement and control.
- Larger size for same conductivity.
- Uniform heating due to bigger size.

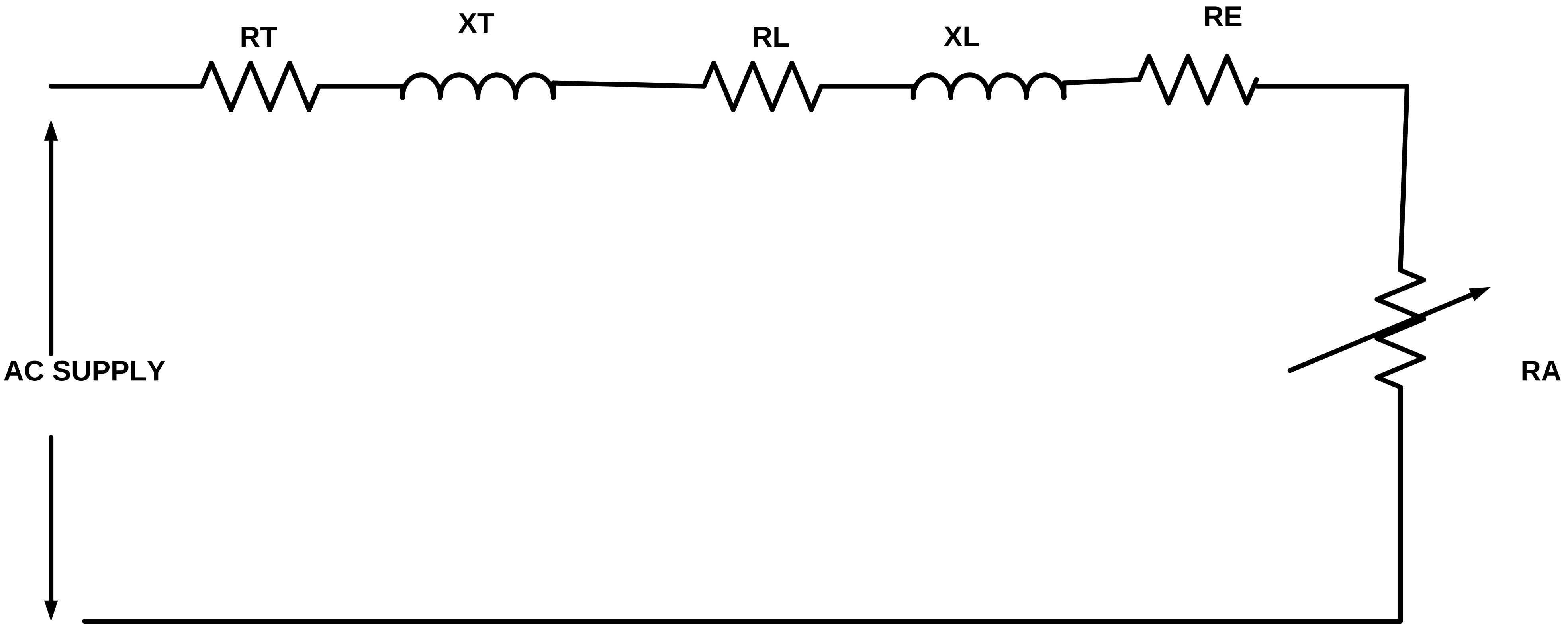
GRAPHITE

- Obtained by heating carbon electrodes at high temperature. Free from impurities.
- Sp. Resistance: 0.003 Ω-cm.
- Size double of that of with carbon for same Resistance.
- Not easy.
- Small in size for same conductivity.
- Consumption of electrode is less than carbon.

Electrodes of Arc Furnace

CARBON	GRAPHITE
• Less expensive	• Costlier.

Power Transformer

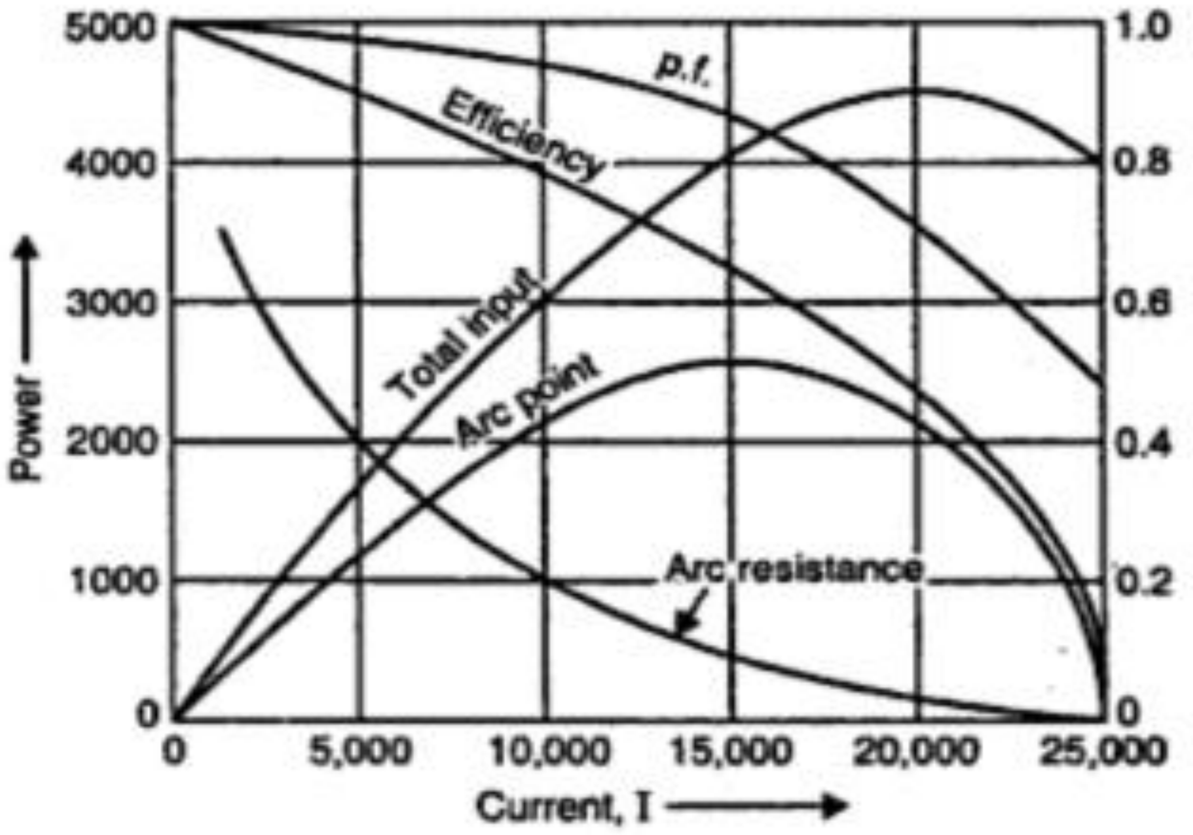


Power Transformer

- Secondary voltage: 50-100 V
- Current: 100 A to Several thousand Amps.
- Electro-mechanical and thermal stresses.
- Shell type
- Tappings are on primary side.
- Placed near to furnace so as to reduce secondary lead length and inductance.
- X’mer behaves like SC and OC when electrodes are shorted and separated for producing and extinguishing arc respectively.

Performance Characteristics

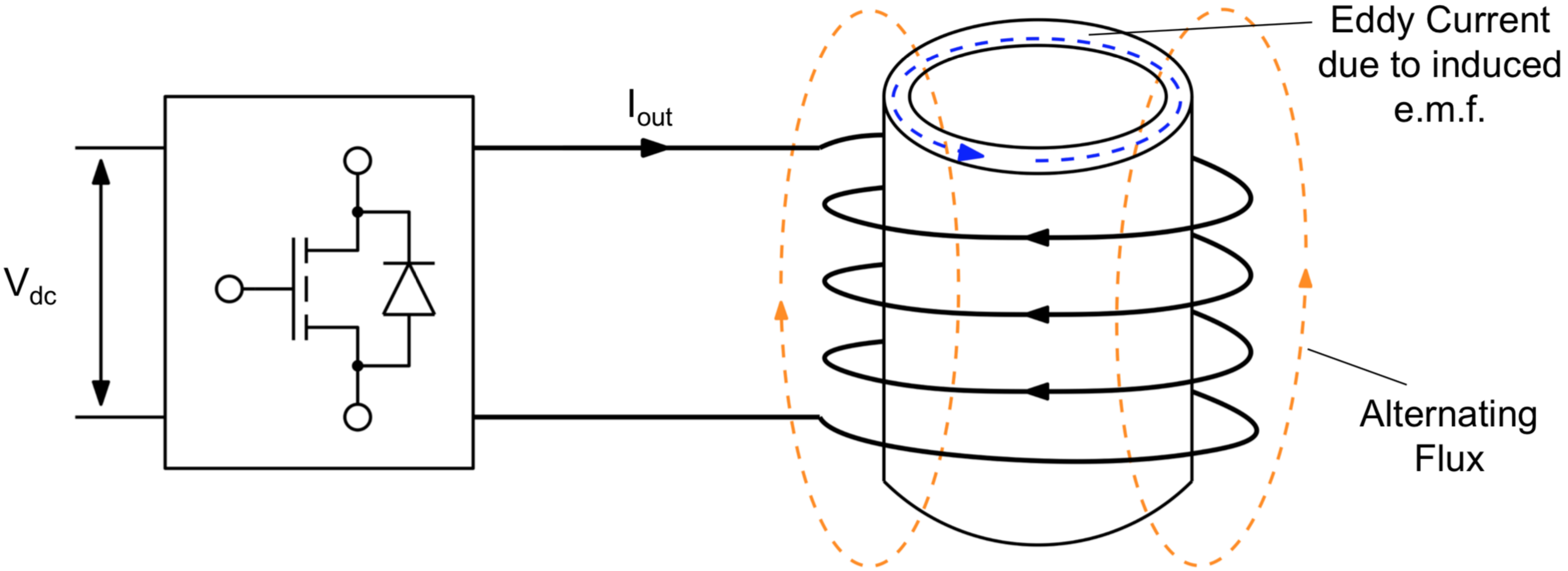
- Arc resistance has –ve temp coefficient.
- Input α Current.
- $\boldsymbol{\eta}$ decreases in proportion to the current.
- Pf decreases with high current.



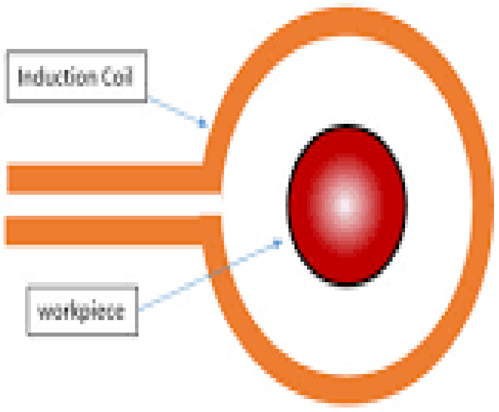
Numerical

1. A three phase arc furnace has to melt 10 tons of steel in 2 hours. Determine the average kW input to the furnace if it's overall efficiency is 50%. If the current input is 9 kA with the above kW input and the resistance and reactance of the furnace are 0.003 Ω and 0.005 Ω respectively, determine the arc voltage and the total kVA taken from the supply. Assume sp. heat of steel 0.12. latent heat of fusion of steel = 8.89 kCal/Kg. and melting point of steel = 1371ºC.

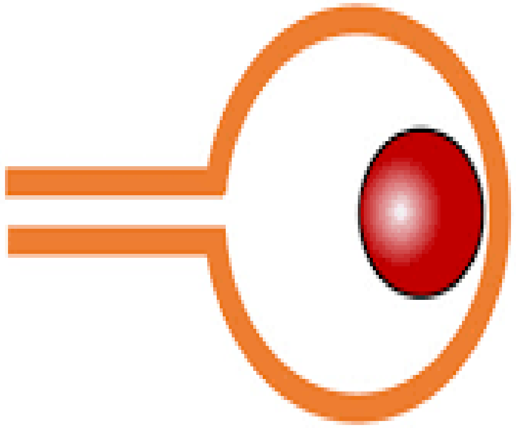
Induction Heating



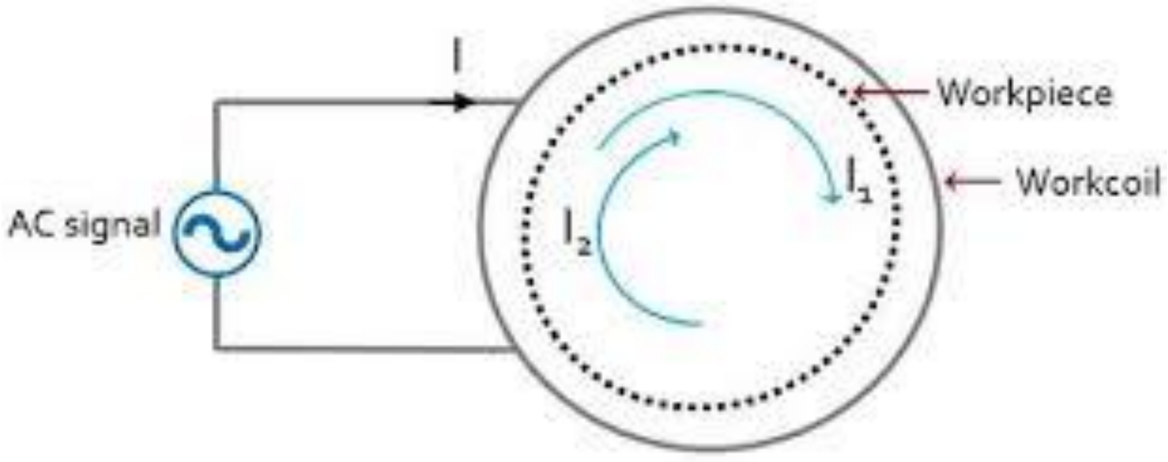
Induction Heating



Workpiece at the center of the coil

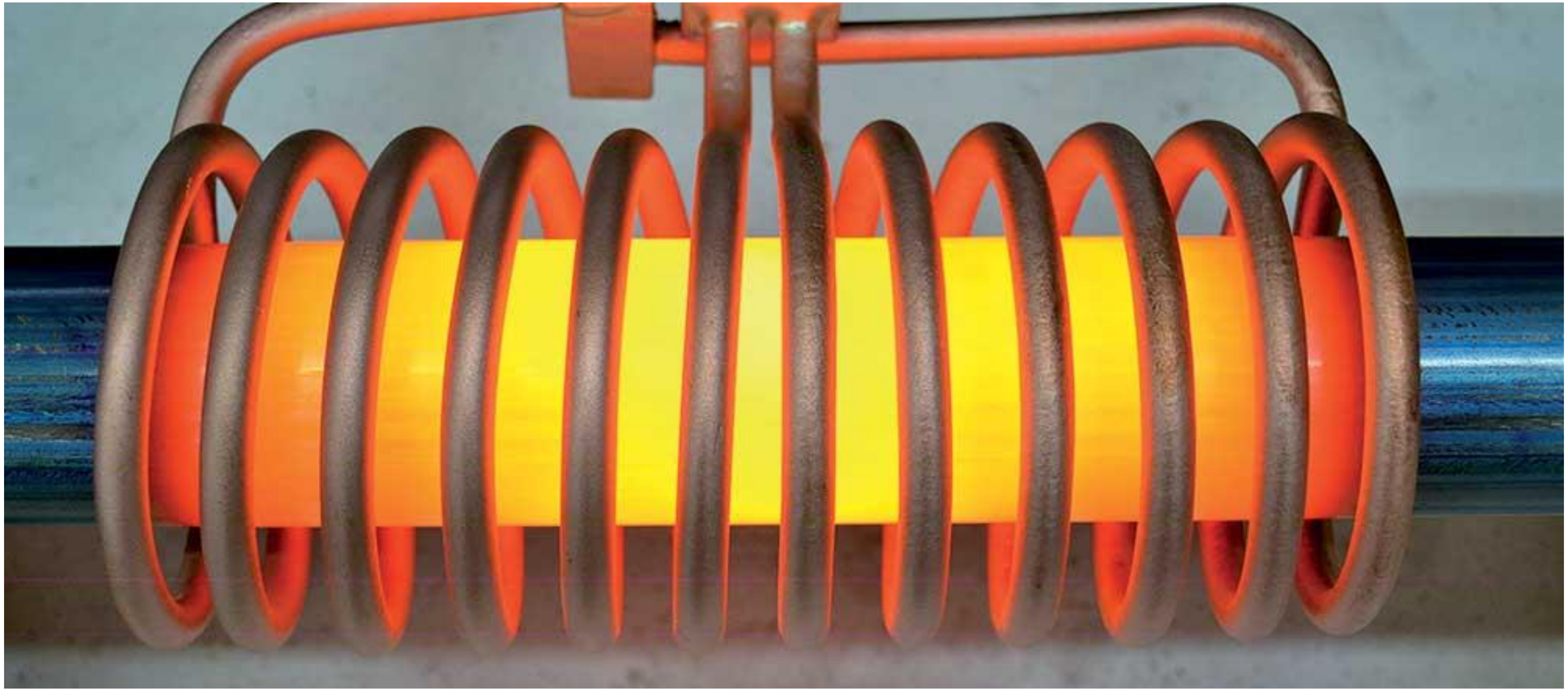


Workpiece off-center



Flow of eddy currents in workpiece

Induction Heating



Source: CEIA

Induction Heating

- Based on principle of Electromagnetic induction.
- Secondary current flowing in the outer disc heats the surface.
- Current flow is restricted by the surface contained within the turns of the coil.
- Heat is transferred @rapid rate as heat is generated within the metal.
- As heat is generated through the magnetic field which can penetrate through any non-metallic substance placed between heating coil and metal to be heated.
- Heat generated becomes high as long as current flows through it.

Induction Heating

The heat in the disc can be increased by

- High coil current.
- More no. of turns.
- High frequency supply.
- Close spacing between the coil and work.
- High permeable disc
- High sp. Resistance (magnetic material)

Induction Heating

The depth of penetration of induced current into the disc:

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

P = sp. Resistance of molten charge in Ω-cm

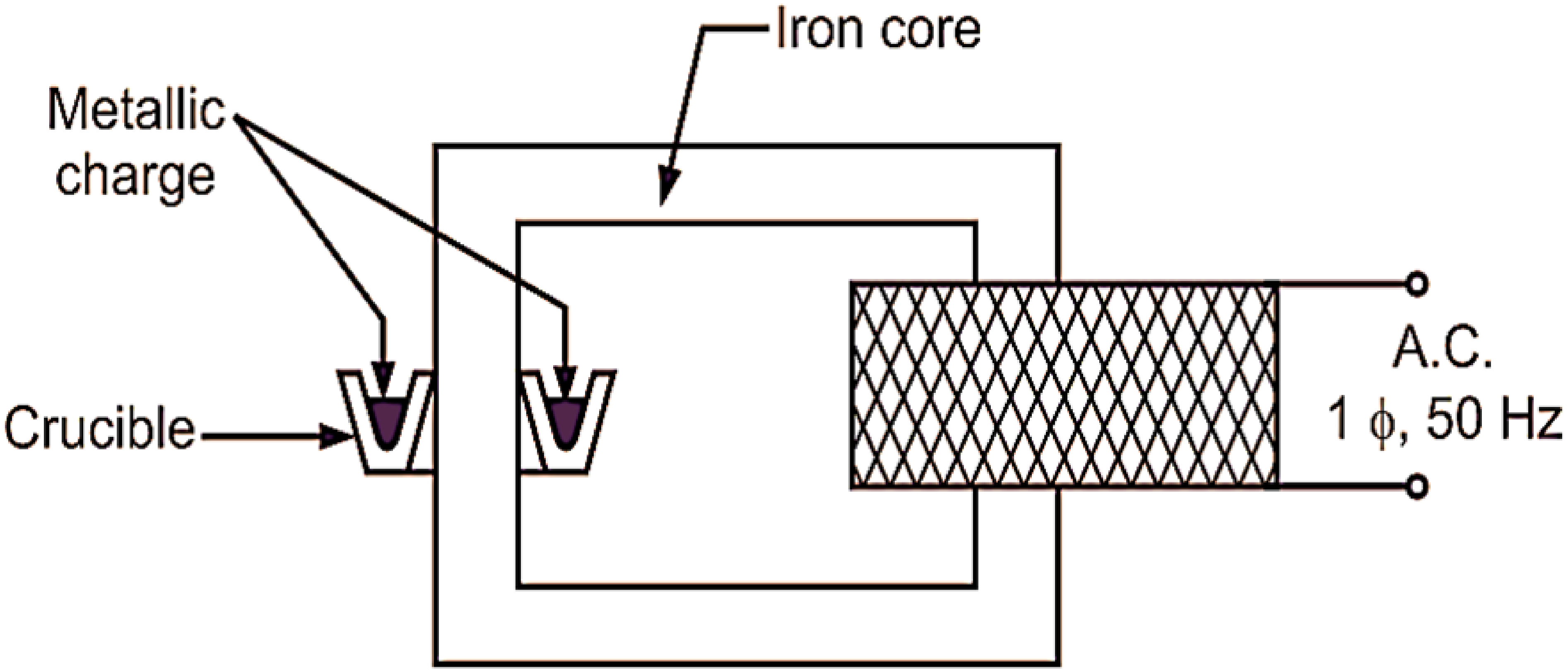
μ = permeability of the charge.

Induction Heating

Types of Induction Furnaces:

A. Core type or low frequency induction furnace.
B. Core-less type or high frequency induction furnace.

CORE TYPE FURNACE

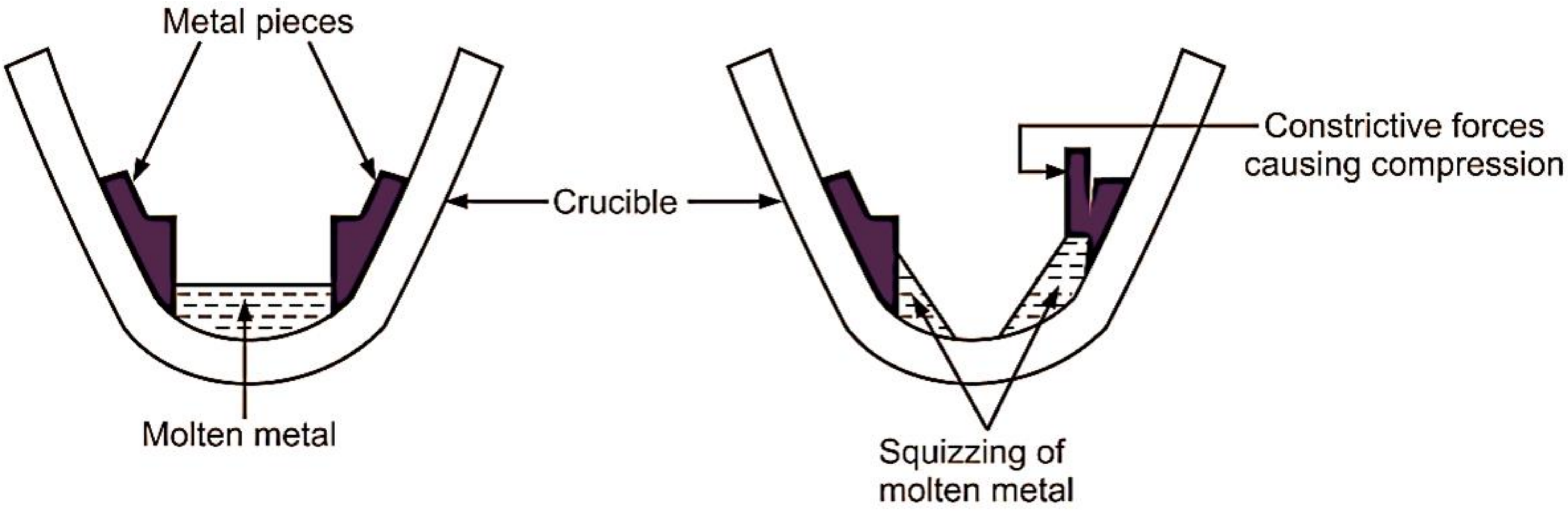


SOURCE: ELECTRICAL WORKBOOK

CORE TYPE FURNACE

- Charge is placed in circular Hearth in the form of annular ring.
- Diameter of metal ring is high and is magnetically linked with supply.
- So it behaves like a transformer with single turn short circuited secondary.
- Poor coupling and hence low power factor.
- It’s operated at low frequencies like 10 Hz.
- Melting is rapid and clean and temperature control is accurate.
- If current density> 500A/sq.cm, pinch effect occurs.

CORE TYPE FURNACE



SOURCE: ELECTRICAL WORKBOOK

CORE TYPE FURNACE

Drawback:

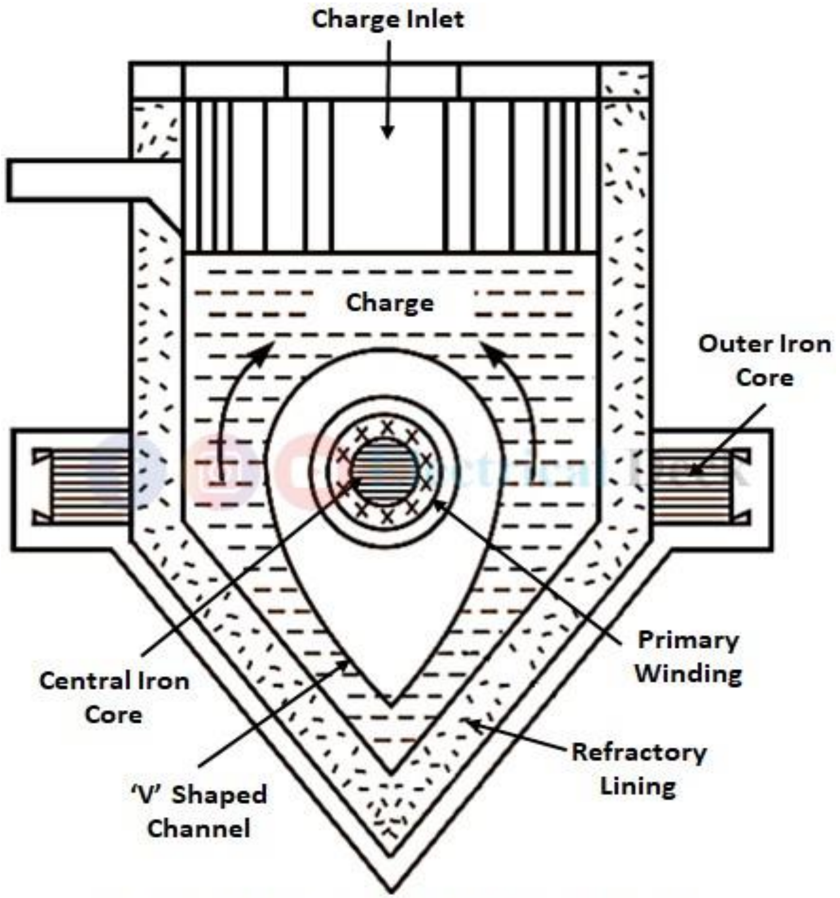
- Necessity of charging furnace with molten metal during starting.
- Pinch Effect.

AJAX-WAYTT FURNACE:

- An improvement of core type furnace.
- Pinch effect is avoided due to weight of charge and vertical mounting.
- The circulation of molten metal is around the Vee portion by convection current.

AJAX WYATT FURNACE

- Vee portion must be kept full of charge in order to maintain the continuity.
- Pf of the furnace is 0.8 – 0.83 operated at power frequency.
- Melting and refining of brass and other non-ferrous metals.

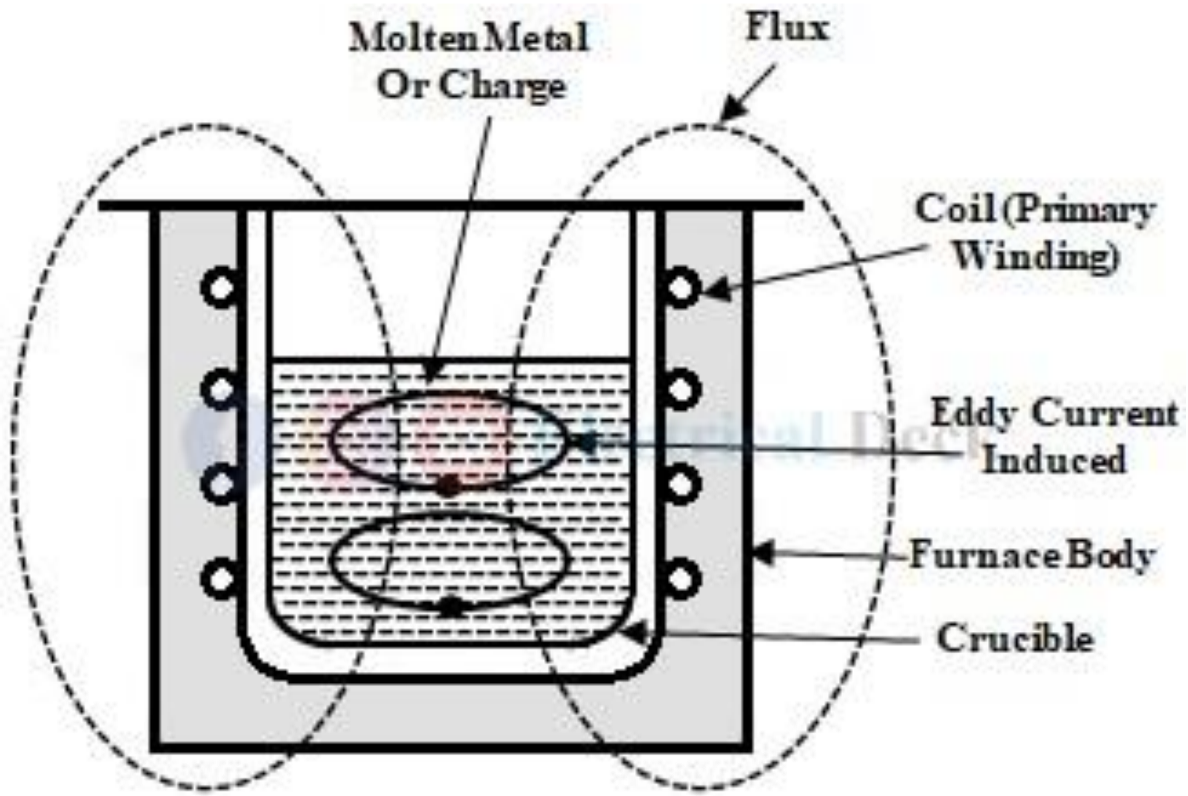


Vertical Core Type Induction Furnace

Source: Electrical Deck

CORE-LESS INDUCTION FURNACE

- Frequency of the supply can be increased.
- Need of heavy iron core got eliminated.
- Cylindrical ceramic crucible is enclosed with coil.
- Eddy currents flow in concentric circles in charge.
- Stirring action occurs inherently.



Coreless Induction Furnace

Source: Electrical Deck

CORE-LESS INDUCTION FURNACE

- Charge need not to be in molten state initially like core type.
- Crucible and coil are lightly constructed that it could be tilted for pouring conveniently.
- Skin effect is high.
- Artificial cooling is required due to high copper loss.
- Copper coil is made hollow and cooling water is circulated through it.
- Heating may occur at supporting structures.

CORE-LESS INDUCTION FURNACE

SOURCE: ZHENGXIN

CORE-LESS INDUCTION FURNACE

Advantages:

- Fast in operation.
- Better uniform heating due to precise control.
- Results in high quality product. Molten metal can be kept at any temperature.
- Intermittent operation is possible. No warm up time is required.
- Used in all industrial heating and melting like steels and non-ferrous metals like brass, bronze and copper.
- Used in soldering, brazing, hardening and annealing dry paints and sterilizing surgical instruments.

SOURCES OF HIGH FREQUENCY FOR INDUCTION HEATING

Three types of equipments are used to produce supply with low frequency to high frequency.

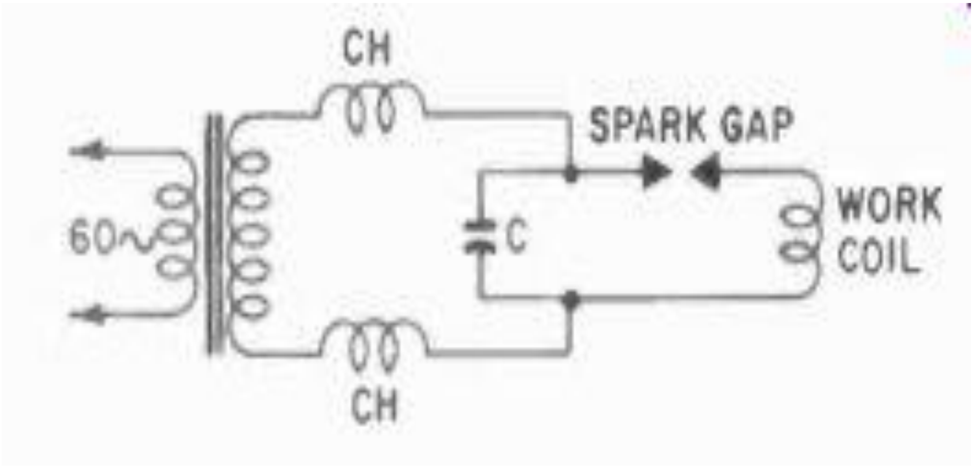
- M-G set
- Spark gap converter.
- Vacuum tube oscillator.

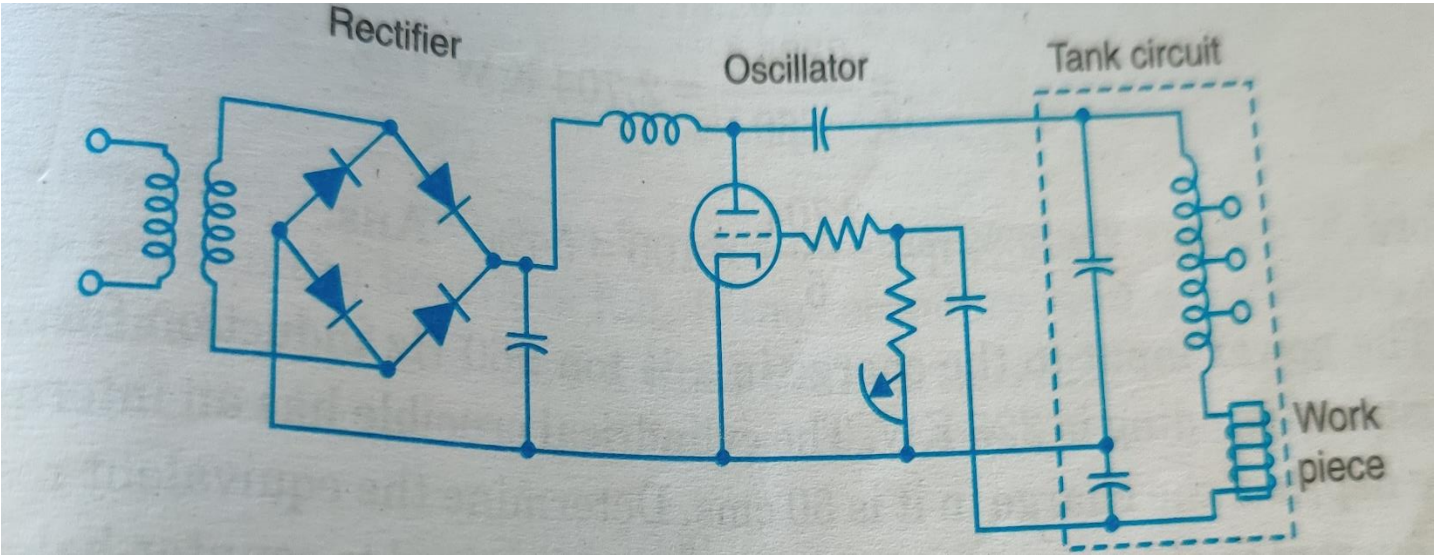
SOURCES OF HIGH FREQUENCY FOR INDUCTION HEATING

Motor-Generator Set:

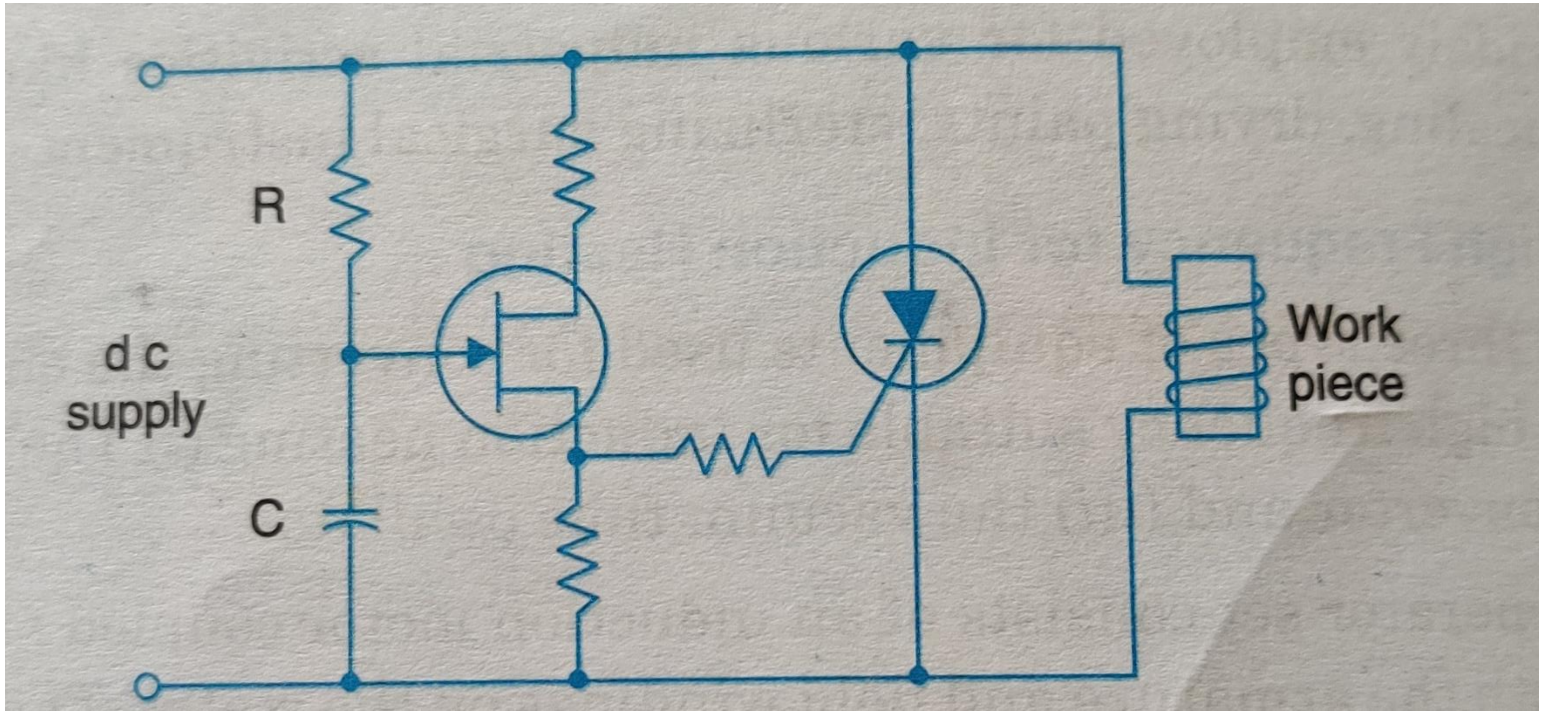
- IM coupled with specially designed generator.
- Both armature and filed winding on stator.
- Change in reluctance produces corresponding change in flux and hence emf is induced in armature.
- Frequency is determined by the number of complete flux reversals.

SOURCES OF HIGH FREQUENCY FOR INDUCTION HEATING





SOURCES OF HIGH FREQUENCY FOR INDUCTION HEATING



NUMERICALS

1. Determine the efficiency of high frequency induction furnace which takes 10 minutes to melt 1.815 kg of Al, the input to the furnace being 5kW and the initial temperature 15º C. Sp. Heat of AL: 0.212.Melting point: 660 ºC. Latent heat of fusion of Al : 76.8 kCal/kg.
2. A low frequency induction furnace has a secondary voltage of 15 V and takes 500 kW at 0.6 pf when the hearth is full. If the secondary voltage is maintained at 15 V, determine the power absorbed and the power factor when the hearth is half full. Assume the resistance of the secondary circuit to be there by doubled and the reactance to remain same.

DIELELECTRIC HEATING

- An insulating material when subjected to an AC field, it gets heated due to inter atomic friction known as dielectric loss.
- Atom is neutral.
- Atom when subjected to electric field , it becomes polarized.
- A dipole is formed having moment qd directed from –ve to +ve charge.
- Dipole moment direction changes with periodical change in alternating field and increases with variation of frequency and strength of electric field.
- High frequency supply is preferred to high voltage supply to avoid dielectric breakdown.

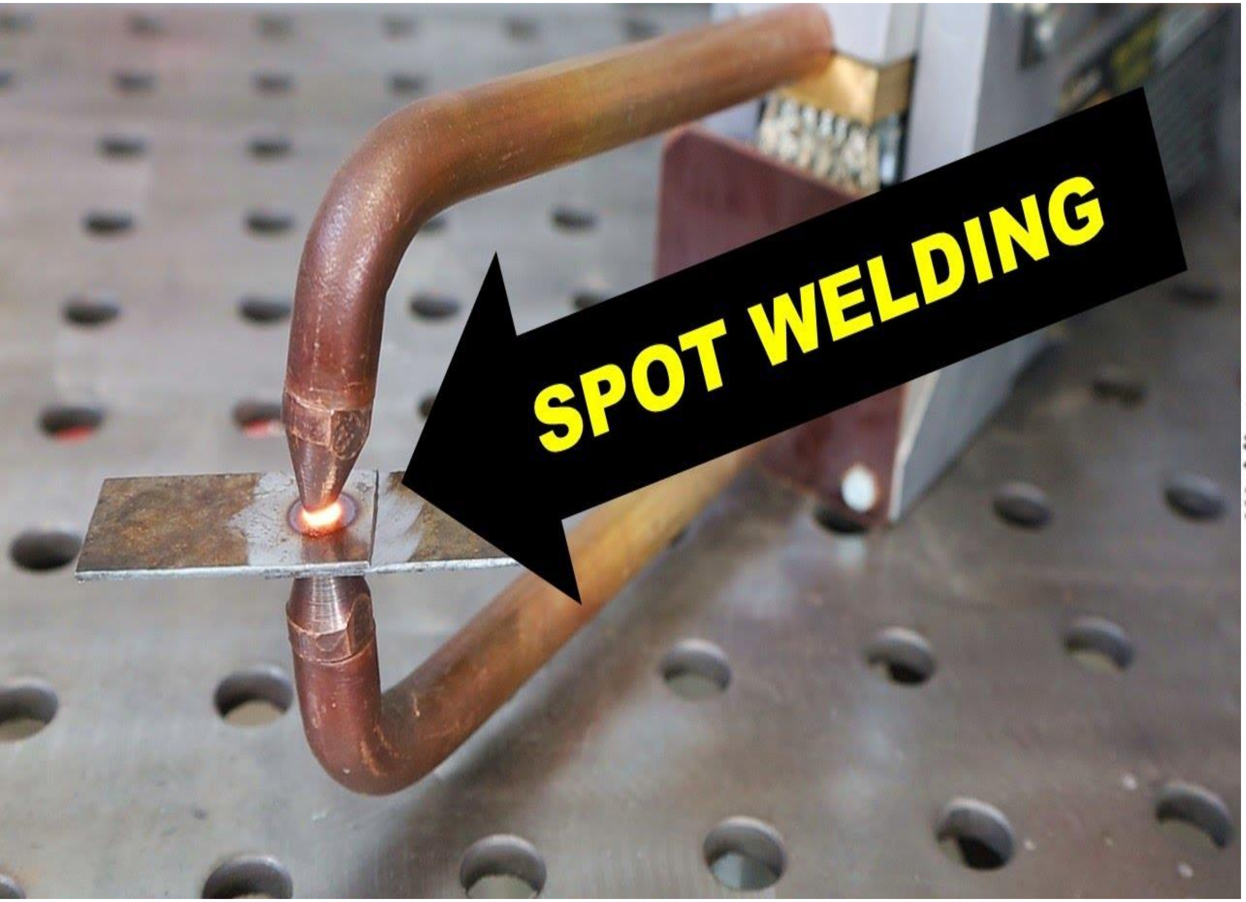
RESISTANCE WELDING

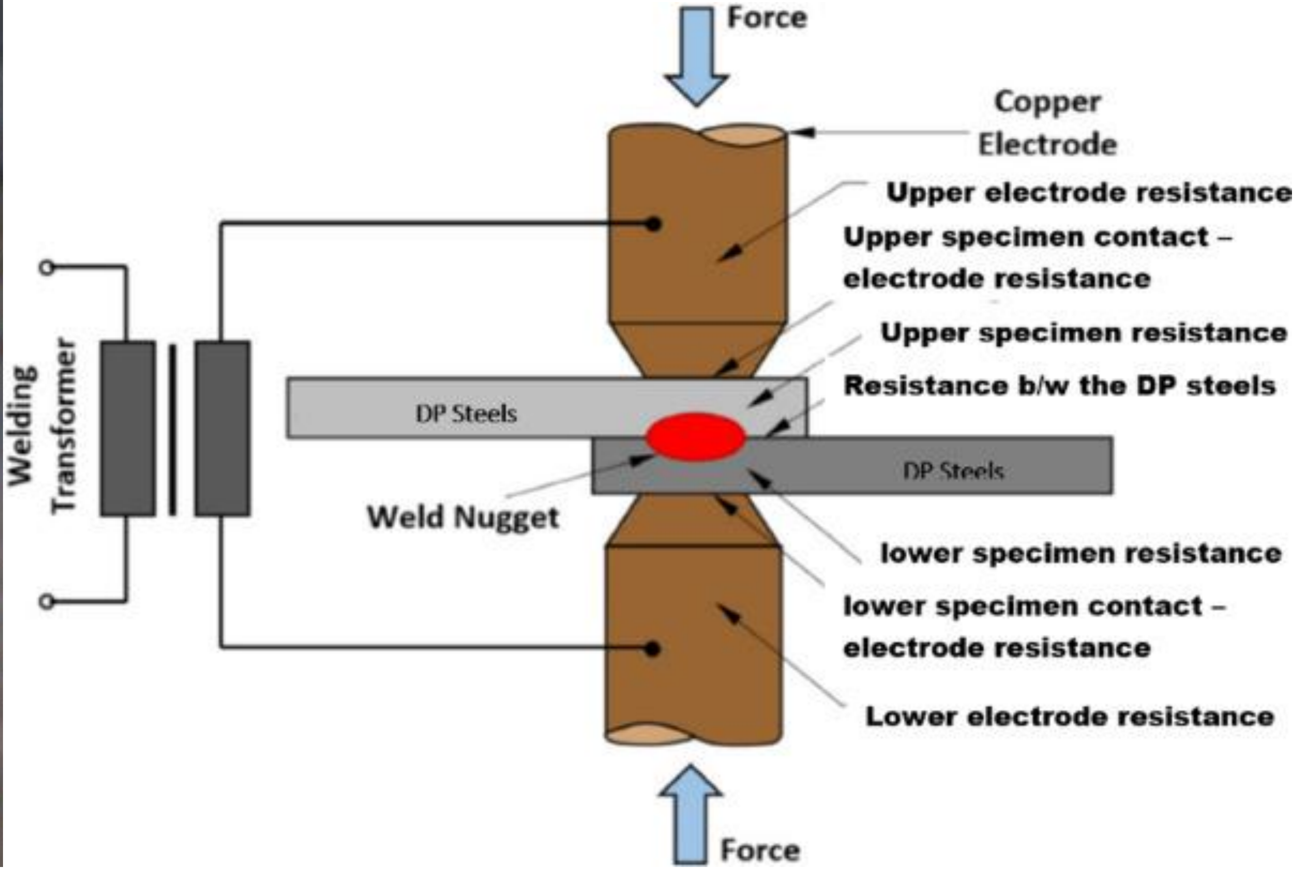
- Pressure is required in addition to heat unlike fusion type welding.
- Pressure refines the grain and weld has properties better than base metal.
- Conductivity of electrodes must be more than the metals to be welded.(current & heat)
- While welding two dissimilar metals, heat balance is obtained by using electrodes having low conductivity so as to prevent rapid heat dissipation.
- Choosing proper electrode for welding is quite important.

RESISTANCE WELDING

- **Squeeze time:** It’s the time that elapses between initial application of electrode pressure of the work and first application of current.
- **Weld time:** The time for which the welding current flows through the parts being welded. It is usually expressed in cycles of supply.
- **Hold time:** The time during which pressure is to the point of welding after welding current has ceased to flow.

SPOT WELDING



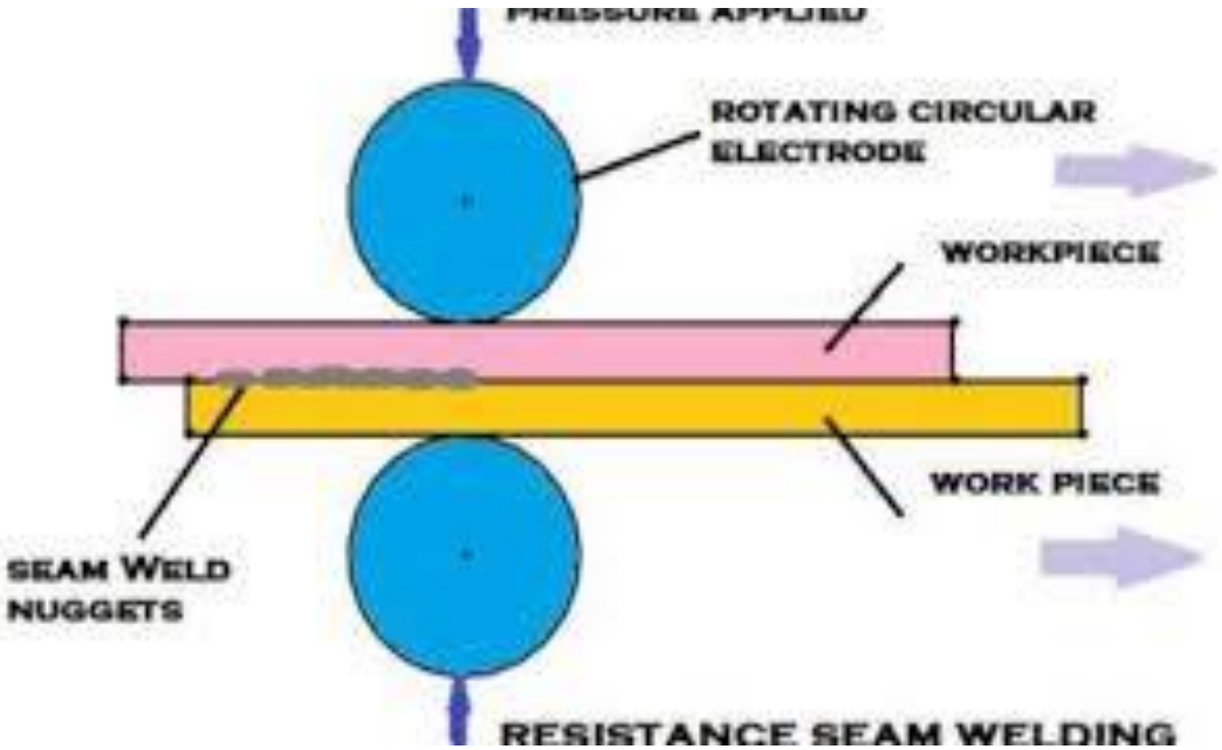


SPOT WELDING

SPOT WELDING

- Most widely used resistance welding.
- Electrodes are made of Copper or Copper Alloy.
- Current is allowed in sufficient magnitude through the pieces so that proper welding can be done.
- It is used for galvanized, tinned, lead coated sheets and mild steel sheet work.
- Also used to weld non ferrous metal like brass, Al, Ni, Bronze.

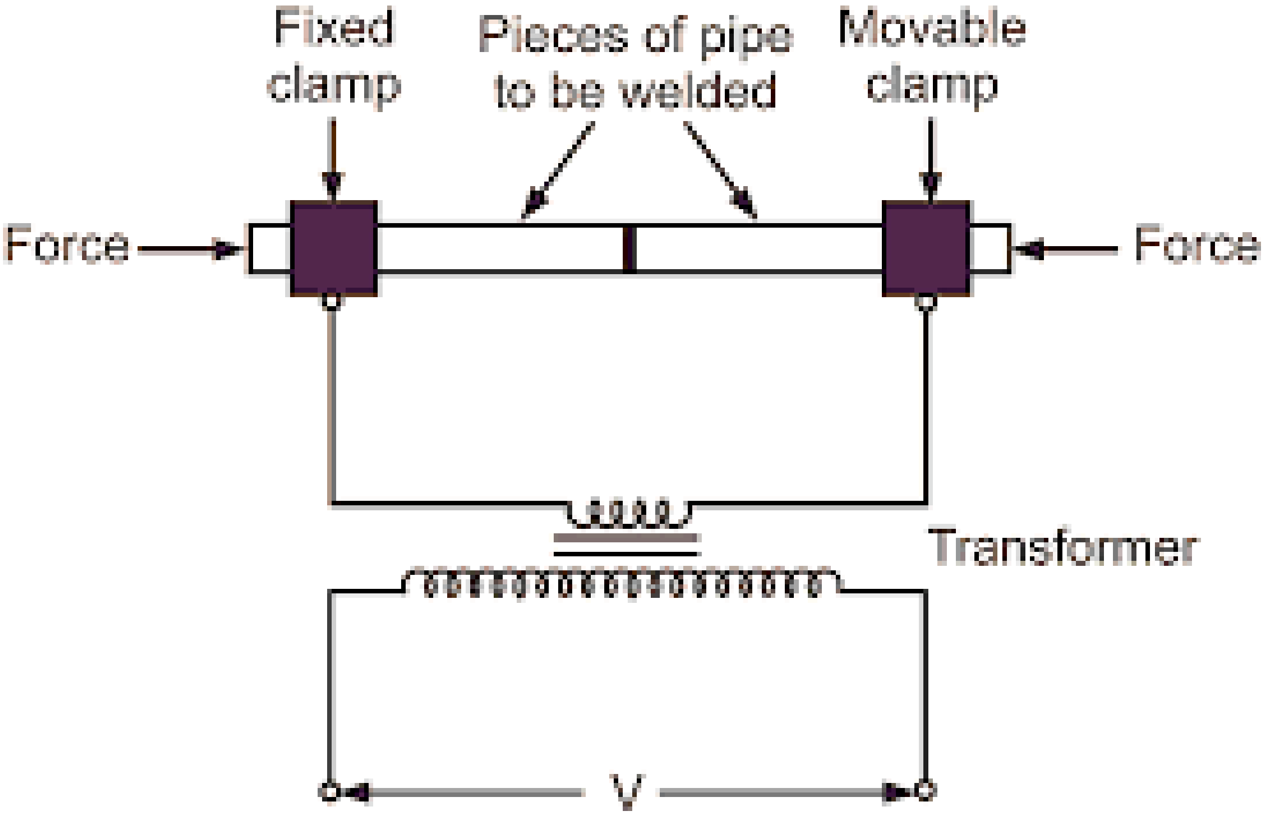
SEAM WELDING



SEAM WELDING

- Same as spot welding except circular roller type electrodes.
- No continuous flow of current for making a continuous weld.
- Overheating may cause burning of sheets.
- So current is passed intermittently and several overlapping spot welds are formed.
- No. of spots per cm vary from 2 to 4.
- Weld surface must be clean and dirt free.
- It’s used for welding transformer, refrigerator, evaporator, air craft tanks, paint & Varnish containers.

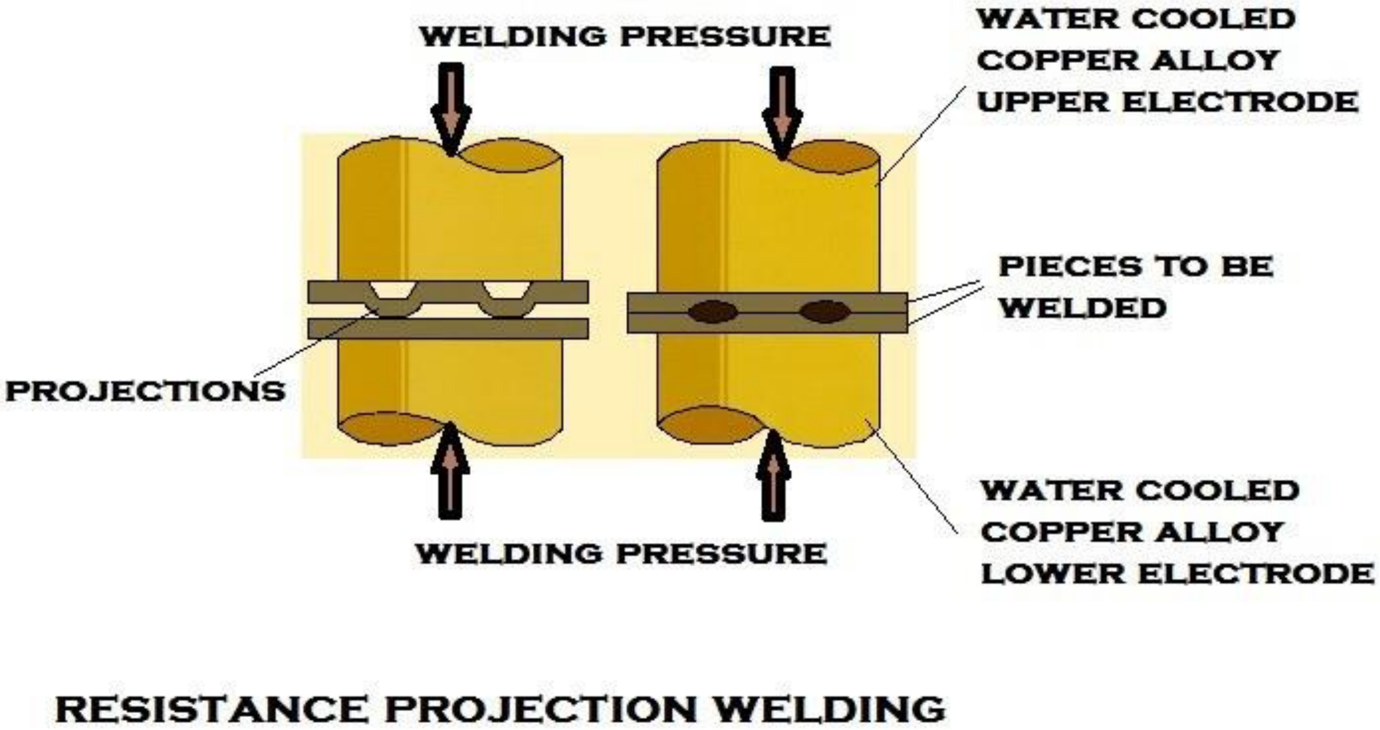
BUTT WELDING



BUTT WELDING

- Materials to be welded used as electrodes.
- The two ends are placed so as to have good contact.
- Then placed in the jaws of the machine which presses them close together end to end.
- Heavy current is passed through the contact resistance between the ends .
- Extra pressure is applied so that they are pushed into each other.
- Wire, tubes, bars and strips can be welded by this method.
- Materials can be welded like brass, Al ally, copper, nickel alloys, stainless , low carbon and high carbon steels.

PROJECTION WELDING



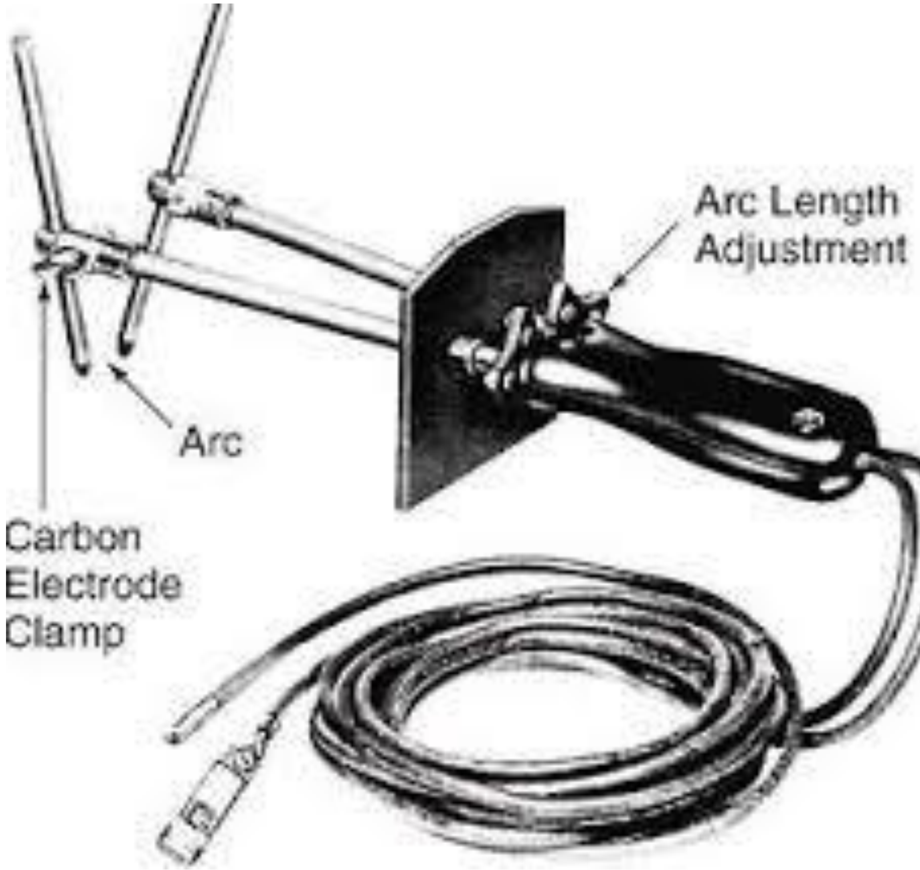
PROJECTION WELDING

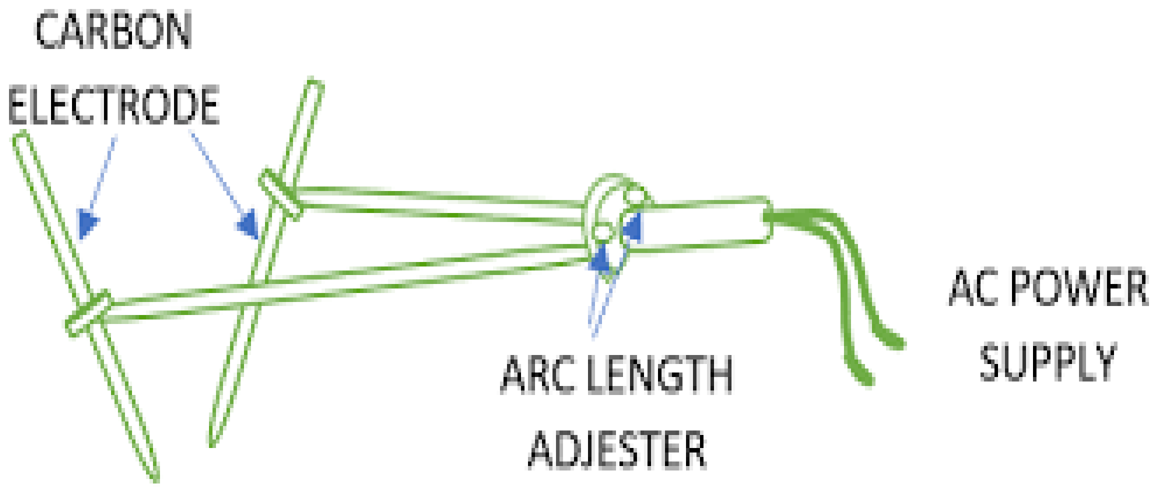
- In this method protrusions are pressed on one of the sheets to be welded and exact location of weld is determined.
- When current is passed and the electrode pressure is applied the projection collapses and the sheets are welded.
- Machines are flat platens with T slots for attachment of special tools.
- Used for welding steel radiator, coupling elements, brake shoes, tin plate tank handle.
- Low carbon steel with 0.2% carbon are used for welding satisfactorily.

ELECTRIC ARC WELDING

- Most widely used welding method.
- Arc is struck between electrode and metal to be welded.
- Two electrodes are kept at distances to maintain arc and joint is heated to fusion.
- Filler material is placed between electrodes to fill the joints by fusion.
- Based on electrode material it is termed as carbon arc or metal arc.
- Carbon electrodes used in dc and metal electrodes used in ac as well as dc.

CARBON ARC WELDING



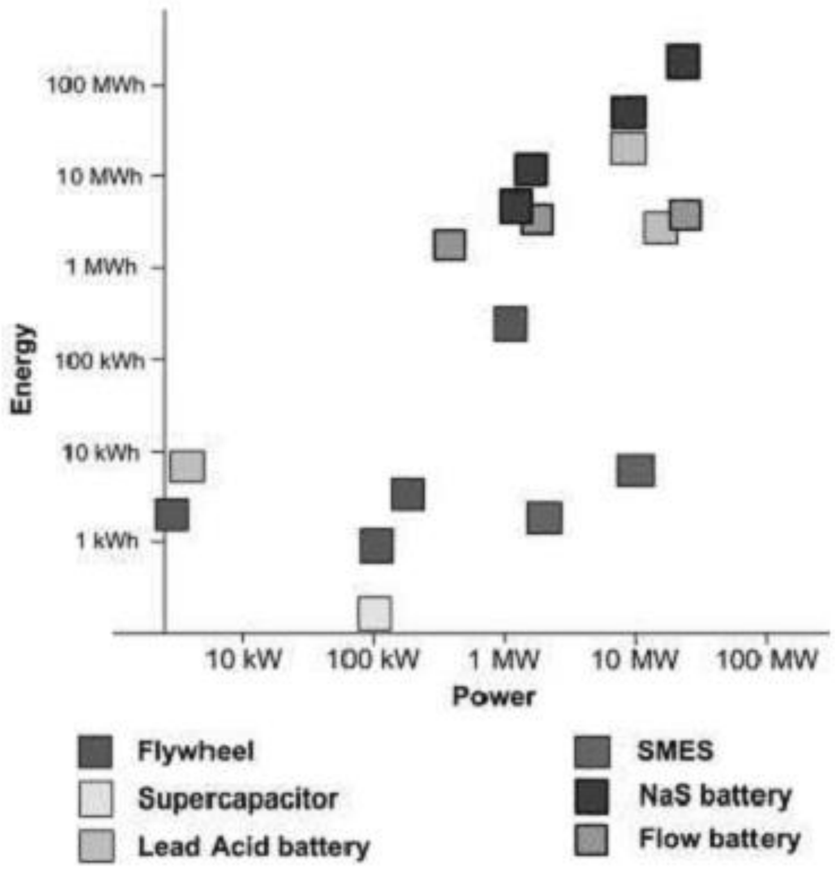


TWIN CARBON ARC WELDING HOLDER

ENERGY STORING DEVICES

- Energy can be stored by using pumped HPP and UG compressed air storage(1-2 GW) or 10-20 GWh.
- Smaller quantities of energy can be stored in batteries, flywheels, Super conducting Energy Storage (SMES) devices, Fuel Cells.
- Energy storing devices in power system are having prime objective of providing power for short time or energy for longer duration.
- Power Quality, voltage support and some frequency support may require short-term power support use batteries, SMES, fly wheels which have high power to energy ratio.

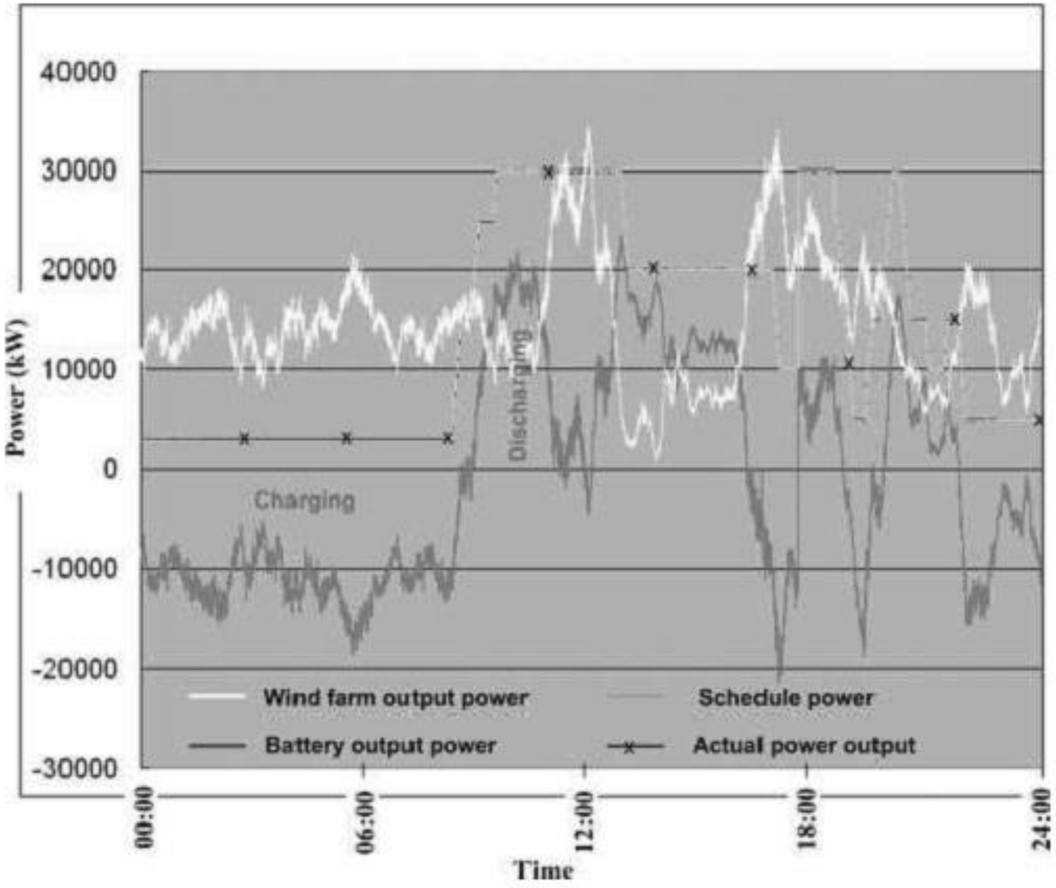
ENERGY STORING DEVICES

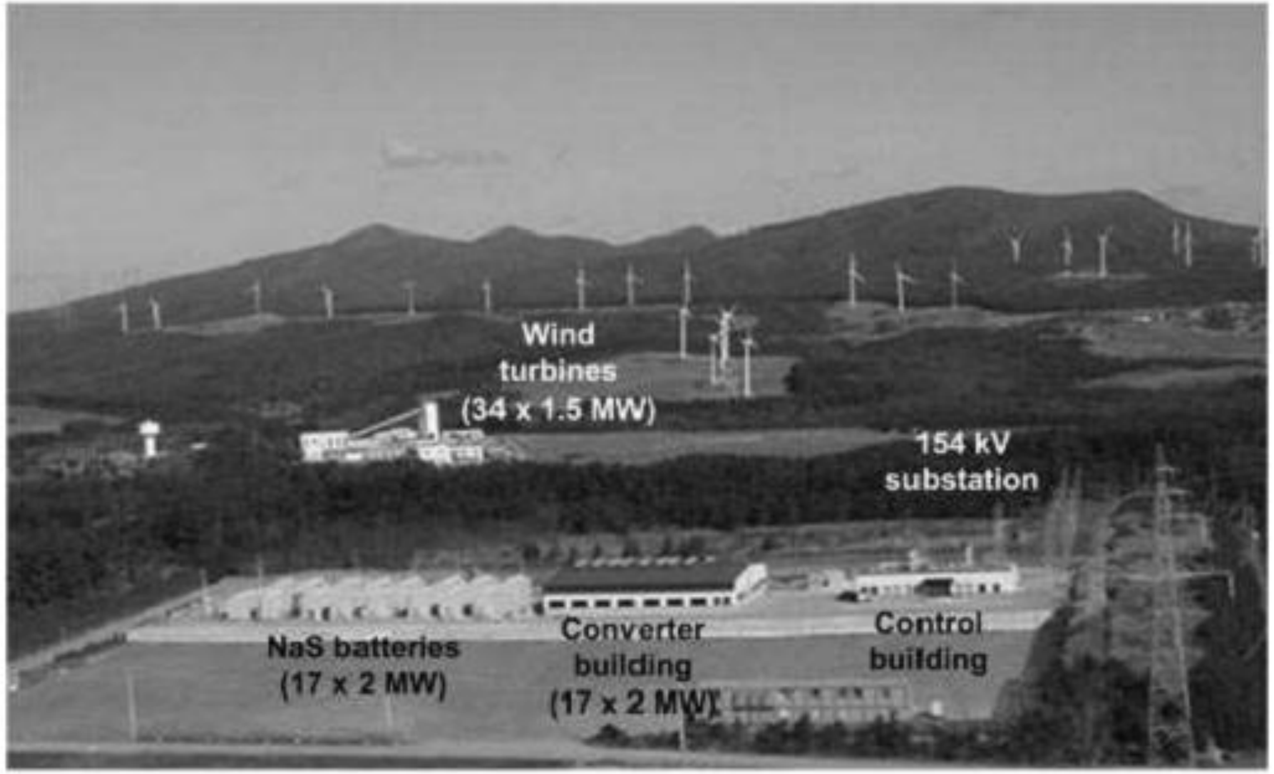


APPLICATION OF ENERGY STORING DEVICES

- Power Quality: Used in UPS
- Service Provision to renewable generation:
- Electrical Energy Time Shifting: Discharging when demand or price is high
- End use Energy Management: time of use tariff, micro generations
- Voltage Support: STATCOM, DG
- Reserve : installing ESS with spinning reserves.
- Load following: Frequent change in power demand.
- Capacity of distribution Circuits: can be enhanced

APPLICATION OF ENERGY STORING DEVICES





Source: Japan Wind Development Co. Ltd.

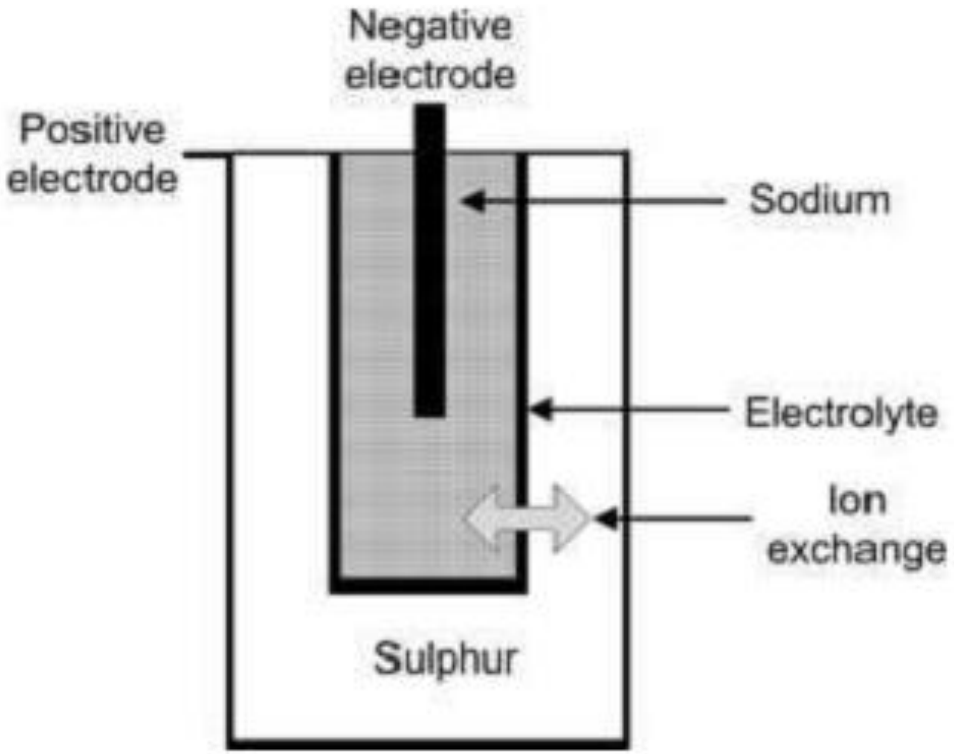
ENERGY STORING DEVICES

Batteries:

- Stores energy in chemical form and discharges in form of electrical energy.
- Consists of two electrodes (+ve and –ve) and electrolyte.
- Common available batteries are NaS, Li-ion, Ni-Cd, NiMH.
- Lead acid battery commonly used is cheap, but life time becomes short if discharged deeply.
- Batteries have low specific power but high specific energy.

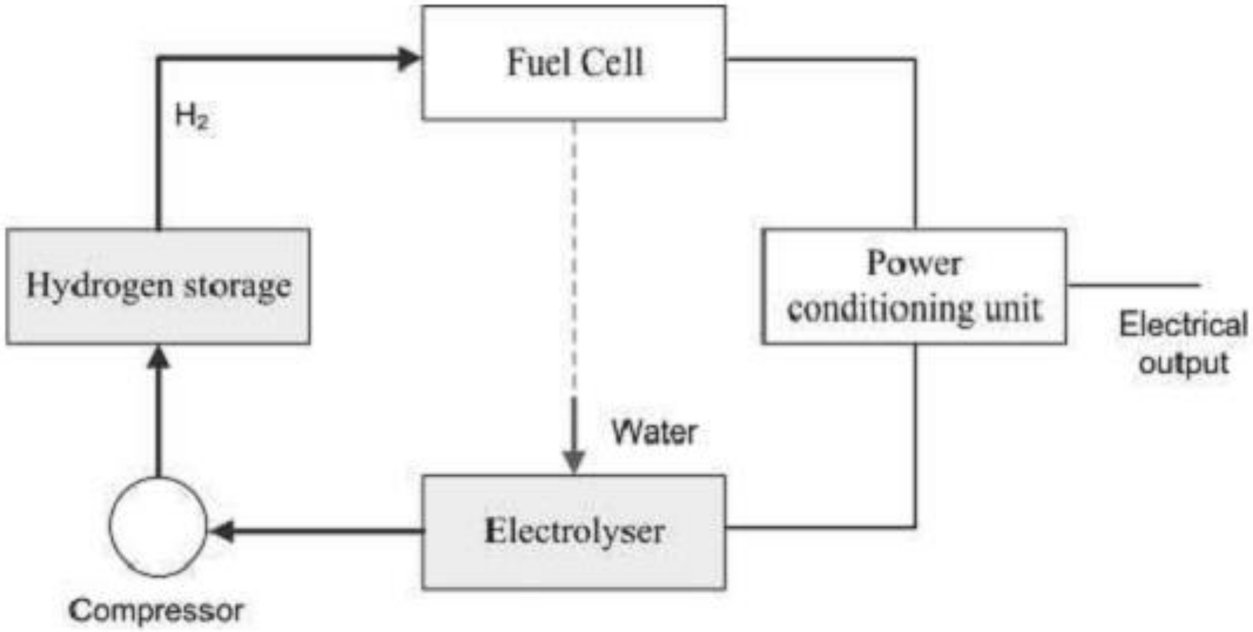
NaS Battery

- It operates at 300-400ºC.
- Large capacity per unit volume & Wt.
- Used for electrical energy time shifting.
- 2MW, 12MWh, Citizens substation USA.
- Wind power support 1 MW, 6MWh, USA.
- +ve: molten Sulphur, -ve: molten Na
- Electrolyte: Na-beta Alumina Ceramic.



Fuel Cell

- Uses H_2& O_2 as fuel.
- -ve electrode: H^+& electrons.
- H^+ moves towards +ve electrode through electrolyte.
- Electrons move through external circuit.
- +ve electrode made from porous materials coated with catalyst.
- H_2& O_2 combine to produce water at the electrode.

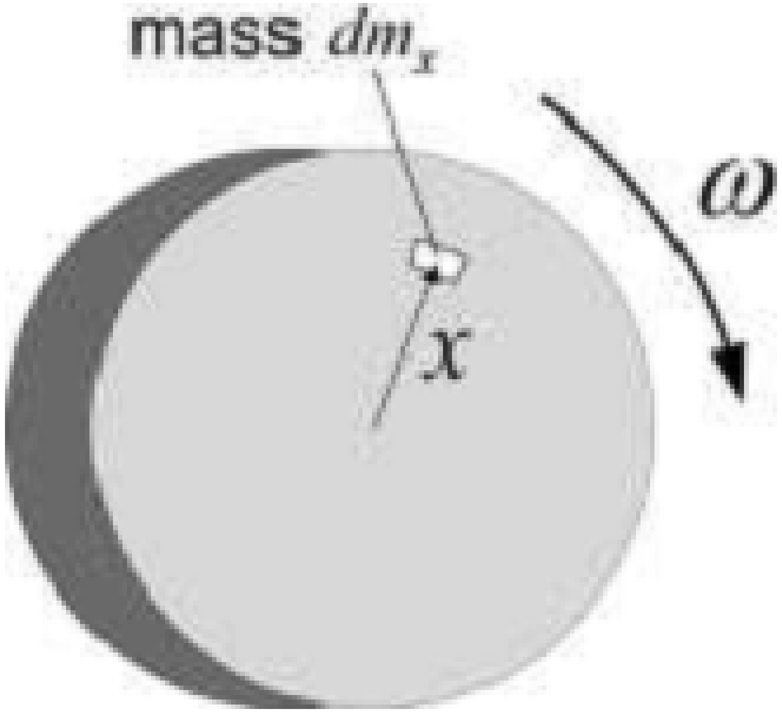


Fuel Cell

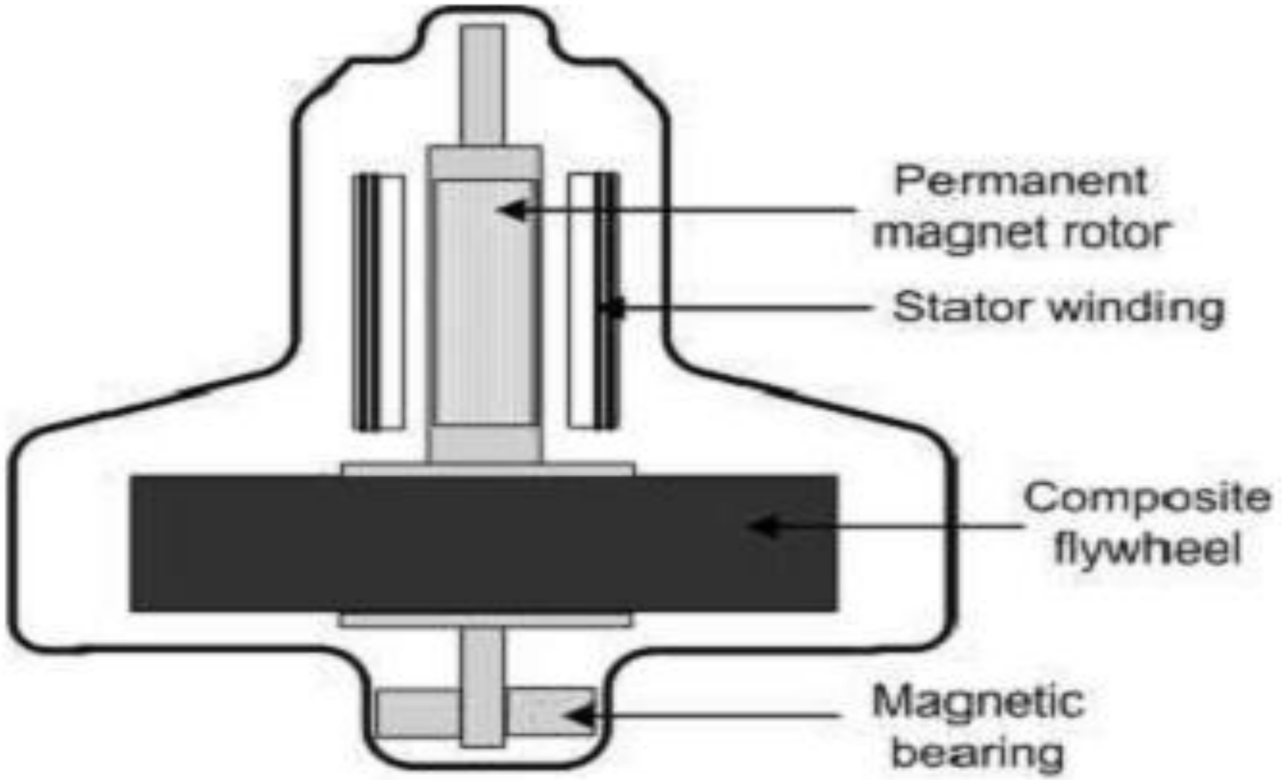
Type	Electrolyte	Operating temperature	Maximum output power reported
Polymer Electrolyte Membrane (PEM)	Organic polymer	80 °C	250 kW
Alkaline Fuel Cells (AFC)	Potassium hydroxide	150–200 °C	12 kW
Phosphoric Acid Fuel Cell (PAFC)	Phosphoric acid	150–200 °C	250 kW
Molten Carbonate Fuel Cells (MCFC)	Potassium, sodium or lithium carbonate	650 °C	2 MW
Solid Oxide Fuel Cells (SOFC)	Ceramic materials	1000 °C	100 kW

Flywheels

- Stores KE in a rotating mass & releases it by slowing down when electrical energy is required.
- Used for improving power quality and provide energy for UPS.
- Most of the applications are on customers premises.

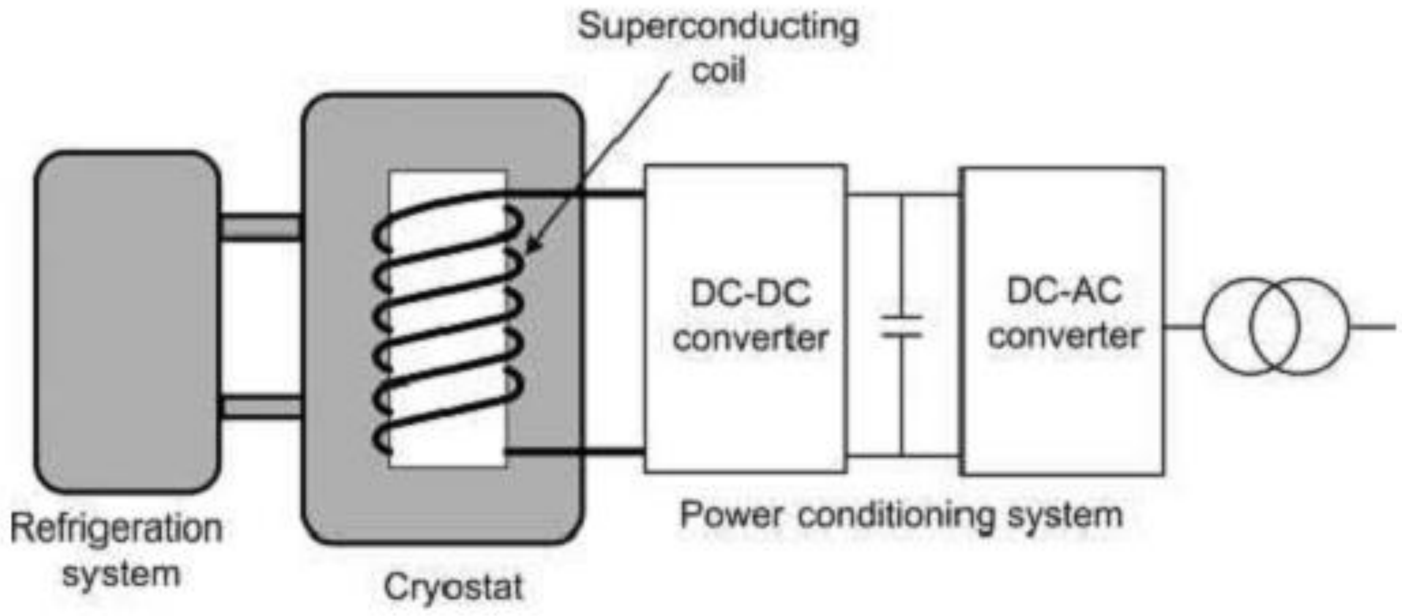


Flywheels


Permanent
magnet rotor
Stator winding
Composite
flywheel
Magnetic
bearing

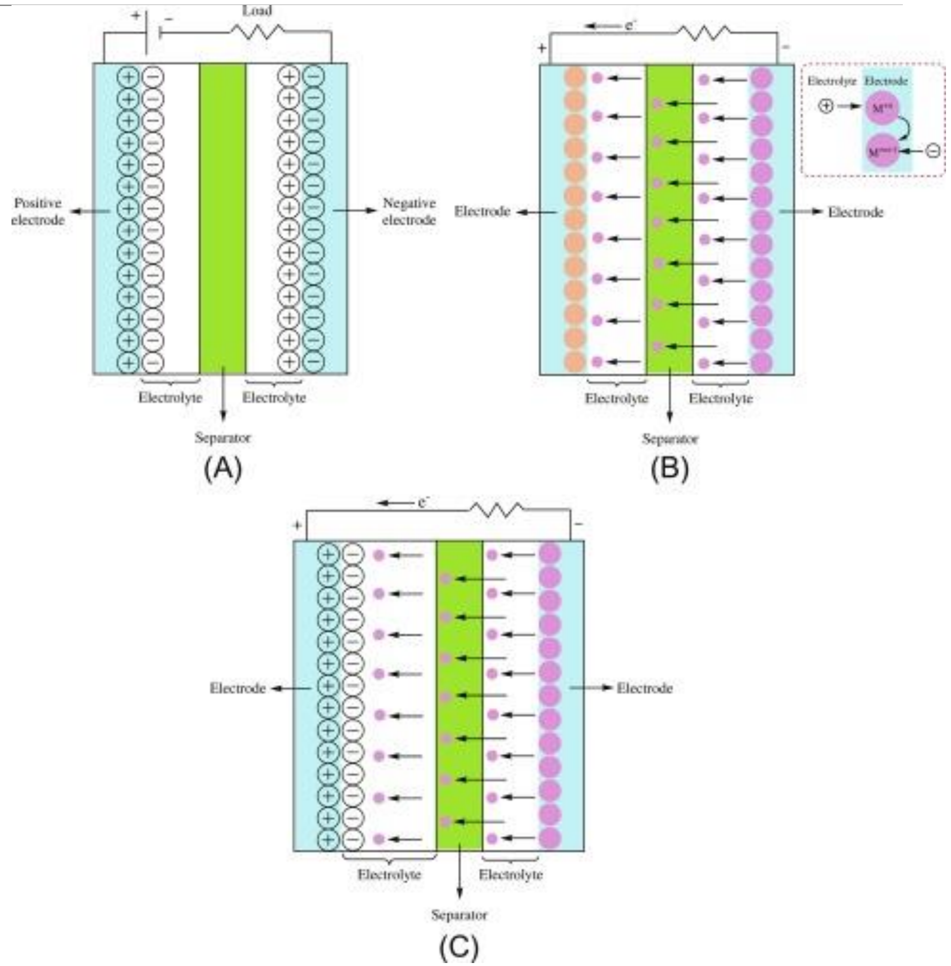
Superconducting Magnetic Storage System(SMES)

- Magnetic field is created by dc current through the superconducting coil.
- Energy stored doesn't reduce due to resistive nature of coil.
- To maintain superconductivity crayostat is used.(50-70ºK).
- Strong supporting structure required for high EMF.
- Stored energy is retrieved by power conditioning system.



Super Capacitors

- It has a double layer structure.
- Porous electrolyte Polythene Terephathalate (PET) is used.
- Double layer structure and high permittivity of PET increases the C.
- Carbonised porous material as one electrode and liquid chemical conductor as other.



Electrical Power T&D losses

- To install a 100 MW power plant 500cr. Required (approx.)
- This cost can be reduced by reducing T&D losses.
- Average T&D losses is 23% in India.(Total Capacity:140000 MW)
- T&D losses are 50% in some states according to TERI.
- State Regulatory commissions have been set up for estimating losses accurately as it affects the tariff of a utility.
- T&D losses include technical loss and commercial loss.
- Technical losses are ohmic losses in the conductors of transmission and distribution lines and equipments used in it.

Electrical Power T&D losses

- Technical losses can be reduced to optimal level using proper techniques of transmitting active and reactive powers.
- Commercial losses are due to pilferage, defective meters and in estimating unmetered supply of energy for agricultural and the loads supply to the weaker sections of the society.

Electrical Power T&D losses

- T & D losses of Indian states: Electricity-Distribution-Report_030821.pdf

Electrical Power T&D losses

System Element	% Power Losses	
	Min.	Max.
Step up transformer & EHV transmission system	0.5	1.0
Transformation to intermediate voltage level, transmission system and step down to sub-transmission voltage level	1.5	3.0
Sub-transmission system and step down to distribution voltage level	2.0	4.5
Distribution lines and service connection	3.0	7.0
Total losses	7.0	15.5

Reasons For Technical Losses

- Inadequate investment in T&D system, sub-transmission& distribution particularly. Ratio of investment in Generation to T&D should be 1:1 unlike 1:0.45 back in 1956-1997 resulting overloading of the system.
- Haphazard growth of sub-transmission and distribution without looking into technical and economical feasibility for short term gains.
- Too many stages of transmission.
- Improper load management.
- Inadequate and non-implementation of trending technology for reactive power compensation.
- Use of Poor quality IM in agriculture sectors.

Reasons For Commercial Losses

- Meter tampering.
- Stopping meter by remote controls.
- Changing the sequence of terminal wiring.
- Changing the CT ratio and reducing the recording etc.

Reduction of Technical Losses

- Only transmitting Active power and feeding reactive power at the load points.
- The distribution losses can be reduced by using high voltage distribution system rather than long LT line.
- The number of distribution transformers with smaller capacity taking care of smaller number of consumers can be increased.
- A better design of transformer with amorphous core will reduce the losses.
- Supply to consumer can be made using insulated wire to avoid theft of power.
- The above methods also improves the voltage profile.

Reduction of non-technical Losses

- According to International Utilities Revenue Protection Association (IURPA) service quality, customer relationships and overall service satisfaction can minimize revenue losses.
- To set up vigilance squads to check and prevent pilferage of power.
- To impose severe penalties on those tampering with meter seals.
- Executive engineers should be assigned to keep log of energy received and sold in each area. They can be given incentives on improving performance of the system.
- Energy meters should be periodically tested and replaced if found faulty.

Reduction of non-technical Losses

- Load of consumers must not be more than declared load.
- Reliable power supply should be provided by doing disaster management.
- Energy audit should be done for big industries and electrical utilities to identify the high loss areas.
- Power factor of IM should be maintained unity.
- UHV & HVDC are the new technology trend introduced to reduce the losses.

Electrical Energy Management & Audit

- Def1: the judicious and effective use of energy to maximize profits (minimize costs) and enhance competitive positions is called energy management.
- Def2: Or, the strategy of adjusting and optimizing energy using systems and procedures so as to reduce energy requirements per unit output while holding constant or reducing total cost of producing output from these systems.
- Energy Audit: Def1:Systematic approach of decision making in the area energy management.
- Def2: Energy Audit means the verification, monitoring and analysis of use of energy including submission of technical report containing recommendations for improving energy efficiency with cost benefit analysis and an action plan to reduce energy consumption.

Need of Energy Audit

- In any industry the main operating costs found to by energy (electrical & thermal), labour and materials.
- Energy has the highest potential for cost reduction.
- Energy audit helps to understand the ways energy is used in industry and help in identifying the areas where waste can occur & where scope for improvement exists.
- EA will review variations in energy costs, availability and reliability of supply of energy, decide on appropriate energy mix, identify energy conservation technologies, retrofit for energy conservation equipment.
- EA is the translation of conservation ideas to realities.

Type of Energy Audit

1. Preliminary EA
2. Targeted EA
3. Detailed EA

Preliminary EA

- It is also known as Walk through audit or diagnostic audit.
- Establish energy consumption in the organisation (Through bills & invoices).
- Obtain related data like production for estimating energy consumption.
- Estimate scope for energy savings.
- Identify most likely and easiest areas for attention. (unnecessary lighting, excess temperature setting, leakage etc.)
- Identify immediate no cost/ low cost improvements/ savings.
- Set up a base line/ reference point for energy savings.
- Identify areas for detailed study/ measurement.

Preliminary EA

Example of no cost energy management:

- Arresting leaks (steam or compressed air).
- Controlling excess air by controlling fan damper.

Examples of low cost energy management:

- Shutting equipment when not needed.(idle running motors)
- Replacement with appropriate lamps and luminaries.

Preliminary EA

Areas for detailed study/measurement:

- Converting from direct to indirect steam heated equipment and recovery of condensate.
- Installing / upgrading insulation on equipment.
- Modifying process to reduce steam demand.
- Investigating scheduling of process operations to reduce peak steam or water demands.
- Evaluating waste heat streams for potential recovery of waste heat.

Targeted EA

- Targeted Energy Audit often results from Preliminary audits.
- It provides data and detailed analysis on specified target projects.
- E.g: an organisation may target it's lighting system or boiler system or steam system or compressed air system with view of effecting energy savings.
- It involves detailed survey of the target subjects and analysis of energy flows and cost associated with the targets.
- Final outcome is the recommendations regarding actions to be taken.

Detailed EA

Detailed EA

Ten Steps Methodology for Conducting Detailed Energy Audit

Step No	PLAN OF ACTION	PURPOSE / RESULTS
PHASE I –PRE AUDIT PHASE		
Step 1	• **Plan and Organise** • **Walk through Audit** • **Informal Interview** with Energy Manager, Production / Plant Manager	• Establish/organize a **Energy audit team** • Organize Instruments and time frame • Macro data collection (suitable to type of industry.) • Familiarization with process / plant activities • First hand observation and Assessment of current level of operation and practices
Step 2	• **Introductory Meeting** with all divisional heads and persons concerned with energy management (1-2 hrs.)	• To built up cooperation and rapport • Orientation, awareness creation • Issue questionnaire tailored for each department

Detailed EA

PHASE II –AUDIT PHASE		
Step 3	• **Primary data gathering, Process Flow Diagram and Energy Utility Diagram**	• Historic data collection and analysis for setting up **Baseline energy consumption** • All service **utilities system diagram** (e.g. Single line power distribution diagram, water, and compressed air and steam distribution). • Prepare **process flow charts** • Design, operating data and schedule of operation • Annual Energy Bill and **energy consumption pattern** (Refer manual, logbook, name plate etc.)
Step 4	• **Conduct survey and monitoring**	• **Measurements** : Motor survey, Insulation, lighting survey etc. with portable instruments for operating data. Confirm and compare operating data with design data.

Detailed EA

Step 5	• **Conduct of detailed trials /** tests for selected major energy equipment	• **Trials / Tests** - 24 hours power monitoring (MD, PF, kWH etc.). - Load variations trends in pumps, fan compressors etc. - Boiler Efficiency trials for (4-8 hours) - Furnace Efficiency trials - Equipments Performance tests etc
Step 6	• **Analysis of energy use**	• **Energy and Material balance** • **Energy loss/waste analysis**
Step 7	• **Identification and development of Energy Conservation (ENCON) opportunities**	• Conceive, develop and refine ideas • Review ideas suggested by unit personnel • Review ideas suggested in previous energy audit report if any • Use brainstorming and value analysis techniques • Contact vendors for new / efficient technology

Detailed EA

Step 8	• **Cost benefit analysis**	• Assess technical feasibility, economic viability and prioritization of ENCON options for implementation • Select the most promising projects • Prioritise by low, medium, long term measures
Step 9	• **Reporting and Presentation** to the Top Management	• Documentation, draft Report Presentation to the top Management. • Final report preparation on feedback from unit
PHASE II –POST AUDIT PHASE		
Step 10	• **Implementation and Follow-up**	**Implementation of ENCON recommendation measures** and Monitor the performance • Action plan, schedule for implementation • Monitoring and periodic review

Phase-I: Pre-audit

In this phase a pre-audit visit to the industry is made by the auditor. The objective of the visit is as follows:

- To finalize energy audit team.
- To know the expectation of management from the audit.
- To identify the main energy areas/ plant items to be surveyed during the audit.
- To identify existing instrumentation and additional metering required prior to audit e.g for measurement of steam, oil, gas, electricity consumptions.
- To plan for audit with time frame.
- To collect macro data on plant energy sources and major energy consuming equipments.
- To build up awareness or support for energy audit.

Phase-II Detailed EA phase

- Sources of energy supply (whether supply from grid or self generated).
- Energy cost and tariff data.
- Generation and distribution of site services (e.g compressed air, steam,water, chilled water).
- Process and material flow diagram.
- Material balance data(use of scraps).
- Energy consumption by type of energy, by department, by major process equipment, by end use.
- Potential for fuel substitution, process modifications and the use of co-generation system.
- Reviewing of ongoing energy management procedures & energy awareness training programs.

Phase-II Detailed EA phase: base line data

- Quantity and type of raw materials.
- Technology, process used, equipment used.
- Capacity utilisation.
- Efficiencies/ yield.
- Percentage rejection/ reprocessing.
- Quantity and types of wastes.
- Consumption of steam, water, fuel, chilled water, compressed air, electricity, cooling water.

Identification of ENCON opportunities

- **Fuel substitution**: fuel for energy efficient conversion
- **Energy Generation:** efficient DG, optimal allocation of DG, Boiler optimization, minimum excess air consumption.
- **Energy Distribution:** Power factor improvement.
- **Energy Usages by Processes:** major opportunity for improvement.

Phase-II Detailed EA phase

Worksheet for Economic Feasibility

Name of the Energy Efficiency Measure		
1. Investment	2. Annual Operating costs	3. Annual Savings
1. Equipment 2. Civil works 3. Instrumentation 4. Auxiliaries	1. Cost of capital 2. Maintenance 3. Manpower 4. Energy 5. Depreciation	1. Thermal energy 2. Electrical energy 3. Raw materials 4. Waste disposal
Net Savings /year = Annual savings – Annual operating costs **Payback period in months = Investment / Net Savings /year x 12**		

Report on

DETAILED ENERGY AUDIT

TABLE OF CONTENTS

4.0 Detailed Process Flow Diagram and Energy & Material Balance

- 4.1 Flow chart showing flow rate, temperature, pressures of all input - output streams
- 4.2 Water balance for entire industry

5.0 Energy Efficiency in Utility and Process Systems

- 5.1 Specific energy consumption
- 5.2 Boiler efficiency assessment
- 5.3 Thermic fluid heater performance assessments
- 5.4 Furnace efficiency analysis
- 5.5 Cooling water system performance assessment
- 5.6 DG set performance assessment
- 5.7 Refrigeration system performance
- 5.8 Compressed air system performance
- 5.9 Electric motor load analysis
- 5.10 Lighting system

6.0 Energy Conservation Options and Recommendations

- 6.1 List of options in terms of no cost, low cost, medium cost and high cost, annual energy savings and payback
- 6.2 Implementation plan for energy saving measures/Projects

ANNEXURE

- Al. List of instruments
- A2. List of Vendors and Other Technical details

Energy Saving Recommendations

S.No.	Energy Saving Recommendations	Annual Energy (Fuel & Electricity) Savings (kWh/MT or kL/MT)	Annual Cost Savings (Rs. Lakhs)	Capital Investment (Rs. Lakhs)	Simple Payback Period
1					
2					
3					
4					
Total					

Energy Saving Measures

	Type of Energy Saving Options	Annual Electricity / Fuel Savings	Annual Savings	Priority
		kWh/MT or kJ/MT	(Rs. Lakhs)	
A	No Investment (Immediate) • Operational improvement • Housekeeping			
B	Low Investment (Short to Medium Term) • Controls • Equipment modification • Process change			
C	High Investment (Long Term) • Energy efficient devices • Product modification • Technology change			

Reporting Format of Energy Calculation

A: Title of Recommendation	:	**Combine DG set cooling tower with main cooling tower**
B: Description of Existing System and its Operation	:	Main cooling tower is operating with 30% of its capacity. The rated cooling water flow is 5000 m3/hr. Two cooling water pumps are in operation continuously with 50% of its rated capacity. A separate cooling tower is also operating for DG set operation continuously.
C: Description of Proposed System and its Operation	:	The DG Set cooling water flow is only 240 m3/h. By adding this flow into the main cooling tower will eliminate the need for a separate cooling tower operation for DG set, besides improving the %loading of main cooling tower. It is suggested to stop the DG set cooling tower operation.

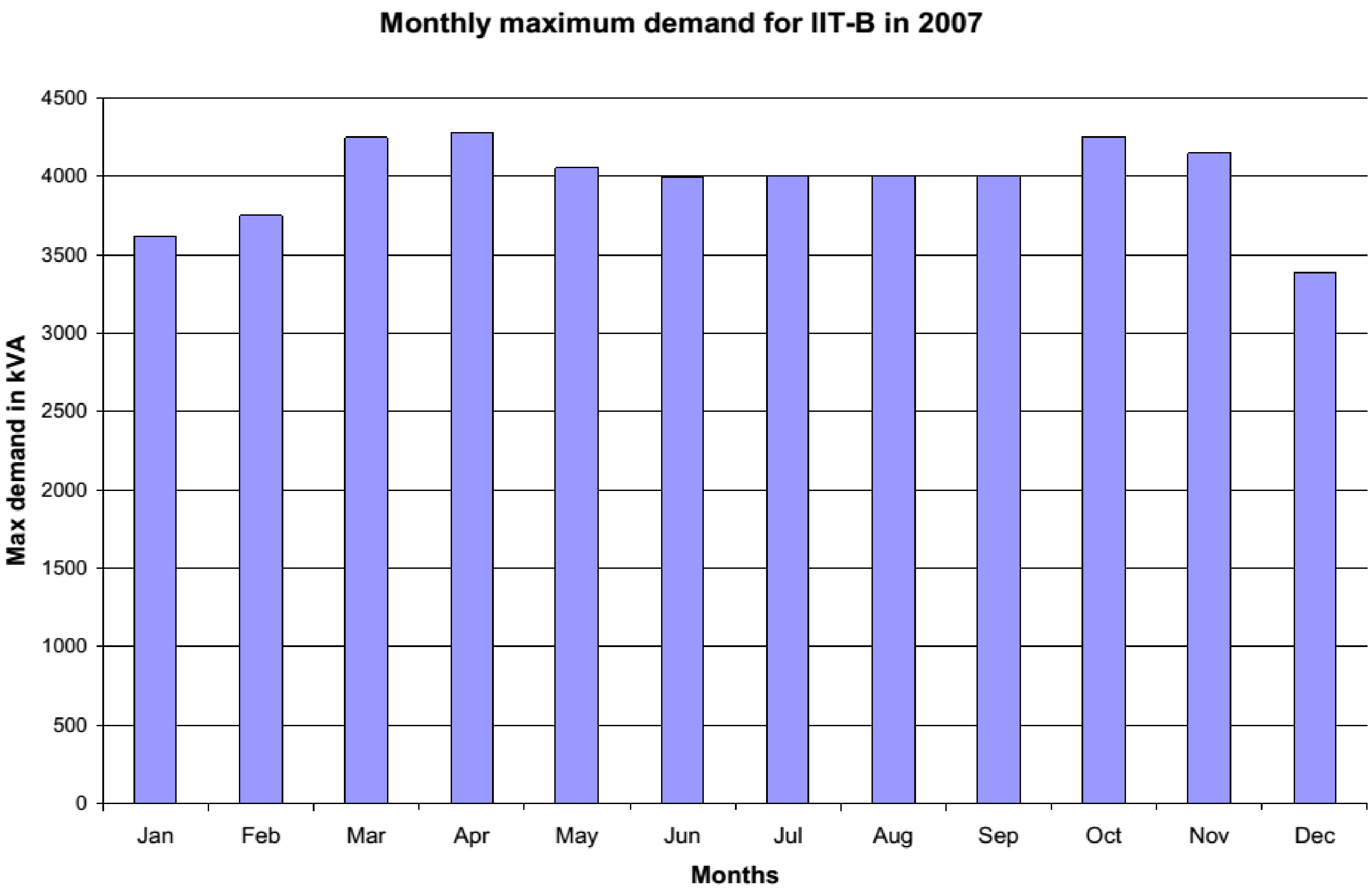
Reporting Format of Energy Calculation

D: Energy Saving Calculations		
Capacity of main cooling tower	=	5000 m^3/ hr
Temp across cooling tower (design)	=	8 ^oC
Present capacity	=	3000 m^3/hr
Temperature across cooling tower (operating)	=	4 ^oC
% loading of main cooling tower	=	(3000 x 4) / (5000 x 8) = 30%
Capacity of DG Set cooling tower	=	240 m^3/hr
Temp across the tower	=	5 ^oC
Heat Load (240 x 1000 x 1 x 5)	=	1200,000 kcal/hr

Reporting Format of Energy Calculation

Power drawn by the DG set cooling tower		
No of pumps and its rating	=	2 Nos x 7.5 kW
No of fans and its rating	=	2 Nos x 22 kW
Power consumption@ 80% load	=	(22 x2 +7.5 x2) x.80 = 47 kW
Additional power required for main cooling tower for additional water flow of 240m^3/h (66.67 l/s) with 6 kg/cm^2	=	(66.67 x 6) / (102 x 0.55) = 7 kW
Net Energy Savings	=	47 – 7 = 40 kW
E: Cost Benefits		
Annual Energy Saving Potential	=	40 kW x 8400 hr = 3,36,000 Units/Year
Annual Cost Savings	=	3,36,000 x Rs.4.00 = Rs.13.4 Lakh per year
Investment (only cost of piping)	=	Rs 1.5 Lakhs
Simple Payback Period	=	**Less than 2 months**

Case Study: IIT Bombay 2007



Case Study: IIT Bombay 2007

Consumption during following hours of the day	Energy Charge (p/u)
2200hrs-0600 hrs	(-)85
0600hrs-0900 hrs	0
0900hrs-1200 hrs	60
1200hrs-1800 hrs	0
1800hrs-2200 hrs	100

Case Study: IIT Bombay 2007

Group 1: Lighting and fans in Main building, Library and staff canteen

Group 2: Lighting and fans in Departments (all departments, offices, class rooms and labs)

Group 3: Lighting common area – Covering street lights, corridors, grounds

Group 4: Lighting and fans in Hostels (Hostel 1 to 7)

Group 5: Lighting and fans in Hostels (Hostel 8 to 13)

Group 6: Electric water heating and washroom/ironing loads in all Hostels (Hostel 1-13)

Group 7: Total energy audit of Gulmohar, old guest house and new guest house

Case Study: IIT Bombay 2007

Group 8: Energy use in Kitchen – Hostels (1-13) and staff canteen

Group 9: Room air conditioners in main building, departments and labs.

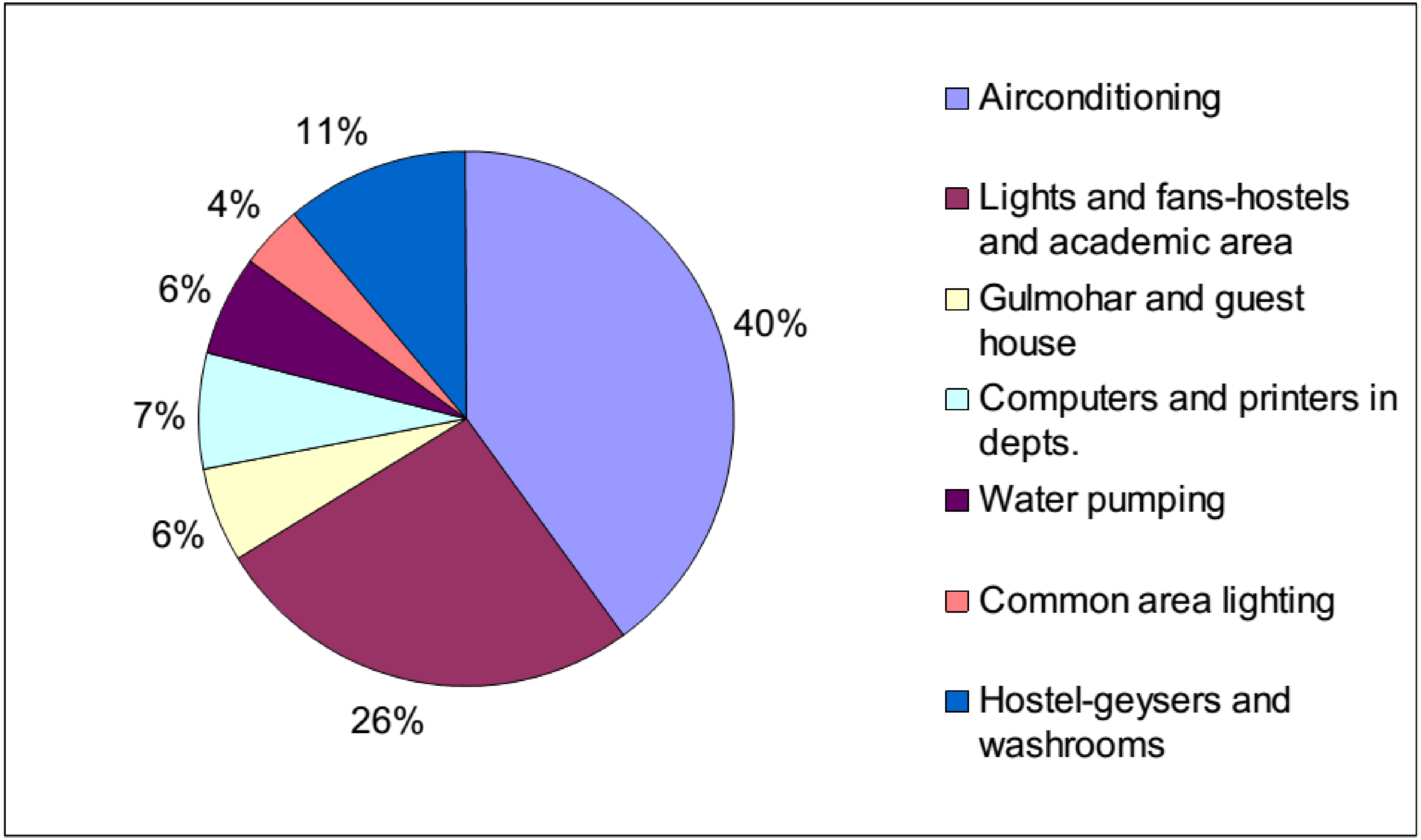
Group 10: Central air conditioning (library)

Group 11: Computers/printers – All departments, labs, library and main building

Group 12: Water Pumps in the entire campus

Group 13: Benchmarking of electricity consumption

Case Study: IIT Bombay 2007



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