Schemes Of BEE Under the energy Conservation Act - 2001

* Energy Conservation Building Codes [ECBC]
* Standards and labeling (S & L)
* Demand Side Management [DSM]
* Bachat Lamp Yojana [BLY]
* Promoting Energy Efficiency in Small and Medium Enterprises [SMEs].
* Designated Consumers
* Certification of energy auditors and energy managers.

1. ENERGY CONSERVATION BUILDING Codes [ECBC]:-

* Energy Conservation Building Codes was developed to deal with rapidly increasing energy consumption in commercial buildings.

i) Building function, comfort, health and the productivity of the occupants is considered.

ii) Life Cycle Costs.

2. STANDARDS AND LABELING (S&L)

* The main provision of the Standards and Labeling are:

i) Recommend to the Central Government, the norms for Processes & energy consumption.

ii) Standards for any equipment which Consumes, generates, transmits or supplies energy.

iii) Spread Information on the benefits to consumers.

STANDARD:-

1. Well-defined test Protocols to obtain a sufficiently accurates estimate of the energy Performance of a Product.

* target limits on energy Performance of usually maximum use or a minimum efficiency a test Protocol.

Labels:-

* Energy-efficiency labels are informative labels affixed to manufactured Products to describe the Product's energy Performance. they are two types.

1. Comparative label: allow Consumers to Compare efficiency of all the models of a Product in order to make an Informed choice. It Compared to other models available in market.

2. Endorsement Label:- defined a group of Products as efficient when they meet minimum energy performance criteria specified in respective Product Schedule / regulation / statutory order.

Minimum Energy Performance Standards (MEPS):-

* MEPS prescribe minimum efficiencies (or maximum energy consumption) that manufactures must achieve in each product.
* The MEPS will be reviewed and upgraded periodically to enhance & ensure the availability of energy efficiency product in the market.

Star Ratings:-

* A Ranking system based on energy efficiency of an appliance declared by manufacture. they are rated on a scale of star 1 to star 5. * the number of stars depends on the highest pre-set threshold of energy performance the able to meet.
* star 1 is least energy efficiency. star 5 is most energy efficient.

Label Period:-

* the validity period of the energy consume the standard in central Government under clause (a) of section 14 and in case the end period of new energy efficiency level is announced by the central Government.

Appliances / equipment Covered under S&L Program:-

1. Household Frost Free Refrigerators
2. Room Air Conditioners
3. Tabular Fluorescent Lamps
4. Distribution Transformers (upto 200 KVA)

3. Demand Side Management (DSM):-

* Demand side management means managing of the demand for power, by utilities / Distribution companies, among some or all its customers to meet current or feature needs.
* DSM also enables end-users to better manager their load curve and thus improves the profitability.
* Pilot study undertaken by BEE has indicated energy saving potential of 40% by replacement of inefficient pumps with star rated pumpset.
* BEE has prepared an agricultural DSM programme in which pumpset efficiency upgradation could be carried out by an energy service company (ESCOs) company.

4. Bachat Lamp Yojana (BLY):-

* The "Bachat lamp Yojana", which literally means "save Lamp Scheme", aims at the large scale replacement of inefficient incandescent bulbs in household by Compact Fluorescent Lamps (CFLs).
* The Clean Development mechanism (CDM) to recove the cost difference between

the mark price of the CFLs and the price at which they are sold to house holds.

* The Bachat Lamp Yojana is designed as public-private partnership between the Government of India Private sector CFL suppliers to ~~Federal~~ State level Electricity Distribution Companies (DISCOMs).

5. SMALL AND MEDIUM ENTERPRISES (SMEs)

* Energy Efficiency in the SME Sector assumes importance because of the prevailing high costs of energy and supply related concerns.

* It will be useful number of units energy efficiency awareness by funding / subsidizing need based studies in large number of units in the SMEs.

6. DESIGNATED CONSUMERS (DC):-

No.	Industry	Energy Consumption.
1.	Thermal power stations	30,000 metric tonne of oil equivalent (MTOE) per year and above.
2	Fertilizer	30,000 metric tonne of oil equivalent (MTOE) per year and above.
3	Cement	30,000 metric tonne of oil equivalent (MTOE) per year & above
4	Iron & steel	30,000 metric tonne of oil equivalent (MTOE) per year & above
5	Chlor-Alkali	12,000 metric tonne of oil equivalent (MTOE) per year & above
6	Aluminium	7,500 metric tonne of oil equivalent (MTOE) per year & above
7	Railways	Electric traction sub-section (TSS) having total annual energy consumption 30,000 MTOE.
8	Textile	3,000 metric tonne of oil equivalent (MTOE) per year & above
9	Pulp & paper	30,000 metric tonne of oil equivalent (MTOE) per year & above

i) 1kg of oil Equivalent : 10000 Kcal.

ii) 1 metric Tonne of oil Equivalent (MTOE) : 1×10^7 Kcal.

iii) In case of coal, petroleum products and other fuels in absence of supplier certificate.

As per Act, Designated Consumers have fulfill the following.

* Designated Consumer have to appoint Energy managers with prescribed qualifications.

* Designated Consumer are required to adhere to energy efficient consumption norms stipulated.

7. Certification of Energy Managers and Auditors

* It is a certified ~~staff~~ energy manager and has passed the examination in "Energy Performance for Equipment and utility Systems" conducted by Bureau.

* It has experience of five years in energy audit out of which atleast three year shall be in any of energy intensive industries.

* It has been granted a certificate of accreditation by the Bureau of Energy Efficiency.

Energy Management and Audit:

Energy Management

Definition:

The strategy of adjusting and optimizing energy using systems and Procedures so as to reduce energy requirements Per unit of output while holding constant or reducing total costs of Procedureing the output from these system.

The objectives of Energy management:

☆ To minimise energy costs/waste without affecting Production and quality.

☆ To minimise environment effects.

Energy Audit Definition:

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 for Energy Audit:

☆ In any Industry, the three top operating costs are often found to be energy (both electrical and thermal), labour and materials.

☆ Among the three energy has the highest Potential for cost reduction.

☆ Energy audit will help to understand more about the ways energy is used in the industry.

☆ such an audit programme will review variations in energy costs.

Types of Energy Audit and Approach:

☆ The type of energy audit to be performed depends on the types of industry.

☆ Thus energy audit can be classified into the following types. Preliminary Audit, Targeted Energy Audits and Detailed Audit.

Preliminary Energy Audit:

Preliminary energy Audit, which is also known as walk through Audit and Diagonostic Audit, The scope of Preliminary energy audit is to:

☆ Estimate the scope for energy savings.

☆ Identify immediate especially no/low cost improvements/savings.

☆ set up a baseline or reference Point for energy consumption.

☆ Identify areas for more detailed study/measurements.

some example of no-cost energy manangement measures are:

☆ Arresting leaks (steam, compressed air)

☆ controlling excess air by adjusting fan damper

Some examples of low-cost energy manangement measures are:

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

Area for detailed study/measures are:

- Installing/upgrading insulation on equipment.
- Modifying process to reduce steam demand.

Targeted Energy Audits:

- Targeted energy audits often results from Preliminary audits.
- They provide data and detailed analysis on specified target projects.

Detailed Energy Audit:

- One of the key elements in detailed energy audit is the energy balance.
- Datailed energy Audit is carried out in three Phases:

a) Pre Audit Phase b) Audit Phase c) Post Audit Phase.

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 Familiarization with Process/ Plant activities.
Step 2	Introductory meeting with all divisional heads and persons concerned with energy manangments (1-2 hrs)	To built up cooperation and rapport. Orientation, awareness creation Issue questionnaire tailored for each department.

Phase II - Audit Phase		
Step3	✪ Primary data gathering, Process flow diagram and energy utility diagram.	✪ Historic data collection and analysis for setting up Baseline energy consumption. ✪ Prepare process flow charts. ✪ Design, operating data and schedule of operation.
Step4	✪ conduct survey and monitoring.	✪ Measurements: Motor survey, Insulation, lighting survey etc. with Portable instruments for operating data.
Step5	✪ conduct of detaile trials tests for selecting major energy equipment	✪ Trials/Tests ✪ 24 hours power monitoring ✪ Boiler efficiency trials for (4-8 hours) ✪ Furnase Efficiency trials ✪ Equipments Performance tests.
Step6	✪ Analysis of energy use	✪ Energy and meterial balance ✪ Energy loss/waste analysis.
Step 7	✪ Idntification and development of Energy conservation (ENCON) opportunities	✪ conceive, develop and refine ideas. ✪ Review ideas suggested by unit personnel. ✪ Use brainstorming and value analysis techniques. ✪ contact vendors for new efficient technology.
Step8	✪ cost benefit analysis	✪ Assess technical feasibility, economic viability and priortization of ENCON options for implementation. ✪ select the most promising projects. ✪ Priortise by low, medium, long term measures.
Step 9	✪ Reporting and Presentation to the top manangement	✪ Documentation, draft Report. Presentation to the top manangement. ✪ Final report presentation on feedback from unit.

Phase III - 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 Phase:

An initial study of the site should always be carried out as Proper Planning is a Pre-requisite for an effective audit.

During the initial site visit the energy Auditor/Engineer should carry out the following actions:

☆ Discuss the site's senior manangement about the aims of the energy audit.

☆ Explain the purpose of the audit and indicate the kind of information needed during the facility tour.

☆ Obtain site drawings where available - Plant/building layout, steam distribution, compressed air distribution, electricity distribution etc.

☆ Tour the site accompanied by site representative.

The outcome of this visit should be:

☆ To finalise Energy Audit team.

☆ To know the espectation of manangement from the audit.

☆ To Plan for audit with time frame.

☆ To collect macro data on Plant energy resources.

☆ To build up awareness and support for detailed energy audit.

Phase II - Detailed Energy Audit Phase:

Depending on the nature and complexity of the site, a detailed audit can take from several weeks to several monts to complete.

The information to be collected during the detailed audit includes:

☆ Sources of energy supplies.

☆ Energy cost and tariff data

☆ Process and meterial flow diagrams.

☆ Generation and distribution of site servises.

☆ Review of ongoing energy manangement Procedures.

Energy audit team should ensure that the following basline data are collected:

☆ Quantity and type of raw materials.

☆ Capacity uitilization.

☆ Efficiency /yield

☆ Percentage rejection/reProcessing

☆ Quantity and types of wastes.

1) Understanding Energy Cost.

* Energy costs are not a fixed overhead, there is often a huge potential for making savings
* understanding energy cost is vital factor for awareness creation & saving calculation

Energy invoices can be used for the following.

* They provide a record of Energy purchased in a given year which gives a baseline for future reference.
* when electricity is purchased on the basis of maximum demand tariff.
* They can suggest where savings are mostly liked to be made.

  * Fuel cost
  * power cost.

Fuel cost :

* wide variety of fuels are available for thermal energy supply, some fuels are

* Fuel oil
* low sulphur Heavy stock (LSHS)
* Light Diesel oil (LDO)
* Liquid petroleum gas (LPG)
* coal
* Lignitic
* wood etc....

* Availability, cost and quality are the main three factors that are;
  * price at source, transport charge, type of transport
  * Quality of fuel
  * Energy content

Power costs :

Electricity price in India not only varies form state to state, But also city to city & consumer to consumer though it does the same work everywhere.

* Maximum demand charges, KVA
* Energy charges, Kwh
* power factor charge, P.F
* High tension tariff and low tension tariff rate charges.
* slab Rate cost and its variation.
* Type of tariff clause and rate for various categories; such as
  * commercial * Residental * Industrial,
  * Government * Agriculture etc..
* Tax holiday for new projects . . .

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2. Instrument And Metering For Energy Audit.

* The requirement for an energy audit is to identify and quantify where energy is being used necessitates measurement.

* These measurement require the use of instruments.

* The basic instruments used in energy audit work are listed below.

1. Eletrical Measuring instruments:-

* These are instrument for measuring major eletrical parameters such as kVA, kW, PF, Hertz, KVAR Amps and Volts.

* These instrument are appiied on-line.

2. Fyrite.

* In this a hand bellow pump draws the flue gas sample into the solution inside the fyrite.

* Orsat method of volumetric anaysis using chemical absorption of a sample gas as carbon dioxide or oxygen.

3. Fuel Efficiency Monitor.

* This measures oxygen and temperature of the flue gas.

* calorific values of common fuels are fed into the microprocessor which calculated the combustion efficiency.

4. combustion Gas Analyzer:

* This instrument has in-built chemical cells which measure various gas such CO_2, CO, NOx, SOx etc.

* It is light and easier to handle compared to the fuel efficiency monitor.

5. Manometer with pitot tube.

* Attach these two tubes to the ends of the point tube.
* make 6-cm monitoring hole in duct or pipeline.
* Insert the pitot tube into the monitoring hole.

6. Contact Thermometer.

* Thermometer in example flue gas, hot air, hot water temperatures by insertion of probe into the stream.

* The surface temperature a leaf type probe is used with the same instrument.

7. NON contact infrared Thermometor.

* Infrared theromometer calculate the amount of thermal radiation emitted from the object.

* The most common design of a IR thermometer Consists of a lens to focus the infrared energy on to a detector.

8. Ultrasonic flow Meter.

* This is one of the popular means of non-contact flow measurement

* there are two main type of ultrasonic flow meters.

* Transit time and Doppler.

* Transit time ultrasonic flow meters usually monitor clean liquids.

9. Speed Measurements:

* A simple techometer is a contact type instrument which can be used where direct access is possible.

* A Stroboscope uses this principle for measurement of RPM.

* More sophisticated and safer ones are non contact instruments such as stroboscopes

10. psychrometer.

* A Sling psychrometer consists of two thermometers mounted together with a handle.

* Then the temperature of both thermometers are read.

* to evaporates from the cooling the wet-bulb thermometer more, so greate difference b/w the temperatures.

11. Lux meters.

* A light sensitive cell measures the incident light in the visible spectrum is measured.

* The resulting value is the measurement result in lux.

12. Smart Energy meter.

* The primary purpose of smart use their eletricity on real-time basis.

* The Smart energy meter use a wireless communication to help track the eletricity.

13. Thermography.

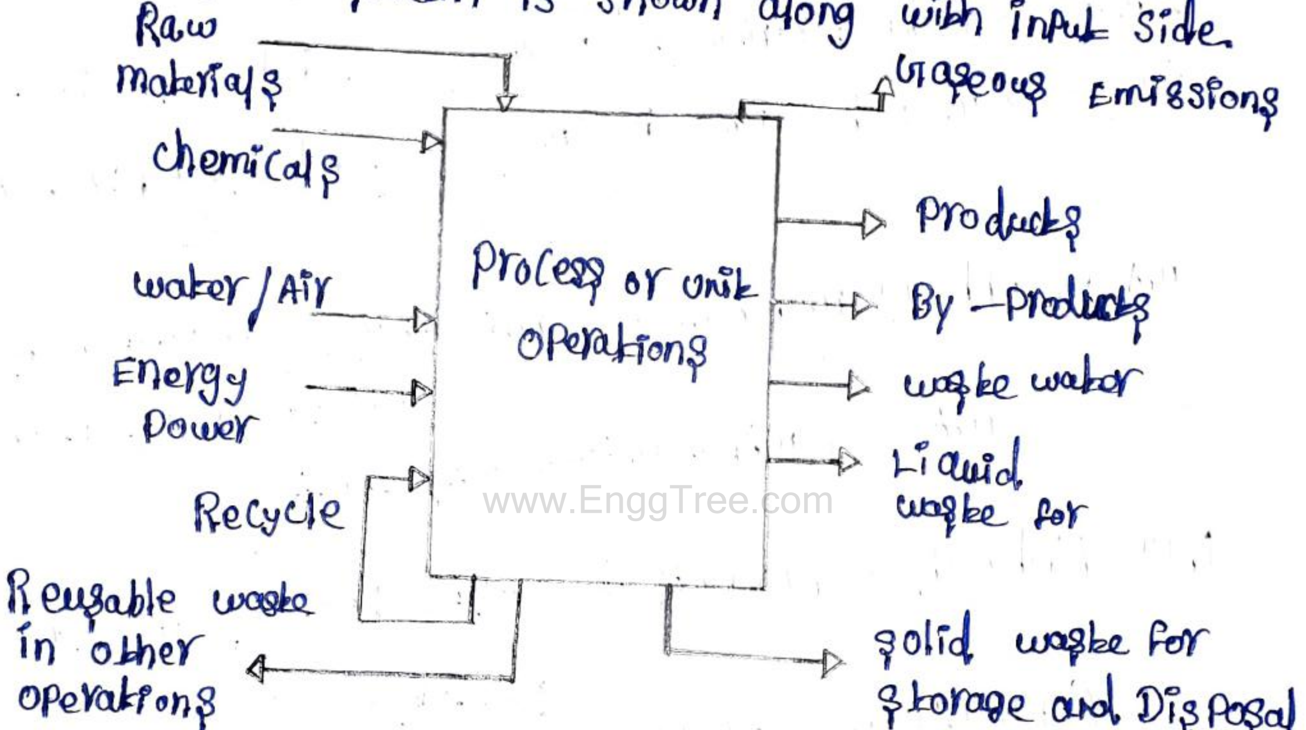
* The thermal camera unit converts electromagnetic thermal energy (IR) radiated object eletronic video signals.

* The amplified and transmitted via interconnected cable to a display monitor.

MATERIAL AND ENERGY BALANCE

1) Components of Material and Energy Balance

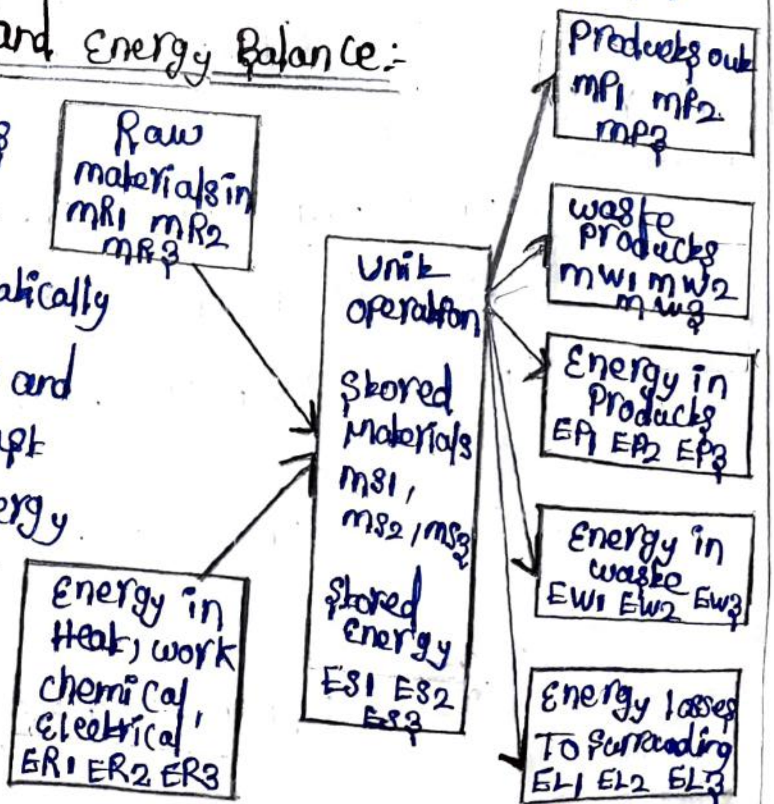
* Typical components of material and energy balance for a process or unit operation is shown in it may be noted that recycle stream is shown along with input side.



2) Basic principles of material and Energy Balance:-

* if the unit operation, whatever its nature is seen as a whole it may be represented diagrammatically as a box, as shown in The mass and energy going into the box must balance with the mass and energy coming out.

Mass in = mass out + Mass stored



Raw Materials = Products + wastes + stored Materials

$$\Sigma m_R = \Sigma m_p + \Sigma m_w + \Sigma m_s$$

$\Sigma m_R = \Sigma m_{R1} + \Sigma m_{R2} + \Sigma m_{R3}$ = Total Raw materials

$\Sigma m_p = \Sigma m_{p1} + \Sigma m_{p2} + \Sigma m_{p3}$ = Total Products

$\Sigma m_w = \Sigma m_{w1} + \Sigma m_{w2} + \Sigma m_{w3}$ = Total waste products

$\Sigma m_s = \Sigma m_{s1} + \Sigma m_{s2} + \Sigma m_{s3}$ = Total stored products

mA in entering materials = mA in the exit materials + mA stored in Plant

$$mA = (mA_p + mA_w + mA_s + mA_u)$$

Raw Materials = Products + waste products + stored products + Losses

(Energy in = Energy out + Energy stored)

$$\Sigma E_R = \Sigma E_P + \Sigma E_W + \Sigma E_L + \Sigma E_S$$

where:

$\Sigma E_R = E_{R1} + E_{R2} + E_{R3} +$ = Total Energy entering with raw materials

$\Sigma E_P = E_{P1} + E_{P2} + E_{P3} +$ = Total Energy leaving with products

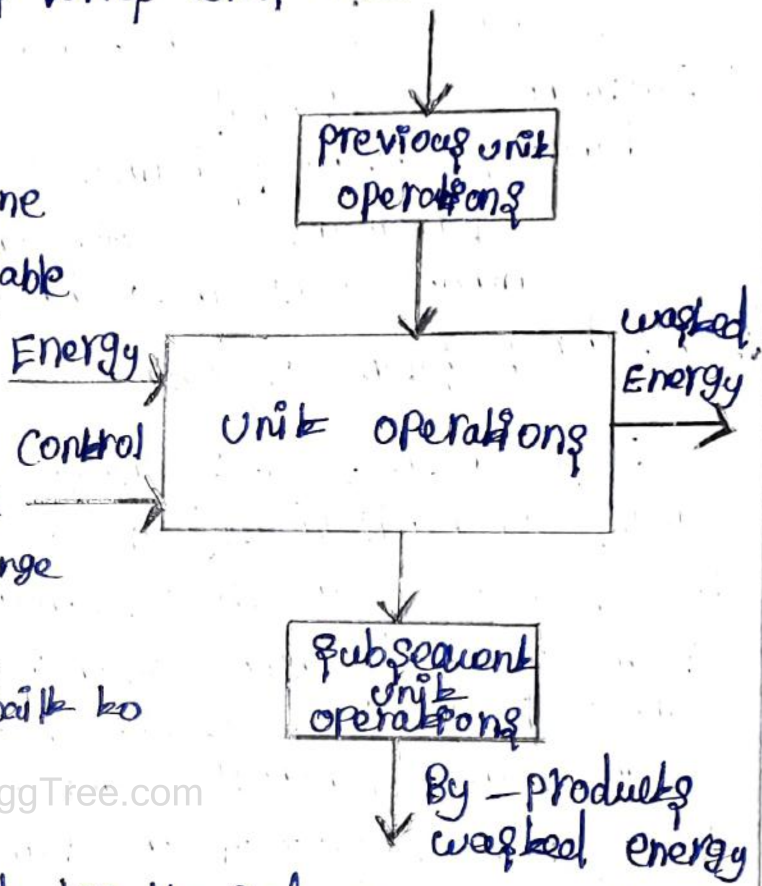
$\Sigma E_W = E_{W1} + E_{W2} + E_{W3} +$ = Total Energy leaving with waste materials

$\Sigma E_L = E_{L1} + E_{L2} + E_{L3}$ = Total Energy lost to surroundings

$\Sigma E_S = E_{S1} + E_{S2} + E_{S3} +$ = Total Energy stored

3.) Classification of processes

A) Based on how the process varies with time



Steady - state
* process is one where none of the process variable change with time

unsteady - state
* Process is one where the process variables change with time

B) Based on how the process was built to operate

a continuous process
* is one that has the feed streams and products streams moving into and out of the process all the time.
examples are oil refinery, distillation process etc.

a batch process
* is one where the feed streams are fed to the process to get it started. The feed material is then processed through various process steps and finished products are taken out at specific times.

4.) Material Balance:-

* Levels of Material Balance

1) The material balances can be developed at various level.

2) overall Material balance. This involves input and output streams for complete Plant.

3.) Section wise material balances: This involves M & E balances to be made for each section / department / cost centre. This would help to prioritise focus areas for efficiency improvement.

4.) Equipment-wise Material balances: Material balances for key equipment would help assess performance of equipment, which would in turn help identify energy and material losses.

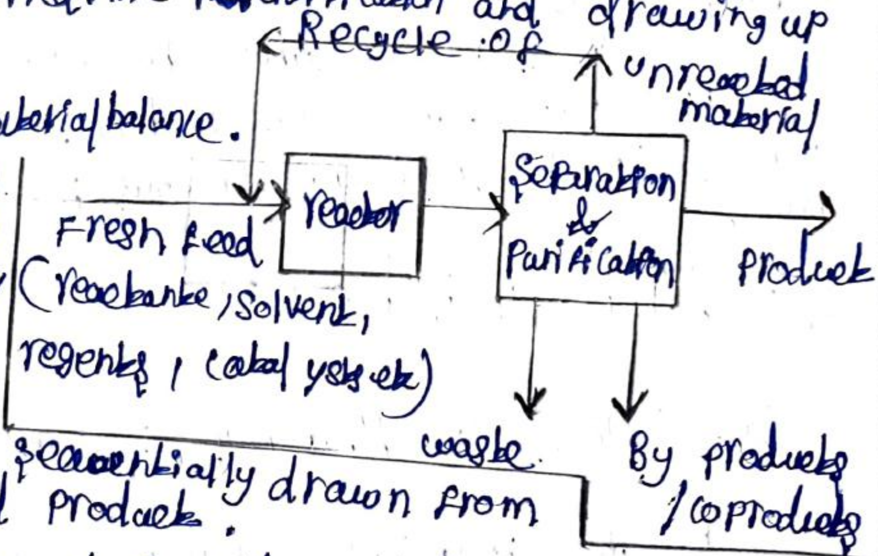
* Material Balance procedure:-

a) Define basis & unit: choose a basis of calculations on quantity (mass for batch process) or flow rate (mass per hour for continuous process) of one of the process streams.

* The weight / weight concentration is the weight of the solute divide by the total weight of the solution and is the fractional form of the percentage composition by weight.

* The mole fraction is the ratio of the number of moles of the solute to the total number of moles of all species present in the solution.

b) Draw a flowchart: Establish a boundary so that the flow streams in and out can be indentified. The identification and drawing up a unit operation / process in prerequisite for energy and material balance.



* inputs: of the process could include raw materials, water, steam, energy (electricity etc)

* process steps: should be sequentially drawn from raw material to finished product.

* wastes: by products could include solids, water, chemicals, energy etc. For each process steps (unit operation) as well as for an entire plant.

* output: of the process is the final product produced in the plant

Financial Analysis Techniques:

* Investment in energy efficiency is not different from any other of financial management.
* It have three types:
  * Payback period
  * Net present value
  * Return on investment

Payback period;

* Is a measure of how long it will be before the investment recovers itself. This can determine how long the financing term needs to be there.

Equation:

$$\text{Simple payback period} = \frac{\text{capital cost}}{\text{Annual net savings}}$$

Advantages:

* A shorter payback generally indicates a more attractive investment.

Limitations:

* The payback period does not consider the savings that are accrued after the payback period has finished.

ROI

=) Return on investment.

* ROI express the annual return expected from a project as a percentage of capital (or) initial investment.
* ROI is an inverse of payback period.

$$ROI = \frac{\text{Annual net cash flow}}{\text{capital cost}} \times 100.$$

Advantages:

* Simple method
* Easy to calculate

Limitations of ROI

* It does not take account the time of value of money.
* It does not account for the variable nature of annual net cash flows.

Time value of money

* This " method which varies cash flows are related is called discounting.

FORMULA:

$F_v = NPV(1+i)^n$ (or) $NPV = FV/(1+i)^n$

where,

FV = Future value cash flow

NPV = Net value "

i = Interest

n = Number of years.

Net present value method;

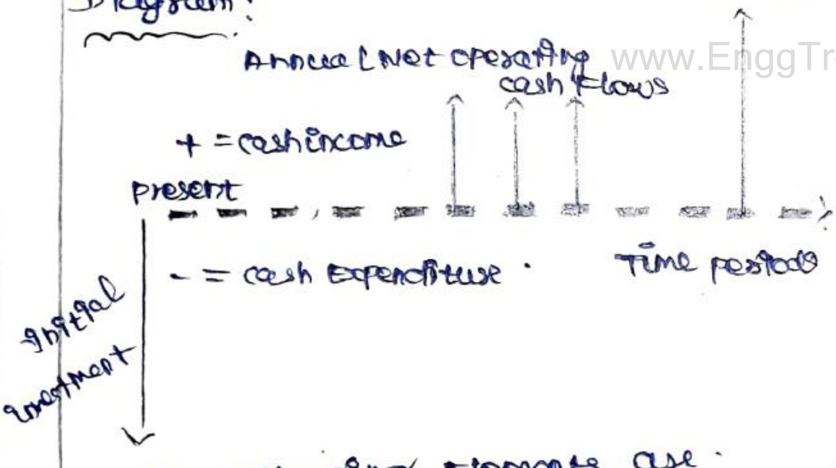
* The Net present value method considers the time value of money
* The present value of any Future cash Flow
* The NPV method calculates the present value of all yearly cash Flows
* That is capital cost & Net savings.

Advantages:

* It takes into account the time value of money.
* It considers the cash Flow stream.

Cash Flow:

Diagram:



* The Following Elements are.
  * Initial capital cost
  * Net operating cash Flow
  * Economic life.
  * salvage value.

Micro Factors:

* operating Expenses
* capital structure
* cost of debt, equity
* changing the project life.

MACRO FACTORS:

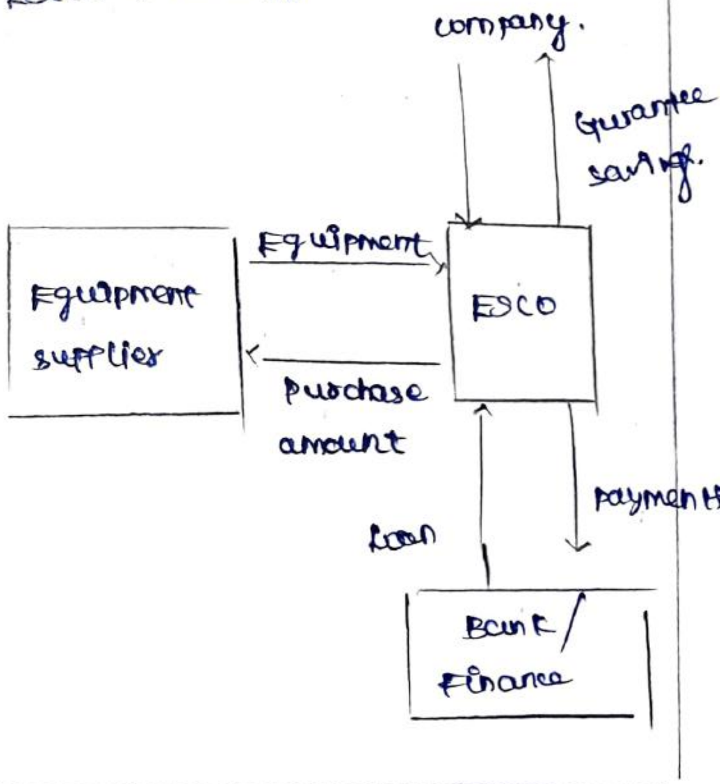
* change in Interest Rates
* change in tax rates
* change in depreciation Rates
* Energy price change
* Technology changes.

Financing options:

* Debut, * Equity * Title
* capital, * Retained

Role of ESCOs:

ESCOs ⇒ Energy service companies



Performance Evaluation of Boiler:-

1. Boiler Efficiency:-

Thermal efficiency of boiler is the percentage of heat input that is effectively utilised to generate steam.

They are two types boiler efficiency:-

1. Direct method
2. Indirect method

1. The Direct method where the energy gain of the working fluid (water and steam) is compared with energy content of the boiler fuel.

2. The indirect method where the efficiency is the difference between the losses and the energy input.

1. Direct Method:-

* It is also known as "input-output method" due to fact that it needs only the useful output (steam) and the heat input (i.e fuel) for evaluating the efficiency.

* $$\text{Boiler efficiency} = \frac{\text{Heat output}}{\text{Heat input}} \times 100$$

Parameters to be monitored for calculation of boiler efficiency by direct method are:

* Quantity of steam generator per hour (Q) in kg/hr.
* Quantity of fuel used per hour (q) in kg/hr.
* The working pressure (in $kg/cm^2(g)$) and superheat temperature (°C).
* The temperature of feed water (°C).
* Type of fuel and gross calorific value of the fuel (GCV) in kCal/kg of fuel.

* $$\text{Boiler efficiency} (\eta) = \frac{Q \times (h_g - h_f)}{q \times GCV} \times 100$$

where;

h_g - Enthalpy of saturated steam in kCal/kg of steam.

h_f - Enthalpy of feed water in kCal/kg of water.

Advantages of direct method:-

* It can quickly evaluate the efficiency of boiler.
* A few parameters for computation.

DisAdvantages of direct method:-

* It does not operator as to why efficiency of system is lower.
* It does not various losses accountable for various efficiency levels.

2. InDirect Method:-

* Indirect method is called as heat loss method.
* The efficiency can be arrived at, by subtracting the heat loss fractions from 100.
* It include blowdown loss in efficiency determination process.

* the principle losses of heat that occurs in a boiler are due to:
  1. dry flue gas
  2. moisture in fuel and combustion air
  3. to combustion of hydrogen
  4. radiation
  5. unburnt.

* The data required for calculation of boiler efficiency using indirect method are:
  1. ultimate analysis of fuel (H_2, O_2, S, C, moisture content, ash content).
  2. Percentage of oxygen or CO_2 in the flue gas.
  3. Flue gas temperature in °C (T_f)
  4. Ambient temperature in °C (Ta).

GCV of fuel in Kcal/kg.

GCV of ash in Kcal/kg (in a case of solid fuels).

Boiler Evaporation Ratio:

* Heat loss due to dry fuel gas - 9.14%.
* Heat loss due to evaporation of water formed due to H_2 in fuel - 7.10%.
* Heat loss due to moisture present in air - 0.322%.
* Heat loss due to radiation and other unaccounted loss - 2%.
* Boiler Efficiency = 100 - [9.14 + 7.10 + 0.332 + 2]
  = 100 - 18.56 = 81% (app).

* Evaporation Ratio = Heat utilised for steam generation / heat addition to the steam.
  = 10900 × 0.83 / (660 - 60)
  = 14.11

Boiler Evaporation Ratio:

Evaporation ratio means kilogram of steam generated per kilogram of fuel consumed.

Type example:-

Coal fired boiler - 6

oil fired boiler - 13

i.e. 1kg of coal can generate 6kg of steam.

1kg of oil can generate 13kg of steam.

It will depend upon type of boiler.

Types Of Boilers:-

they are many different types of boilers ~~...~~ in namely;

1. Fire tube Boiler
2. water Tube Boiler
3. Package boiler.
4. stoker-fired Boiler.
5. Pulverised Fuel Boiler.
6. Fluidised Bed Combustion (FBC) Boiler.

1. Fire tube Boilers:-

* A long steel tubes are hot gases from a around the water to be converted to steam circulates.

* Fire tube Boilers are typically, have a lower initial cost.

* It is more fuel efficient and easier to operate a capacities 25 tons/hr. Pressure of 17.5 kg/cm².

* the gases turn from 180 degrees and pass back through the shell.

2. Water Tube Boiler:-

* the water passing through the tubes and the hot gases passing out side the tube.

* the steam capacities and pressures, and have higher efficiencies than fire tube boilers.

* the high-pressure, high-energy steam, including steam turbines power generation.

* water tube boilers make them highly favourable in process industries including chemical manufacturing, pulp and paper manufacturing and refining.

* water-tube boilers account for the majority of boiler capacity.

3. Packaged Boiler:-

* Small combustion space and high heat release rate resulting in faster evaporation.

* large number of small diameter tubes leading to good convective heat transfer.

* number of passes resulting in better overall heat transfer.

* higher thermal efficiency levels compared with other boilers.

4. Stoker - fired Boilers:-

* the method of feeding fuel to furnance and the type of grate the main classifications

1. chain-grate or travelling-grate stoker.
2. spreader stoker.

1. Chain-grate or travelling-grate stoker boiler.

* Coal is fed onto one end of a moving steel chain grate.

* the length of the furnance, the coal burns before dropping off at the end as ash.

* the grate, air dampers and baffles, to ensure clean combustion leaving minimum of unburnt carbon in the ash.

2. Spreader stoker:-

* Spreader stokers utilise a combination of suspension burning and grate burning.

* the coal is continually fed into the furnace above a burning bed of coal.
* The coal fines are burned in suspension.
* the spreader stoker is favoured over other types of stokers in many industrial applications.

5. Pulverised Fuel Boiler:-

* the larger industrial water-tube boilers also the pulverised fuel.
* there are thousand of units around the world, over 90% of coal-fired capacity.
* the combustion air into the boiler plant through a series of burner nozzles.
* Particle residences time in boiler typically 2 to 5 seconds, small enough for complete combustion to have place during this time.

6. Fluidised Bed Combustion (FBC) Boiler:-

* FBC => Fluidised Bed combustion
* The particles are undisturbed at low velocity
* It have the ignition temperature of the coal.
* proper air distribution is vital for maintaining uniform fluidisation across the bed

1. Proper Selection, Operation and Maintenance Of Steam Traps:-

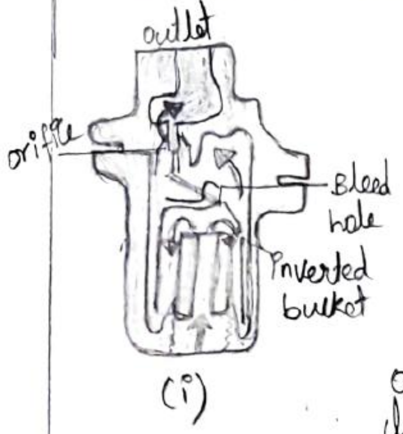
* The steam traps is to obtain fast heating and product of equipment.
* the steam lines and equipment free of condenste, air and non-condensable gases.

*Function Of Steam Traps:-

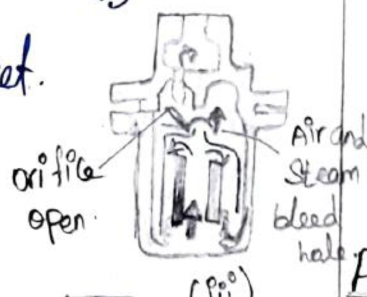
* It is formed to a discharge condenste.
* Not to allow steam to escape.
* To capable of discharge air and other incondensable gases.

*Types Of Steam Traps:-

1. thermostatic (operated by changes in fluid temperature).
   * A thermostatic trap will pass condenste when it lower temperature insensed.
   * the temperature increases and trap closes.
2. Mechanical (operated by changes in fluid density).
3. Thermodynamic (operated by changes in fluid density).
4. Inverted Bucket.



(i)



(ii)

(iii)

Advantages Of The Inverted bucket Steam trap:-

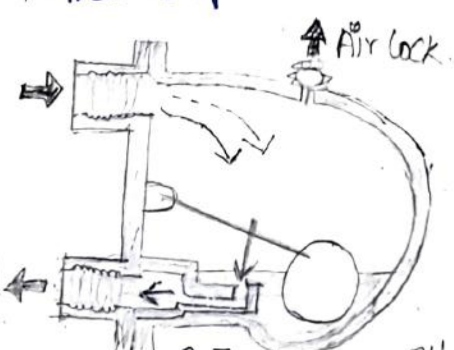
i) Inverted bucket steam trap to withstand high pressures.
ii) Like a float-thermostatic steam trap.

DisAdvantage Of Inverted bucket Steam trap:-

i) It can only discharge air very slowly.
ii) The steam can be wasted through the outlet value.

*Float And Thermostatic:-

* The ball float type traps operates in sensing.
* the trap will cause lifting the value off it seat and releasing condenste.
* the value is always flooded and neither steam nor air will pass through it.
* the trap is also handling condensate.



A Float trap with air lock.

Advantages of float trap-thermostatic steam trap.

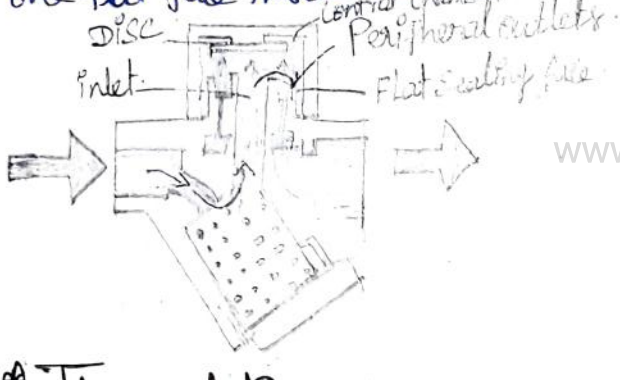
i) It has a large capacity for its size.
ii) It is resistance to water hammer.

Dis Advantage of Float-thermostatic steam trap:-

i) the float type trap can be damaged by severe freezing the body well lagged.
ii) It required to allow operation over varying pressure ranges.

* Thermodynamic:-

* The thermodynamic trap is an extremely robust trap operation.
* The trap operates by means of the dynamic effect of flash steam passes through the trap.
* the only moving part is the disc about the flat face inside the control chamber or cap.



* Thermostatic:-

* the temperature of saturated steam is determined by its pressure.
* the producing condensate at steam temperature.
* trap will pass condensate when this lower temperature is sensed.
* Thermostatic traps are small, light weight, and compact.

Thermostatic Trap.

* Bimetallic type:-

* the Bimetallic steam traps operate on the same principle as heating thermostat.
* the wafer connected to a valve bends or distorts in change temperature.
* The valve closed off against a seat at steam is present.

Advantages:-

1. To damage the resistance from water hammer.
2. A small size for condensate loads they handle.

Dis Advantages:-

1. A particular steam operating pressure
2. The trap is used for a lower pressure discharge live steam.

Installation Of Steam Traps:-

Properties to be considered:-

1. Drain Point
2. Pipe sizing
3. Air binding
4. Steam locking
5. Group trapping Vs. Individual trapping
6. Drift
7. Water hammer
8. Lifting the condensate.

Drain Point:-

* the Condensate Can easily flow into the trap.
* It is useless to provide a 15mm drain hole in the bottom of a 150mm steam main.
* The Condensate will be carried away by the steam velocity.
* the condensate Can drop of at least 100mm diameter is needed such cases.

2. Pipe Sizing:-

* the steam traps should be of adequate size.
* the excessive resistance to flow in the Condensate Pipe work.
* the trap will excessive back Pressures in certain circumstances.

3. Air binding:-

* the trap space the stam, the trap function cases.
* It Provision is made for removing air either by way of steam trap.
* A Long time in warming up and may never give its full output.

4. Steam Locking:-

* Air binding except that the trap is locked steam instead of air.
* the typical example is a drying cylinder.
* A steam lock release arrangement.

5. Group trapping Vs. Individual trapping:-

* A Connecting several units to a Common Steam trap is a group trapping.
* the water-logging and loss of output.
* the steam space own trap and then Connect the outlets of Common Condensate return main.

6. Dirt:-

* Drit is the Common of steam traps of the Causes of many failures.
* the inside of the Pipe work and fittings, are exposed to Corrosive Condensate Can rusted.

7. Water Hammer:-

* the steam System is Caused by Condensate Collection in the plant or Pipe work picked up fast moving steam and Carried along.
* the water hammer Can be eliminated by positioning the pipes so that is a continous slop in direction of flow.

8. Lifting the Condensate:-

* It is necessary to lift condensate a steam trap to a higher level Condensate return line.
* The condensate will rise up the lifting Pipe work.
* The steam Pressure upstream of the trap is higher than the Pressure downstream of the trap.

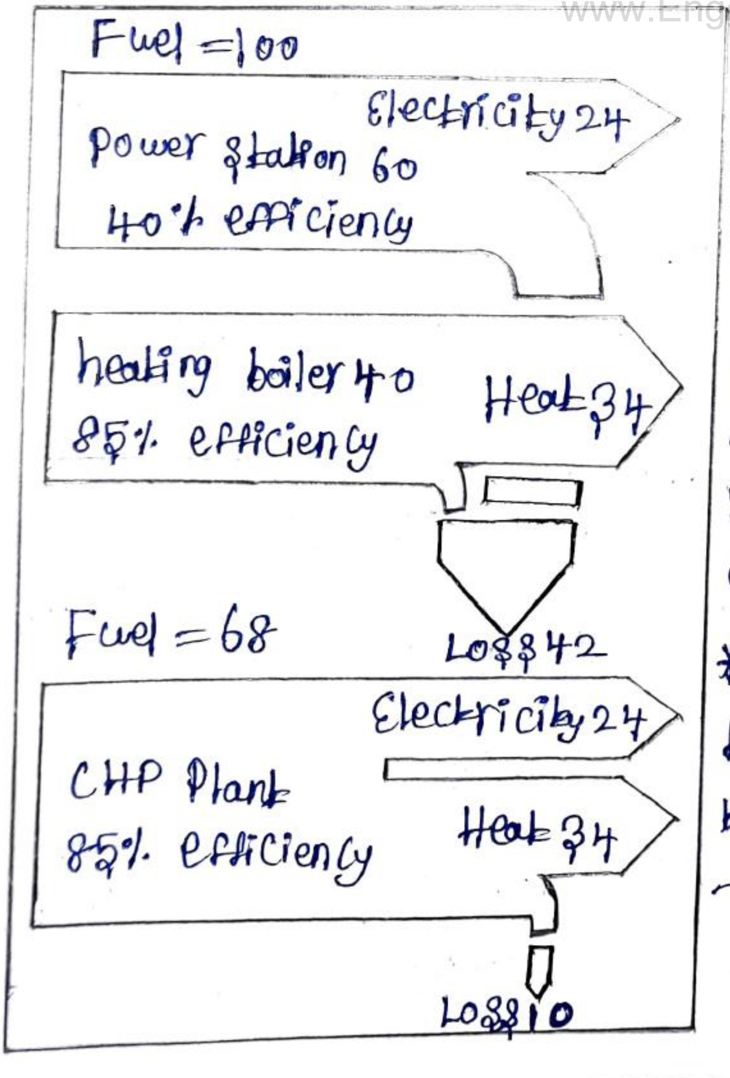
COGENERATION

Principle of Cogeneration :-

* Cogeneration or combined Heat and power (CHP) is defined as the sequential generation of two different forms of useful energy from a single primary energy source, typically mechanical energy and thermal energy.

* Mechanical energy may be used either to drive an alternator for producing electricity, or rotating equipment such as motor, compressor, pump or fan for delivering various services

* The overall efficiency of energy use in cogeneration mode can be up to 85 per cent and above in some cases.



* For example in the industry requires 24 units of electrical energy and units of heat energy

* It can be observed that the losses, which were 42 units in the case of, separate heat and power has reduced to 10 units in cogeneration mode.

* Along with the saving of fossil fuels, cogeneration also allows to reduce the emission of green-house gases (particularly CO_2 emission)

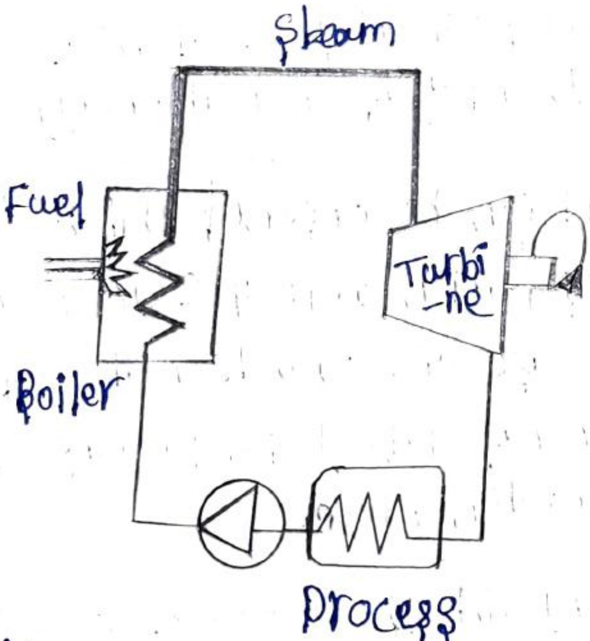
Technical options for cogeneration

* Cogeneration technologies that have been widely commercialized include extraction/back pressure steam turbines, gas turbine with heat recovery boiler (with or without bottoming steam turbine) and reciprocating engines with heat recovery boiler.

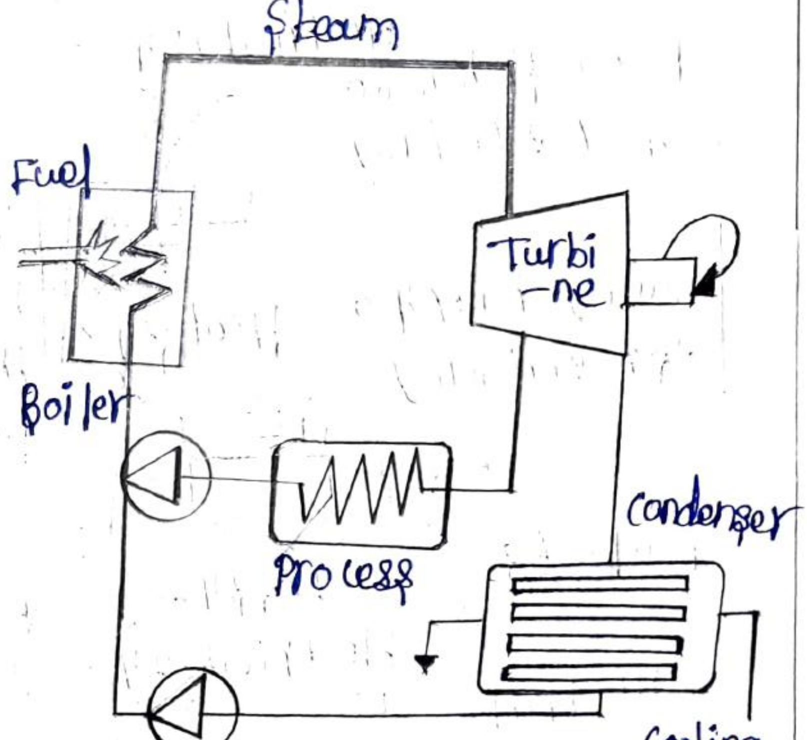
1) Steam turbine cogeneration systems

* The two types of steam turbines most widely used are the back pressure and the extraction-condensing types. The choice between back pressure turbine and extraction-condensing turbine depends mainly on the quantities of power and heat, quality of heat, and economic factors.

* The extraction points of steam from the turbine could be more than one, depending on the temperature levels of heat required by the processes.



(i) Back-Pressure Turbine

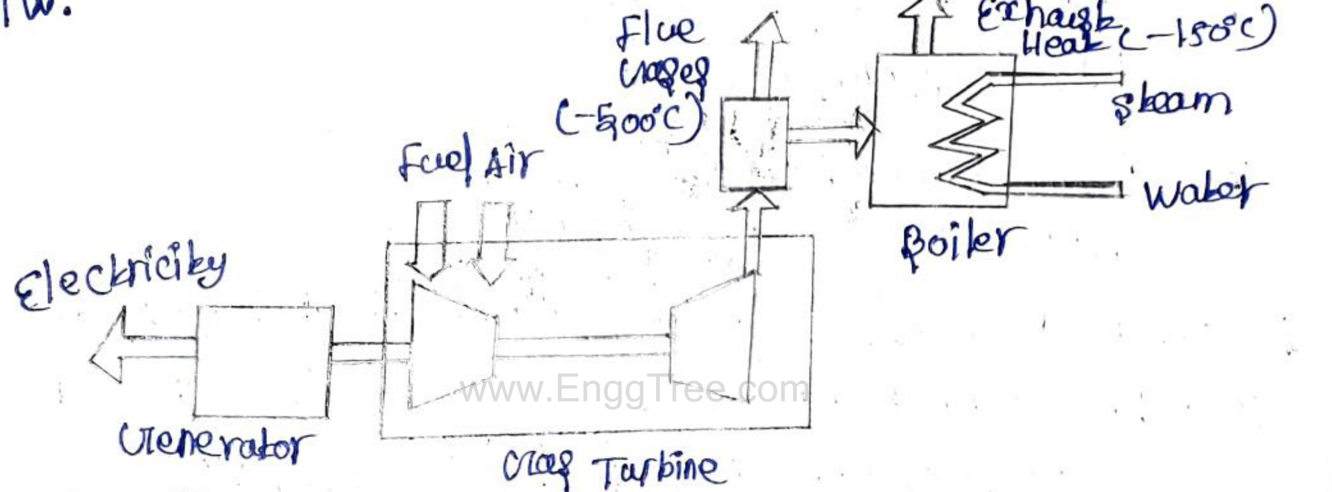


(ii) Extraction-Condensing Turbine

ii) Gas turbine cogeneration systems

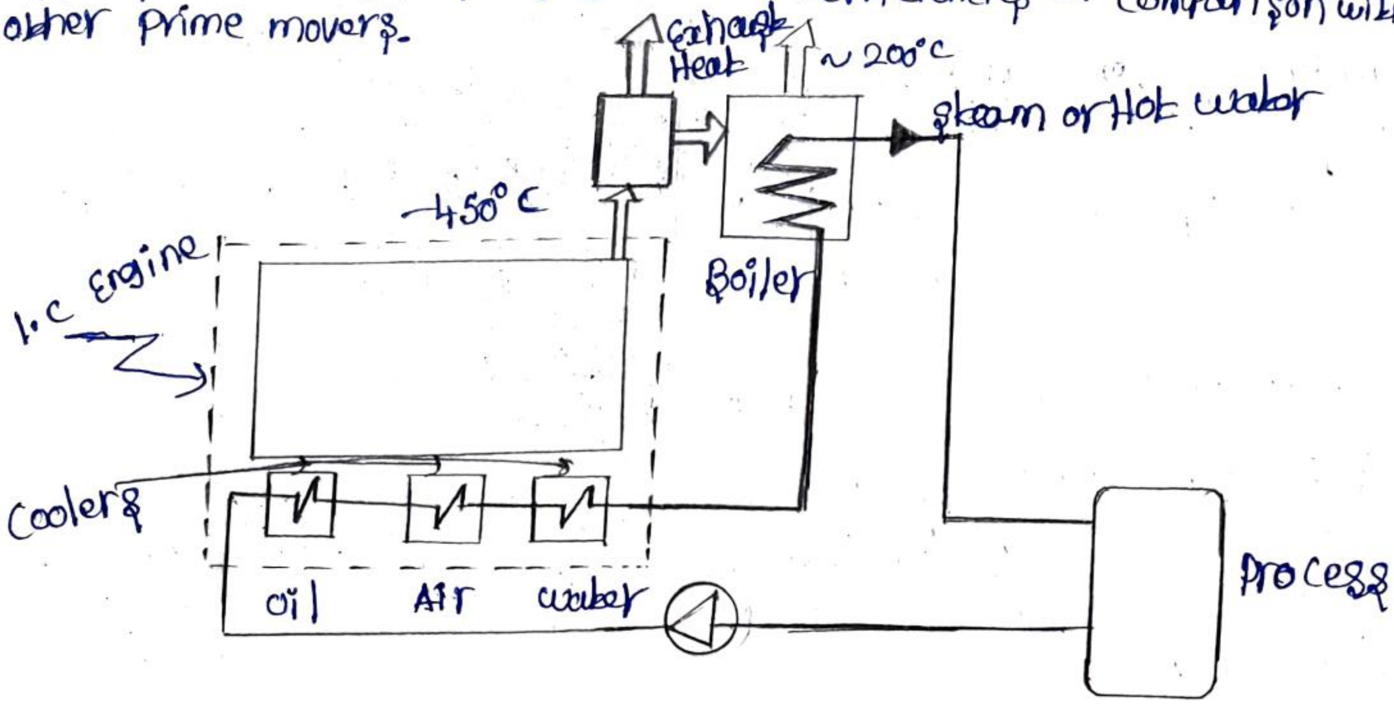
* Gas turbine cogeneration systems can produce all or a part of the energy requirement of the site, and the energy released at high temperature in the exhaust stack can be recovered for various heating and cooling applications.

* Though natural gas is most commonly used, other fuels such as light fuel oil or diesel can also be employed. The typical range of gas turbines varies from a fraction of a MW to around 100 MW.



3) Reciprocating engine cogeneration systems

* Also known as internal combustion (I.C) engines, these cogeneration systems have high power generation efficiencies in comparison with other prime movers.



* Though diesel has been the most common fuel in the past, the prime movers can also operate with heavy fuel oil or natural gas.
* These machines are ideal for intermittent operation and their performance is not as sensitive to the changes in ambient temperatures as the gas turbines.

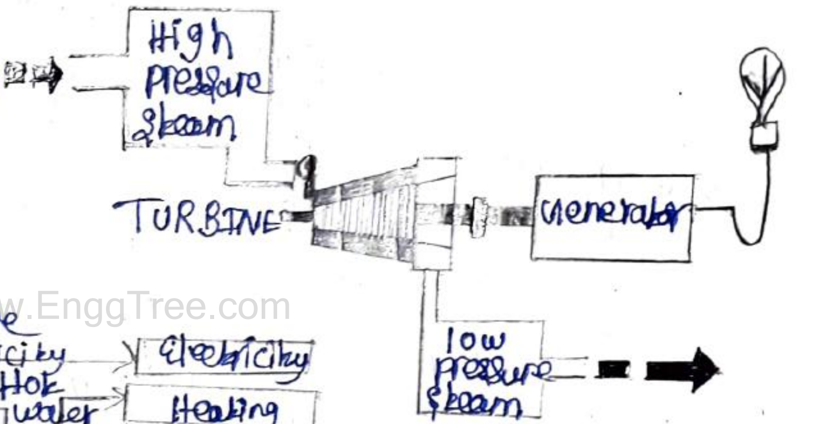
Classification of cogeneration systems

1) Topping cycle. 2) bottoming cycle

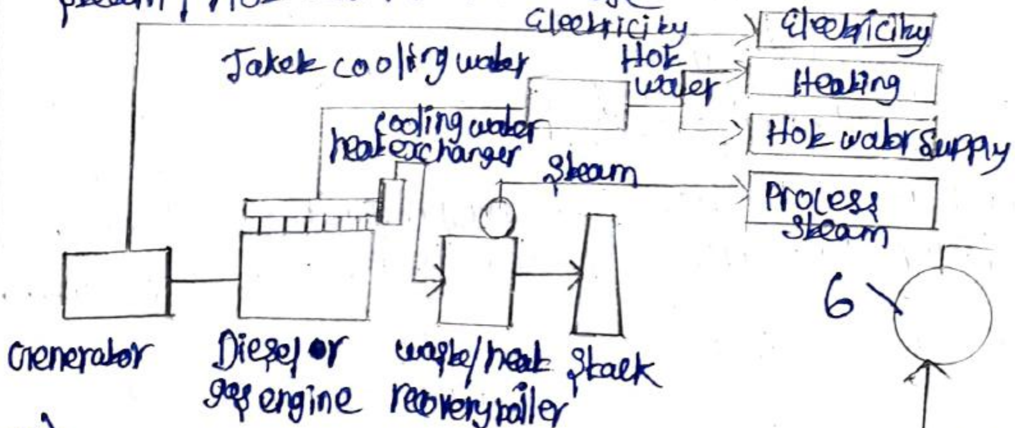
1) Topping cycle:-

*) combined-cycle topping system

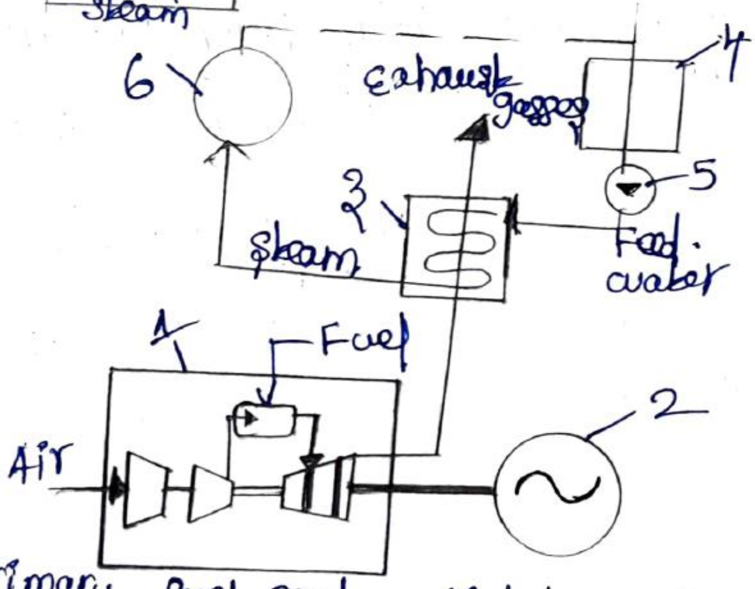
*) steam-turbine topping system.



*) converted to process steam / hot water for further use



*) gas turbine topping system



2) Bottoming cycle:-

* In a bottoming cycle, the primary fuel produces high temperature thermal energy and the heat rejected from the process is used to generate power through a recovery boiler and a turbine generator.

Benefits Of Waste Heat Recovery

* Waste heat Recovery Can be Classified in two categories Namely.

1. Direct Benefits:-

* A direct effect on the efficiency on the Processor.

* It is reduced the utility consumption of Costs, and Process Cost.

2. INDirect Benefits:-

* It is Reduction in Pollution.

* It is Reduction in equipment sizes.

* It Reduction in auxiliary energy Consumption:-

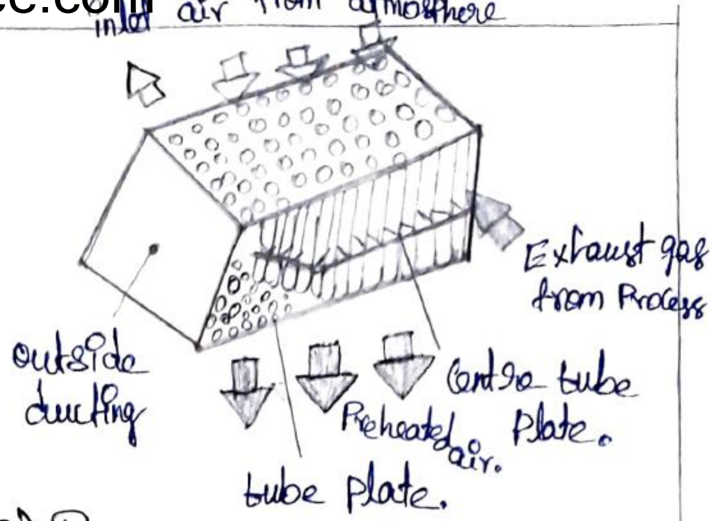
Commercial Waste Heat Recovery Devices:-

i) Recuperators:-

* Duct or tubes carry the air for Combustion to be Pre-heated.

* the other side contains the waste heat Steam.

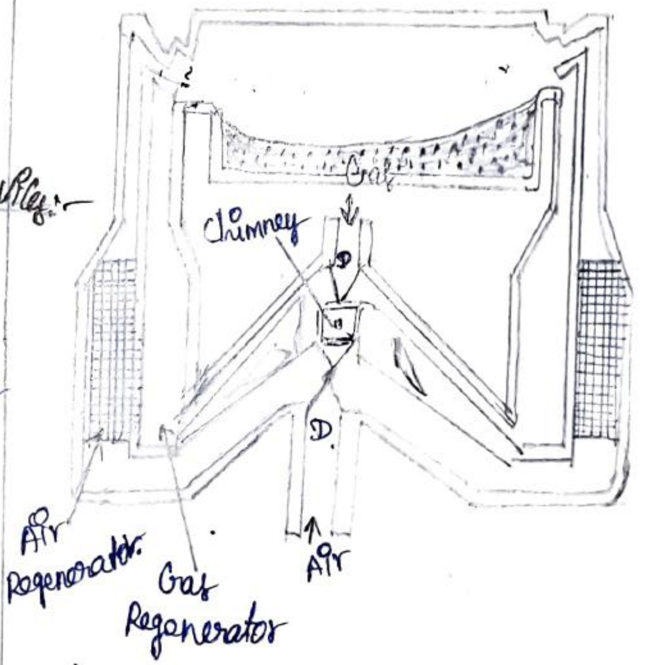
* A recuperator for recovering waste heat from fuel gases.



ii) Regenerator:-

* Perferable for a large Capacities has been very widely used in glass and Steel melting furnances.

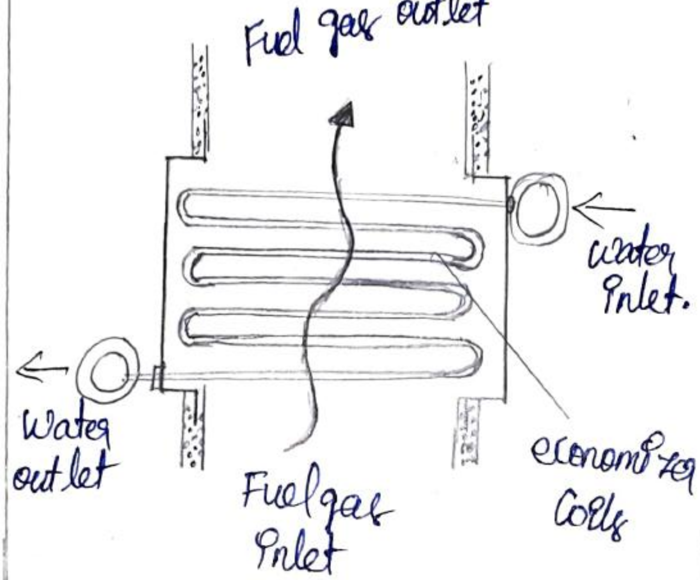
* the Size of regenerator, time between reversal, thickness of bricks, conductivity of heat storage ratio of the brick.



iii) Economiser:-

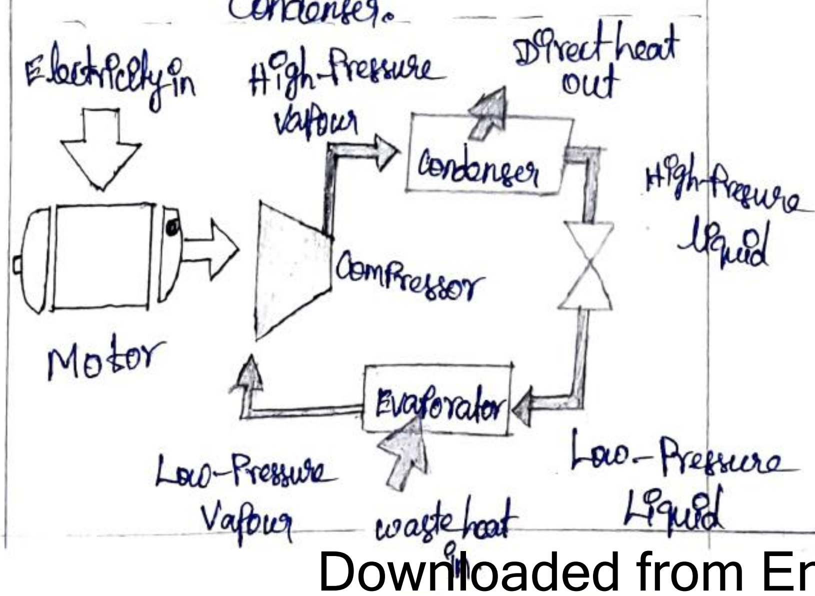
* In Case of boiler System, economiser Can be Provided utilize the flue gase of heat for Pre-heating the boiler feed water.

* The waste heat is used to heat Combustion air.
* there is a corresponding reduction in the fuel of the boiler.



iv) Heat Pumps:-

* the heat source to boil the circulating substance.
* It pressure and temperature to a level of energy becomes available.
* The heat is delivered to the Condenser.



FURNACES

Types and classification of Different Furnaces

*) Based on the method of generating heat, furnaces are broadly classified into two types namely combustion type (using fuels) and electric type.

*) Based on the mode of charging of material furnaces can be classified as (i) intermittent or Batch type furnace or Periodical furnace (ii) continuous furnace

Characteristics of an Efficient Furnace:-

*) Furnace should be designed so that in a given time, as much of material as possible can be heated to a uniform temperature as possible with the least possible fuel and labour. To achieve this end, the following parameters can be considered.

Furnace Energy Supply:-

*) Since the products of flue gases directly contact the stock, type of fuel chosen is of importance.

Oil Fired Furnace:-

*) Furnace oil is the major fuel used in oil fired furnaces, especially for reheating and heat treatment of materials.

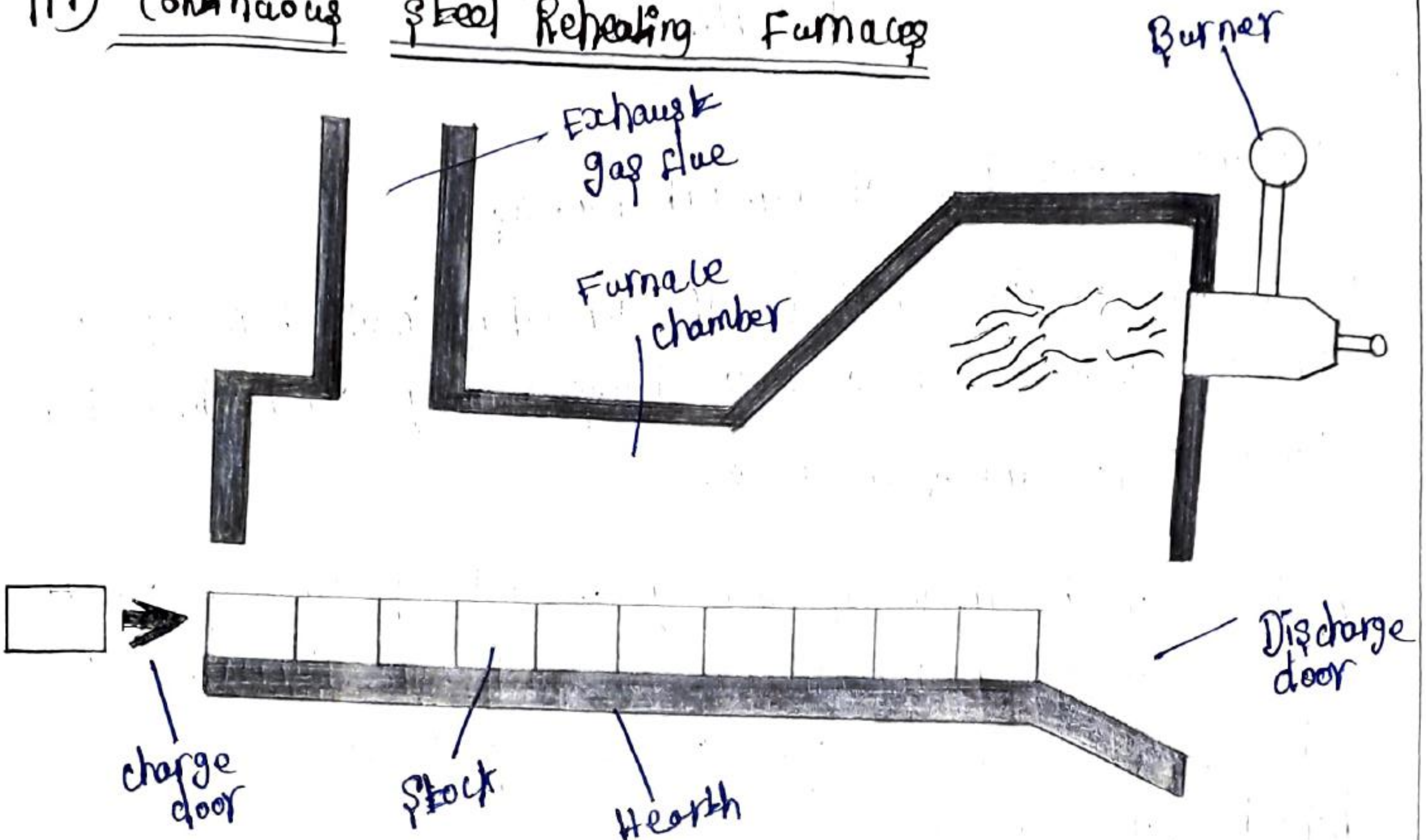
Typical Furnace System:-

i) Forging Furnaces

ii) Rerolling Mill Furnace

(a) Batch type (b) Continuous Pusher Type

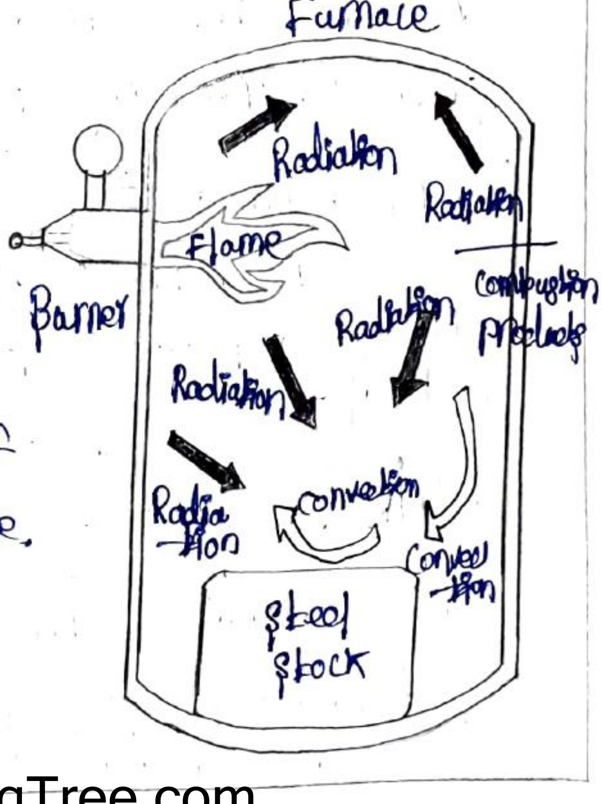
iii) Continuous Steel Reheating Furnaces



*) A refractory chamber constructed of insulating materials for retaining heat at the high operating temperatures.

*) A hearth to support or carry the steel. This can consist of refractory materials or an arrangement of metallic supports that may be water-cooled.

Heat Transfer in Furnaces :-



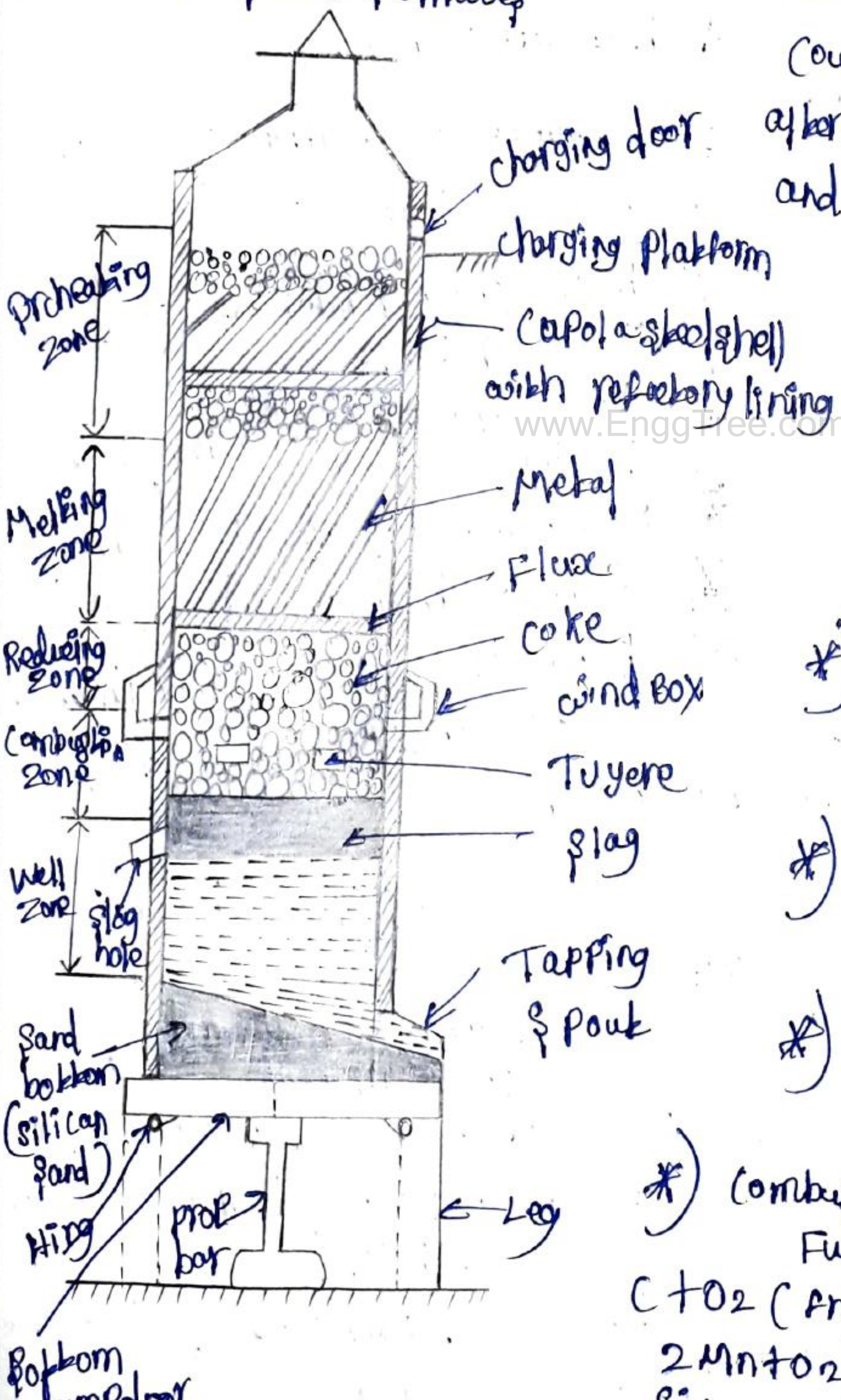
*) Radiation from the flame, hot combustion products and the furnace walls and roof

*) Convection due to the movement of hot gases over the stock surface.

Types of continuous Reheating Furnace :-

i) Pusher Type Furnaces
ii) walking Hearth Furnaces
iii) Rotary hearth Furnace
iv) continuous Recirculating Bogie type Furnaces
v) walking Beam Furnaces
vi) Cupola Furnace

*) A cupola furnace is tall cylindrical melting device used in foundries to melt pig iron, cast iron, foundry returns. The charge used in coupola furnace consists of alternate layers of coke flux and metal (iron).



*) Melting in cupola Furnace

*) zones of cupola Furnace

*) Well zone in cupola Furnace

*) combustion zone in cupola Furnace

$C + O_2$ (from air) → CO_2 + heat

$2Mn + O_2$ → $2MnO$ + heat

$Si + O_2$ → SiO_2 + heat

$CO_2 + C$ (coke) → $2CO$ - heat

Melting zone in Cupola Furnace:

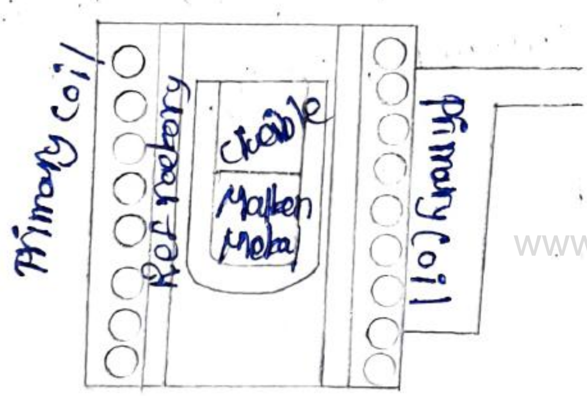
$3Fe + 2CO \rightarrow Fe_3C + CO_2$

*) Preheating zone in Cupola Furnace

*) Hot Blast Cupola

vii) induction Furnaces

*) Coreless Induction Furnace



Furnace efficiency:

$$\text{Efficiency\%} = \frac{\text{Theoretical total heat required for melting } (H_T) \text{ kWh}}{\text{Actual electricity consumed for melting } (H_A) \text{, kWh}} \times 100$$

Theoretical heat required for melting (H_T)

$$\text{Heat required for melting } H_1, \text{ kWh} = \frac{W_m \times (C_p \times (T_2 - T_1) + L_h)}{3600}$$

*) Distribution of losses in induction furnace

*) Factors affecting the furnace efficiency

1) Due to poor maintenance the total production stops sometimes. Higher breakdown results in increasing the cost of production.

*) Hot air generator

Performance Evaluation of a Typical Fuel Fired Furnace:

*) High stack temperature and excess air levels

*) Low capacity utilization/hearth loading.

*) Radiation losses due to opening.

*) Surface heat losses.

*) Batch operation involving heating, cooling and soaking cycles.

Direct method:

$$Q_s = m \times C_p \times (t_1 - t_2)$$

where

Q_s = Quantity of heat imparted to the stock in kcal

m = weight of the stock in kg

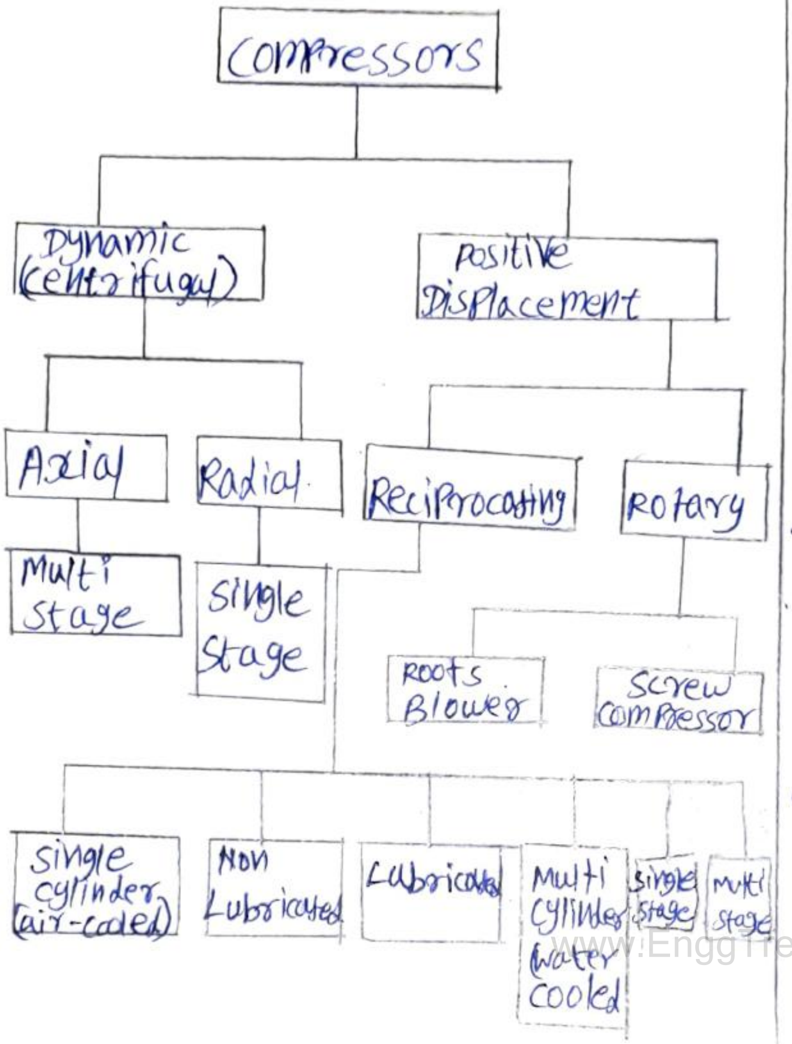
C_p = mean specific heat of stock in kcal/kg°C

t_1 = final temperature of stock desired °C

t_2 = initial temperature of the stock before it enters the furnace

Compressors:

Types of compressor:



Efficiency of a compressor:

Gas equation

$PV = mRT$

Where

P = Pressure

V = Volume

m = specific mass

R = constant

T = Absolute Temperature

Isothermal power (kW)

$= P_1 \times Q_1 \times \log_e r / 36.7$

Where,

P_1 = Absolute intake pressure kg/cm^2

Q_1 = Free air delivered m^3/hr

r = Pressure ratio P_2/P_1

Volumetric Efficiency

= Free air delivered (m^3/min) / compressor displacement

Compressor Displacement

$= \frac{\pi}{4} \times D^2 \times L \times S \times \chi \times n$

D = cylinder bore (metre)

L = cylinder stroke (metre)

S = compressor speed in rpm

χ = 1 for single acting and 2 for double acting cylinders

n = No. of cylinders

Compressed Air system components:

Intake Air filters:

They prevent dust from entering the compressor.

Example: 5 micron filter can prevent dust particles above 5 microns size.

Inter stage coolers:

compression of the air temperature increases used in multistage compressor.

Afeter coolers:

They are used to remove moisture.

Air Dryers:

Moisture remove from the various locations in pipe line.

Moisture Drain Traps:

Remove moisture in compressed air.

types:

- Manual drain cocks
- Timer based/automatic drain valves etc

Receivers:

Reducing pressure variations from the compressor

Efficient operation of compressor:

- one important issue is the centralised compressor house or disbution system.
- There is no heat sarce is surrounding the compressor.
- Dust free air intake is most important.
- Dry Air is equally important.
- The cooling water circuit is properly maintained.

Capacity Assessment of a Compressor:

Actual Free air discharge (Q)

$$Q = \frac{P_2 - P_1}{P_0} \times \frac{V}{T} \ Nm^3/minute$$

Where,

P_2 = Final Pressure after filling

P_1 = Initial Pressure after bleeding

P_0 = Atmospheric Pressure

V = storage Volume

T = Time

Factors Affecting Performance and Efficiency:

- Prevention of small leakages is economically benifit.
- Another case is the wrong application.
- Many times compressed Air is required for aeration.
- Another consideration is Pnematic conveying.

Types of Refrigeration System

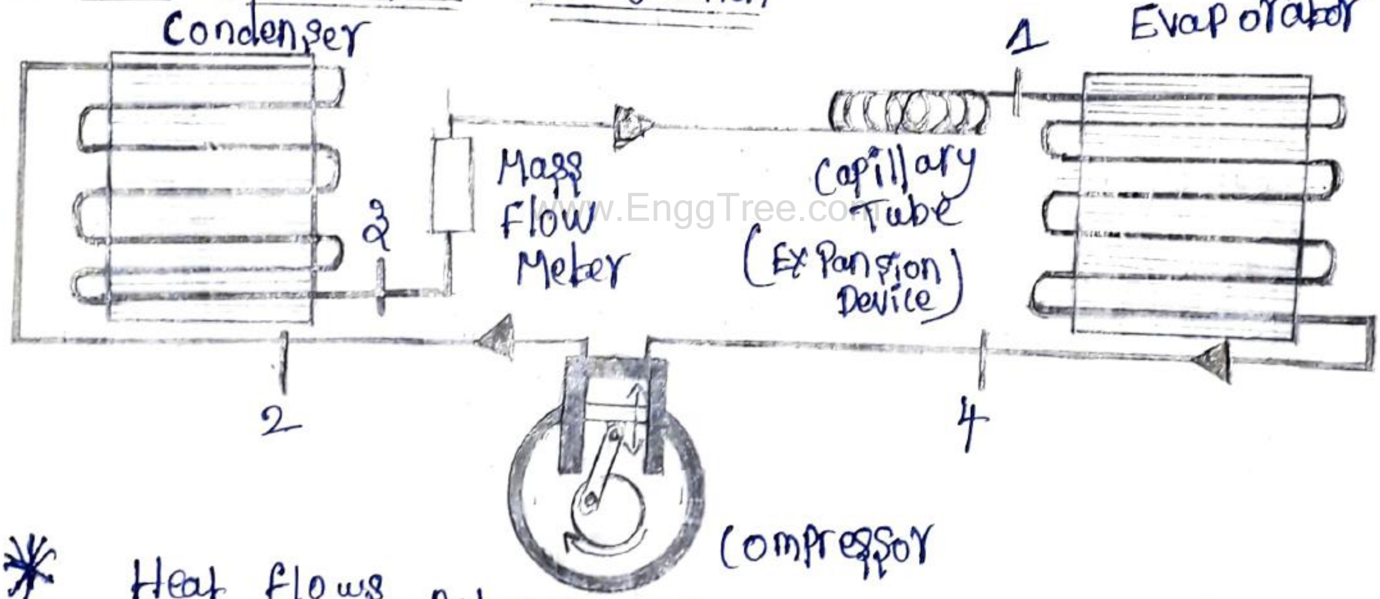
The two principle types of refrigeration plants found in industry include

1) Vapour compression Refrigeration (VCR) and
2) Vapour Absorption Refrigeration (VAR)

*) VCR uses mechanical energy as the driving force for refrigeration.

*) VAR uses thermal energy as the driving force for refrigeration.

1) Vapour compression Refrigeration



* Heat flows naturally from a hotter to colder body. In refrigeration system, the opposite must occur i.e, heat flows from a colder to hotter body. This is achieved by using a substance called a refrigerant which absorbs heat and hence boils or evaporates at a low pressure to form a gas.

* This gas is then compressed to a higher pressure, such that it transfers the heat it has gained to ambient air or water and turns back (condenses) into a liquid.

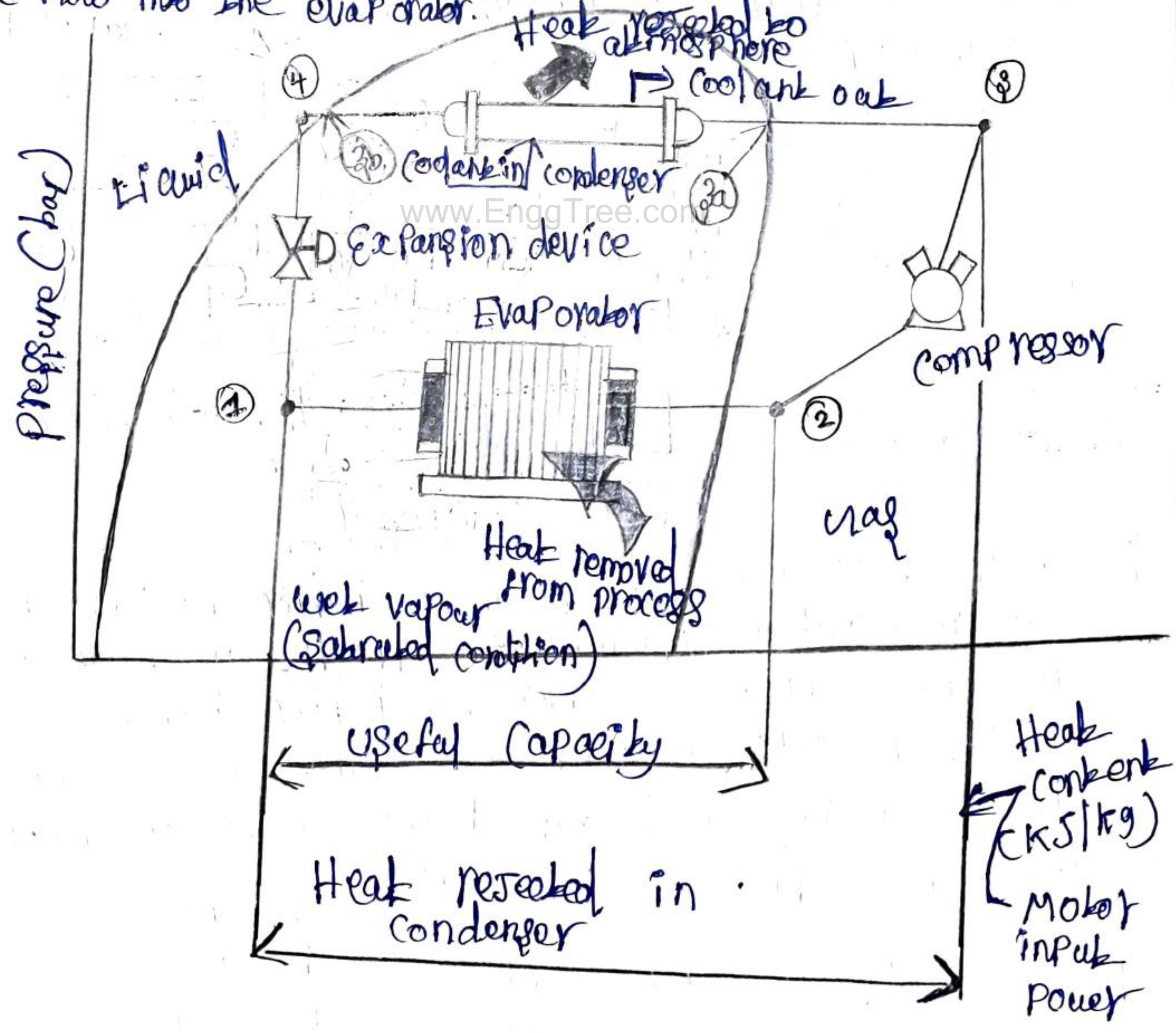
The refrigeration cycle can be broken down into the following stages

* 1-2 Low pressure liquid refrigerant in the evaporator absorbs heat from its surroundings, usually air, water or some other process liquid.

* 2-3 the super heat vapour enters the compressor where its pressure is raised.

* 3-4 the high pressure super heated gas passes from the compressor into the condenser.

* 4-1 The high-pressure sub-cooled liquid passes through the expansion device, which both reduces its pressure and controls the flow into the evaporator.



Alternative Refrigerants for Vapour compression systems

* The use of CFCs is now beginning to be phased out due to their damaging impact on the protective ozone layer present in the stratosphere around the earth.

Performance Assessment of Refrigeration Plants

$$TR = \frac{Q \times C_p \times (T_i - T_o)}{3024}$$

where,

Q = mass flow rate of coolant in kg/hr

C_p = Coolant specific heat in kcal/kg°C

T_i = inlet temperature of coolant to evaporator (chiller) in °C

T_o = outlet temperature of coolant from evaporator (chiller) in °C

The above TR is also called as chiller tonnage

The theoretical Coefficient of Performance (Carnot)

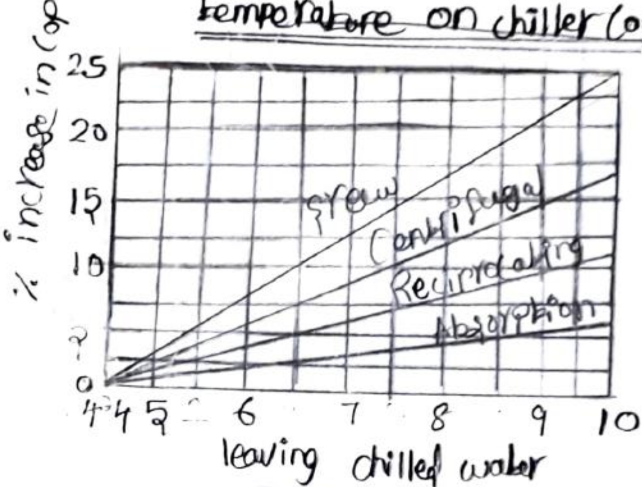
* COPCarnot - a standard measure of refrigeration efficiency of an ideal refrigeration system - depends on two key system temperatures namely:-

$$COP_{Carnot} = \frac{T_e}{(T_c - T_e)}$$

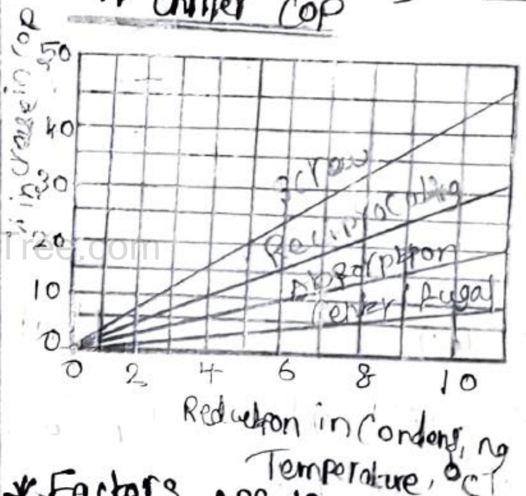
$$COP = \frac{\text{Cooling effect (kW)}}{\text{power input to compressor (kW)}}$$

~~* leaving chilled water Temperature.~~

* Effect of evaporator temperature on chiller COP



* Effect of Condensing temperature on chiller COP



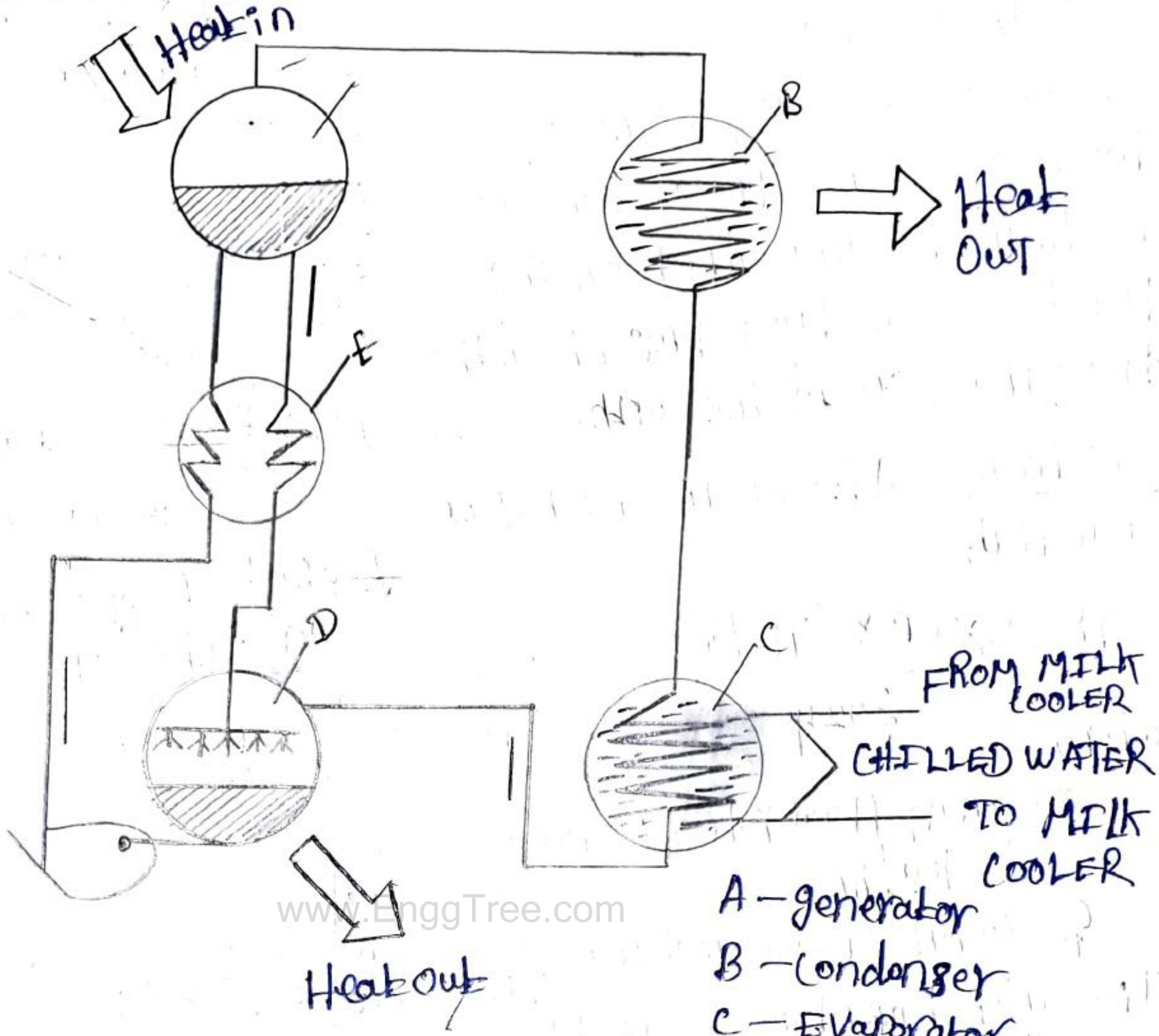
* Factors Affecting Performance and Energy Efficiency of Refrigeration Plants.

* The refrigerant temperature again sets the corresponding suction pressure of the refrigerant which decides the inlet duty conditions for the work of compression of the refrigerant compressor.

* Energy saving opportunities

1) Cold insulation
2) Building envelope
3) Building Heat Loads Minimisation

2) Absorption Refrigeration



A – generator
B – Condenser
C – Evaporator
D – Absorber
E – Heat exchaner
F – PUMP

1) Evaporator

* The refrigerant (water) evaporates at around 40°C under a high vaccum condition of 754 mm Hg in the evaporator.

* chilled water goes through heat exchanger tubes in the evaporator and transfers heat to the evaporated refrigerant.

2) Absorber

* in order to keep evaporating, the refrigerant vapour must be discharged from the evaporator and refrigerant (water) must be supplied.

3) High pressure Generator

* As lithium bromide solution is diluted, the ability to absorb the refrigerant vapour reduces

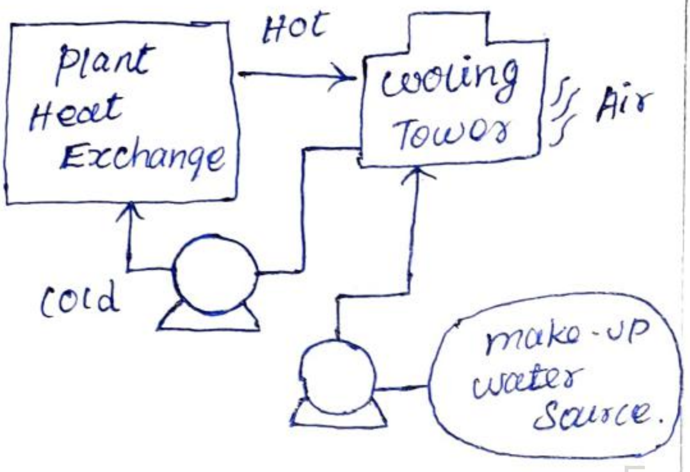
4) Condenser

* To complete the refigeration cycle, and thereby ensuring the refrigeration takes place continously the following two function required.

1. cooling Tower system?

* cooling tower are a very important part of many chemical plants.

* The primary task of a cooling tower is to reject heat into the atmosphere.



* cooling Tower Type.

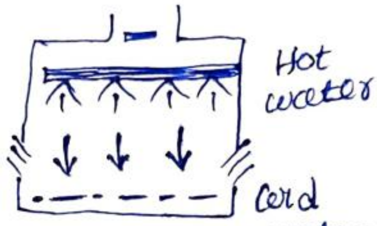
1. neatural draft.
2. mechanical draft.

* Mechanical draft Tower

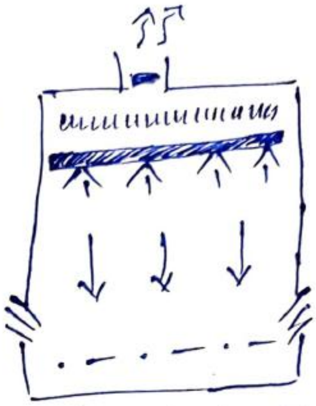
1. available in the flowing airflow arrangement.

* counter flow Induced draft.
* counter flow forced draft.
* cross flow induced draft.

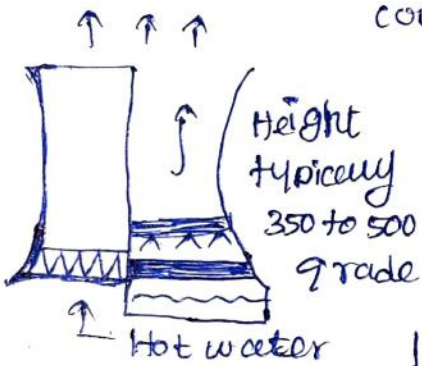
* the cooling Tower type diagram.

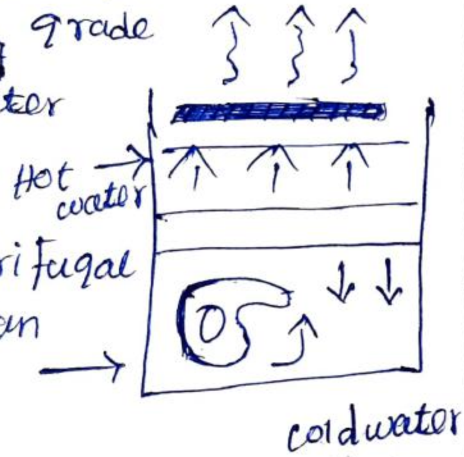


Inducted draft counter flow water - Fill tower



induced draft counter flow tower



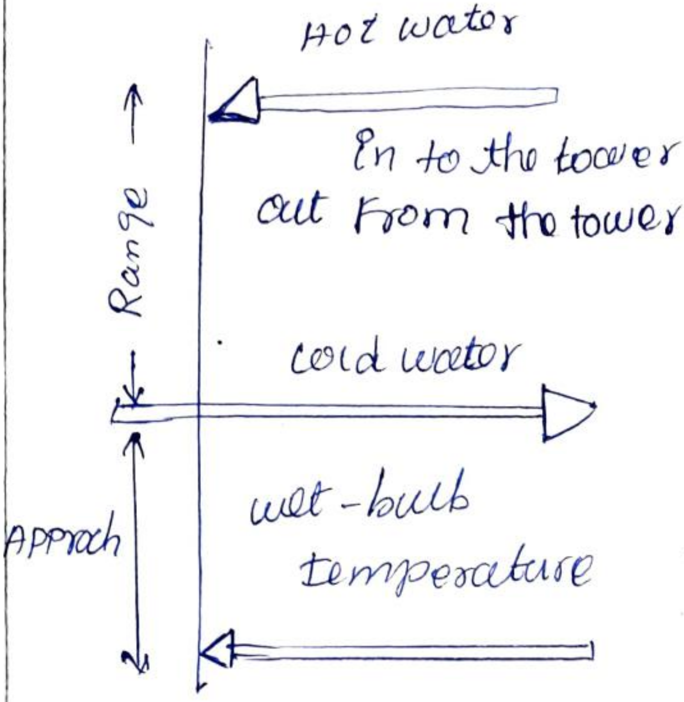


* components of cooling Tower

* Frame and casing.

1. Fill
2. cold water basin
3. drift eliminators
4. air inlet
5. louvers
6. nozzles
7. Fans.

Cooling Tower Performance.



* Range is the difference between the cooling tower water inlet and outlet tempaeture.

$$L(T_1 - T_2) = (h_2 - h_1) G$$

$$L/G = \frac{h_2 - h_1}{T_1 - T_2}$$

L/G = liquid to gas mass flow

T_1 = hot water temperature

T_2 = cold water temperature

factor Affecting cooling Tower performance.

* capacity
* Range

cooling tower size affected by the load, range, approch.

Performance Assessment of Cooling Tower.

* cooling tower design data and curves to be referred to as the basis.
* TDS of cooling water
* Rated cycles of concentration at site conditions.

Flow control strategies:-

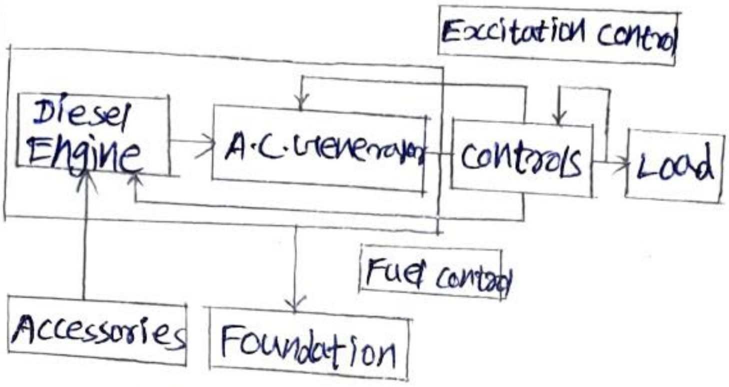
* control of tower air flow can be done by varying methods.
* Starting and Stopping of fans, use of two or three-speed fan motors.
* On-off fan operation of signal speed fans provides the least effective control.

Energy Saving opportunties in cooling Tower.

* Balance flow to cooling tower hot water basins.
* Restrict flows through large loads to design values.
* consider coc improvement measures for water saving
* FRP blade fan energy savings.

DG set system:

DG-Diesel Generator



DG set system

Selection considerations:

Important factors:

- Power
- Speed of the engine

Power:

- The power requirement is determined by the maximum load.
- The equipment pushes up it power consumption.

Speed:

- Speed is measured at the output shaft and given in RPM.
- Running speed is 1300-3000 RPM.

Advantages of adopting Diesel Power Plant:

- Low installation cost
- Short Delivery period
- High Efficiency
- short start up time.
- minimum cooling water requirement.

Selection and Installation Factors:

- Sizing of a genset
- Air cooling Vs water cooling
- safety Features
- Unbalanced Load effects
- Neutral Earthing
- site condition effects

Sizing of a genset:

DG set is required for 100% standby for connected load in HP/KVA should be added.

KVA $=\sqrt{3}\,VI$

KVA Rating = KVA/Load Factor

Load Factor = Average KVA/maximum KVA

Air cooling Vs water cooling:

- water cooled DG set is better than air cooled set.
- cooling water temperature does not exceed the prescribed limits.
- radiator to keep its cooling water temperature within limits.

Safety Features:

- Short circuit, over load and earth fault protection on all DG sets.
- strongly recommended to install a circuit protection
- Reverse power Relay is must for avoid back feeding.

Unbalanced Load Effects:

* Unbalanced loads can cause heating of the alternator
* may result in unbalanced output voltage.

Neutral Earthing:

* Equipment body and neutral should grounded.
* In case of equipment is earth fault, any leackage potential is drain to the ground.

site condition effects:

site condition altitude, intake temperature and cooling water temperature derate diesel engine output.

Load characteristics:

* Power factor
* Unbalanced load
* Trnsient Load
* Special Loads

Power factor:

* Power factor is 0.8 lag as specified by standards.
* Lower power factor demands higher excitation current and increased losses.

Unbalanced Load:

* Unbalanced loads on AC Generator is unbalanced set of voltage and additional heating in AC Generator.
* Unbalanced voltage is additional losses in motors.

Transient Loading:

* Transient voltage dip arising due to transient load application
* Specially designed generator may have be selected.

Special Loads:

* Special loads like rectifier/thyristor loads, welding loads, furnace loads need an application check.
* DG set by specially designed AC generator for complete load

Energy Performance Assessment of DG sets:

* Ensure reliability of all Instruments.
* Collect techanical literature, characteristics and specifications.
* Conduct a 2 hour trial on the DG set.
* The fuel oil/diesel analysis is referred to from an oil company data.
* Analysis trail for Average alternator loading, Averge engine loading, Percentage load on alternator, [illegible] engine.

Energy saving Measures for DG sets:

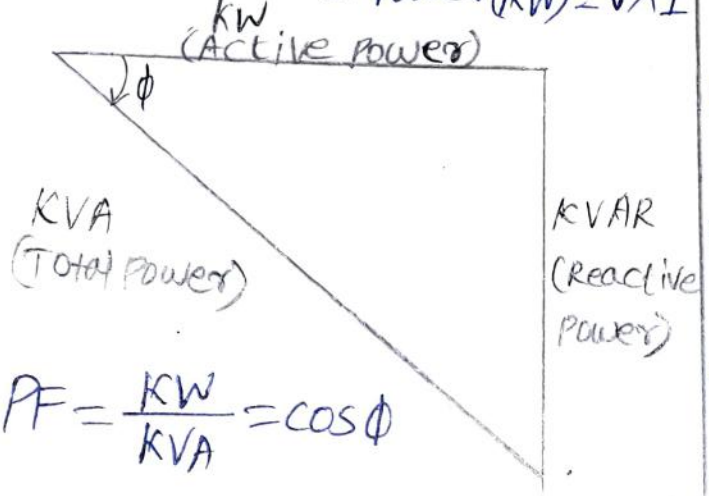
- Improve air filtration
- calibrate fuel injection pumps frequently.
- Ensure compliance with maintenance checklist.
- parallel operation is improved loading and fuel economy
- DG set Performance and maintenance planning is required.

Power factor Improvement and Benefits:

Power factor Basics:

In case of pure resistive loads, the voltage (V), current (I), resistance (R) relations are linearly related.

$V = I \times R$ and Power(KW) $= V \times I$



$PF = \frac{KW}{KVA} = \cos\phi$

KW, KVAr and KVA vector

Improving Power Factor:

★ They act as reactive power generator and provide the needed reactive power to accomplish KW of work.

★ This reduces the amount of reactive power.

The advantages of PF improvement by capacitor addition:

★ Reactive component of the network is reduced.

★ I^2R power losses are reduced

★ Voltage level at the load end is increased.

Cost benefits of PF improvement:

★ Reduced KVA (maximum demand) charges in utility bill.

★ Reduced distribution losses (KWH) in the plant network.

★ Improved performance of motors.

★ A high power factor eliminate penalty.

★ Delivering load is reduced.

Automatic power Factor controllers:

★ Automatic power factor controller is automatically maintain the desired power factor.

★ In such cases the maximum demand will be rise, to overcome this situation automatic power factor controller are deployed.

★ Compare the measured power factor with the desired power factor.

★ If the powe factor is less than the desired power factor, another bank of capacitor is switched on.

★ If the power factor is leading, or above a threshold point, a bank of capacitors is switched off.

Selection and location of capacitors:

The capacitors can be selected based on the following relation.

$$kVAr \text{ Rating} = KW[\tan\phi_1 - \tan\phi_2]$$

Where,

KVAr = size of the capacitor needed

KW = average power drawn

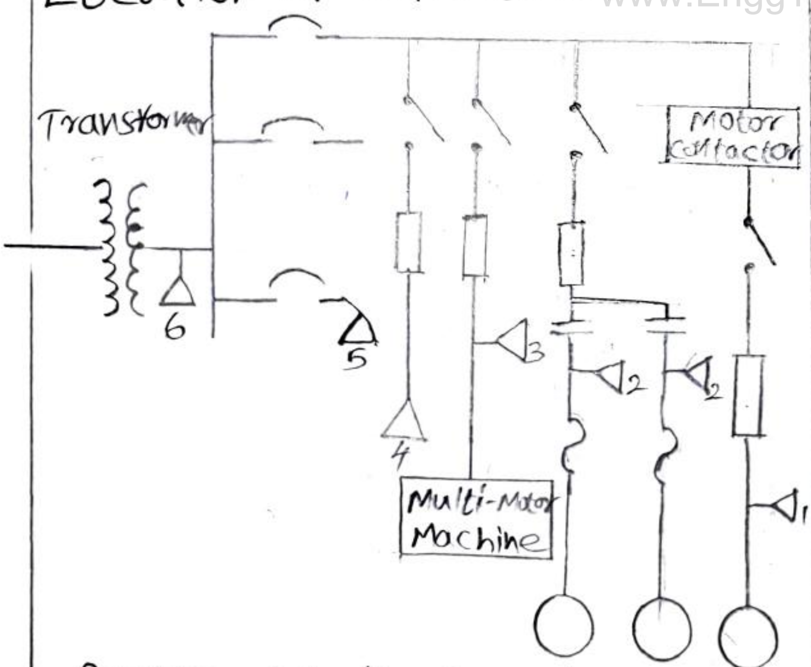
$\tan\phi_1$ = trigonometric ratio for the present power factor

$\tan\phi_2$ = trigonometric ratio for the desired PF.

ϕ_1 = Existing ($\cos^{-1} PF_1$) and

ϕ_2 = Improved ($\cos^{-1} PF_2$)

Location of Capacitors:



Power Distribution Diagram illutratinging capacitor Locations

☆ The primary purpose of capacitors is to reduce the maximum demand.

☆ Additinal benefits are derived by capacitor location.

☆ Reduce power losses of system substantially.

☆ Power losses are proportional to the square of the current.

Capacitor on each piece of equipment (1,2):

Advantages:

☆ Increase load capabilities of distribution system.

☆ Can be switched with equipment, no additional switching is required.

☆ Better voltage regulation.

☆ Capacitor sizing is simplified.

Disadvantages:

☆ Small capacitor cost more per kVAr then larger units.

☆ Economic break point for individual correction is generally at 10HP.

Capacitor with equipment group (3):

Advantages:

☆ Increased load capability

☆ Reduced material cost

☆ Reduced installation cost

Disadvantages:

☆ Switching means may be required to control amount of capacitance used.

Capacitor at main service (4,5&6):

Advantages:

☆ Low material installation cost.

Disadvantages:

* Switching will usually be required to control the amount of capacitance used.
* Does not improve the load capabilities of the distribution system.

Performance Assessment of Power Factor capacitors:

Voltage effects:

* Ideally capacitor voltage rating is to match the supply voltage.
* supply voltage exceeds rated voltage.

Material of capacitors:

Power factor capacitors are available in various types of dielectric material are used.

Connections:

* Shunt capacitor are used industry and end user applications
* series capacitors are used voltage boosting distribution network

Operational performance of capacitors:

Capacitors consume 0.2 to 6.0 watt per kVAr.

some checks that need to be adopted in use of capacitors:

* Name plates can be misleading with respect to rating, so check the charging current.
* capacitor boxes may contain only insulated compound and insulated terminals with no capacitor element inside.
* capacitor for single phase motor starting and those use for lighting circuits for voltage boost.

MOTOR TYPES

1) Induction Motors

* An AC induction motor has a fixed outer portion, called the stator and a rotor that spins inside with a carefully engineered airgap between the two.

* if a 3-phase supply is fed to the stator windings of a 3-phase motor, a magnetic flux of constant magnitude, rotating at synchronous speed is set up. At this point, the rotor is stationary.

* As per the Faraday's law of electromagnetic induction.

2) Squirrel cage Induction Motor

* The windings on the rotor of a squirrel cage motor is comprised of aluminium (or some times copper) bars embedded in the steel laminations of the rotor. The ends of the rotor bars are shorted together by rings at each end of the rotor. There is no external connection to the rotor. The bar and ring structure looks like an exercise wheel for a pet squirrel.

3) Slip-ring motor:-

* The slip-ring motor or wound-rotor motor is a variation of the squirrel cage induction motor. while the stator is the same as that of the squirrel cage motor, the rotor of a slip-ring motor is wound with wire coils. The ends of the windings are connected to slip rings so that resistors or other circuitry can be inserted in series with the rotor coils through carbon brushes that slide on the slip-rings allowing an electrical connection with the rotating coils. This basically is the difference in construction between a squirrel cage and slip-ring motors.

4) Direct-Current Motors

* Direct-current motors, as the name implies, use direct-unidirectional, current. Direct current motors are used in special applications where high torque starting or where smooth acceleration over a broad speed range is required.

5) Synchronous Motors

* AC power is fed to the stator of the synchronous motor. The rotor is fed by DC from a separate source. The rotor magnetic field locks onto the stator rotating magnetic field and rotates at the same speed. The speed of the rotor is a function of the supply frequency and the number of magnetic poles in the stator.

6) Permanent Magnet Synchronous Motor (PMSM)

* The permanent magnet synchronous motor (PMSM) is an alternative for AC induction motors due to various advantages such as power density, better cooling, smaller size, better efficiency and so on. These PMSM which

rotor structures similar to brushless DC Motors which contain permanent magnets.

7) Synchronous Reluctance Motors

* A synchronous reluctance motor has the same structure as that of a salient pole synchronous motor except that it does not have a field winding on the rotor. These motors are becoming popular due its superior performance and capable of achieving IE4 efficiency class.

Motor Efficiency:-

* Two important attributes relating to efficiency of electricity use by A.C induction motors are efficiency (η), defined as the ratio of the mechanical energy delivered at the rotating shaft to the electrical energy input at its terminals and power factor (PF).

* intrinsic losses are of two types
1) fixed losses - independent of motor load
2) variable losses — dependent on Load.

1) Fixed losses:-

* consist of magnetic core losses and friction and windage losses. Magnetic core losses (sometimes called iron losses) consist of eddy current and hysteresis losses in the stator. They vary with the core material and geometry and with input voltage.

2) variable losses:-

* consist of resistance losses in the stator and in the rotor and miscellaneous stray losses. Resistance to current flow in the stator and rotor result in heat generation, that is proportional to the resistance of the material and the square of the current (I^2R)

Field Tests for Determining Efficiency:-

* The efficiency of the motor is given by

$$\eta = \frac{P_{out}}{P_{in}} = 1 - \frac{P_{loss}}{P_{in}}$$

where

P_{out} = output power of the motor

P_{in} = Input power of the motor.

P_{loss} = Losses occuring in motor.

No Load Test:-

* The motor is run at rated voltage and frequency without any shaft load. Input power, current, frequency and voltage are noted. The no load P.F is quite low and hence low PF watt meters are required. From the input power, stator I^2R losses under no load are subtracted to given the sum of Friction and windage (F&W) and core losses.

Stator and Rotor I^2R Losses:-

* The stator winding resistance is directly measured by a bridge or volt amp method. The resistance must be corrected to the operating temperature.

Stray Load Losses:-

* These losses are difficult to measure with any accuracy. IEEE Standard 112 gives a complicated method which is rarely used on shop floor.

Factors Affecting Energy Efficiency & Minimising Motor Losses in operation

Power supply Quality

* Motor performance is affected considerably by the quality of input power that is the actual volts and frequency available at motor terminals vis-a-vis rated values as well as voltage and frequency variation and voltage unbalance across the three phases.

Voltage unbalance

* Voltage unbalance the condition where the voltages in the three phases are not equal, can be still more detrimental to motor performance and motor life unbalance typically occurs as a result of supplying single-phase loads disproportionately from one of the phases.

$$\text{Voltage unbalance} = \frac{\text{Maximum deviation from mean of } V_{ab}, V_{bc}, V_{ca}}{\text{Mean of } (V_{ab}, V_{bc}, V_{ca})}$$

Common causes of voltage unbalance

1) unbalanced incoming utility supply
2) unequal transformer tap settings
3) Large single phase distribution transformer on the system.
4) open phase on the primary of a 3 phase transformer on the distribution system.
5) Faults or grounds in the power transformer

Motor Loading

$$\% \text{ Loading} = \frac{\text{input power drawn by the motor (kW) at existing load}}{\text{Name plate full load kW rating / name plate full load motor efficiency}} \times 100$$

(or)

$$\% \text{ Loading} = \frac{\text{Input Power drawn by the motor (kW) at existing load}}{\sqrt{3} \times kV \times I \times \cos\phi} \times 100$$

$$\text{Motor Loading } \% = \frac{\text{Actual operating load of the motor}}{\text{Rated capacity of motor}} \times 100$$

Motor Load Survey : Methodology

* Large industries have a massive population of LT Motors. Load survey of LT motors can be taken-up methodically to indentify improvement options as illustrated in following case study.

(i) Sampling criteria

*) Utilization factor i.e. hours of operation with preference given to continuously operated drive motors

*) Sample representative basis, where one drive motor analysis can be reasoned as representative for the population. Ex: Cooling Tower Fans, Air washer units, etc

(ii) Measurements

* Studies on selected LT motors involve measurement of electrical load parameters namely volts, amperes, power factor, kw drawn

* Observations on machine side parameters such as speed, load, pressure, temperature, etc (as relevant) are also taken

(iii) Analysis

*) Motor load on kw basis and estimated energy consumption.

*) Scope areas for energy conservation with related cost benefits and source information

The observations are to indicate:-

* % loading on kw, % voltage unbalance if any, voltage, current, frequency, power factor, machine side conditions like load/unload condition, pressure, flow, temperature, damper / throttle operation, whether it is rewound motor, idle operations, metering provisions, etc.

The finding / recommendations may include:-

(*) identified motors with less than 50% loading 50-75% loading, 75-100% loading, over 100% loading.

(*) indentified motors with low voltage / power factor / voltage imbalance for needed improvement measures.

Reducing under-loading

* Probably the most common practice contributing to sub-optimal motor efficiency is that of under loading. under-loading results in lower efficiency and power factor, and higher-than-necessary first cost for the motor and related control equipment.

Improving the Motor Loading by operating in star Mode

* For motors, which consistently operate at loads below 40% of rated capacity, an inexpensive and effective measure might be to operate in star mode.

Sizing to variable Load

* industrial motors frequently operate under varying load conditions due to process requirements. A common practice in cases where such variable-loads are found is to select a motor based on the highest anticipated load.

Power Factor correction

* As noted earlier, induction motors are characterized by power factors less than, unity, leading to lower overall efficiency (and higher overall operating cost) associated with a plant's electrical system.

Maintenance

* Inadequate maintenance of motors can significantly increase losses and lead to unreliable operation. For example, improper lubrication can cause increased friction in both the motor and associated drive transmission equipment.

Rewinding Effects on Energy Efficiency

* Careful rewinding can sometimes maintain motor efficiency at previous levels, but in most cases, losses in efficiency result. Rewinding can affect a number of factors that contribute to deteriorated motor efficiency winding and slot design, winding material, insulation performance, and operating temperature.

Application of variable speed Drives (VSD)

* Although there are many methods of varying the speeds of the driven equipment such as hydraulic coupling, gear box, variable pulley etc. the most possible method is one of varying the motor speed itself by varying the frequency and voltage by a variable frequency drive.

Concept of variable Frequency Drive

* The speed of an induction motor is proportional to the frequency of the AC voltage applied to it, as well as the number of poles in the motor stator. This is expressed by the equation.

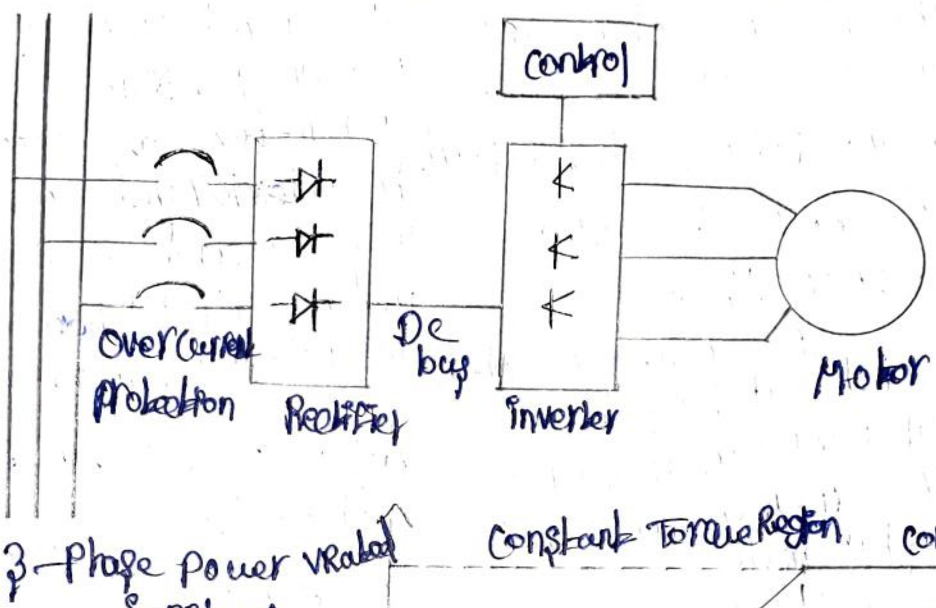
$$RPM = (f \times 120)/p$$

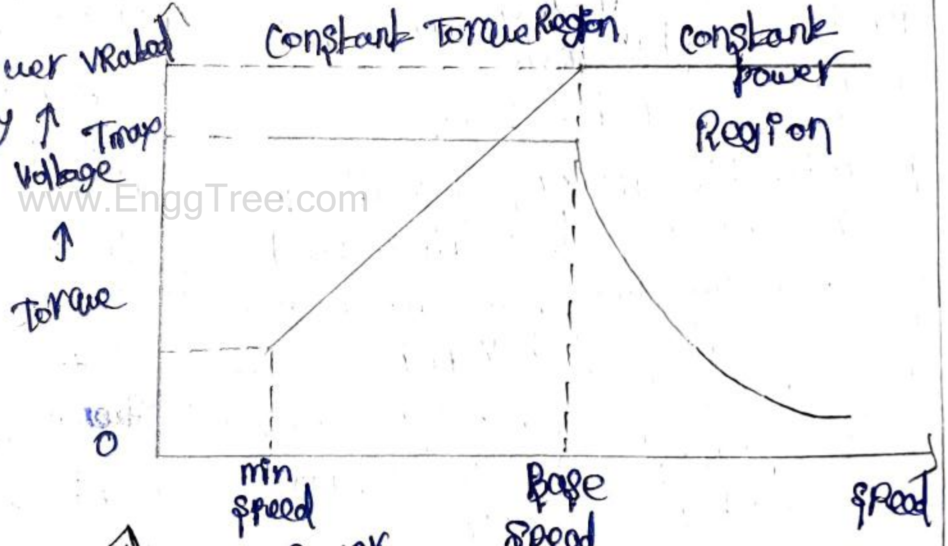
Need for VFD

* Earlier motors tended to be over designed to drive a specific load over its entire range.

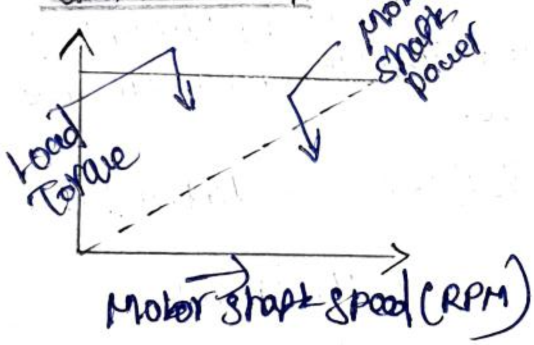
Principle of VFD's

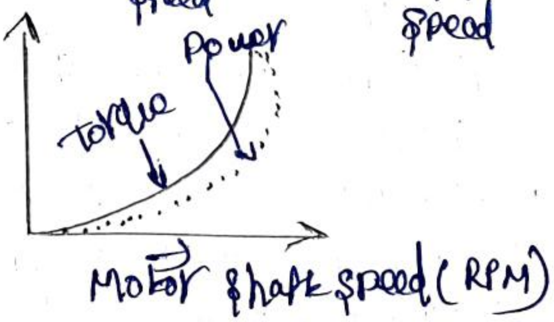
* The VFD is a system made up of active / passive power electronics devices (IGBT, MOSFET, etc) a high speed central controlling unit and optional sensing devices, depending upon the application requirement.





Driven Load Types and characteristics





Soft starter:-

* when starting AC induction motor develops more torque than is required at full speed.

Advantages of soft start:-

1) Less mechanical stress
2) Improved power factor
3) lower maximum demand
4) Less mechanical maintenance

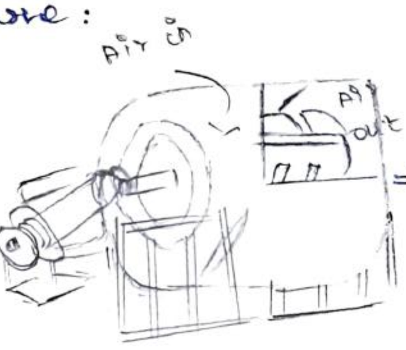
FANS & BLOWERS

Introduction

* Fans & Blowers provide air for ventilation & Industrial process Requirements
* Fans & Blowers selection depends on the volume, Flow Rate, pressure & Efficiency
* For Efficiency differ from design to design & also types
* Fans falls into two types:
  * centrifugal Flow } Fans
  * axial Flow

centrifugal Flow:

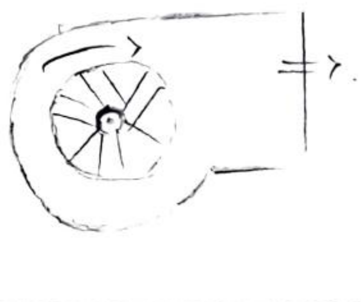
* The major types of centrifugal Flow are; Radial, Forward, Backward curve:



⇒ centrifugal Fan.

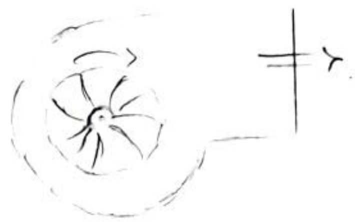
Radial Fans; These Fans for industrial Because of their high static pressure.

* It have ability to handle the heavily contaminated airstearms.



Forward curved Fans:

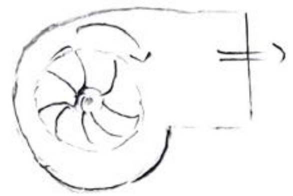
* These Fans are used in clean environments & operate at lower temperatures
* These Fans are well suited For moving large volumes of air against Relatively low pressure.



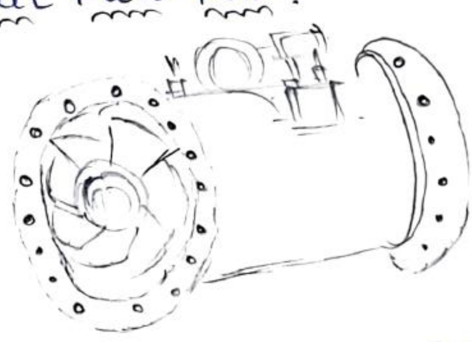
Backward curved Fans:

* These Fans are more efficient than Forward-curved Fans.
* Backward inclined Fans are known as "non-loading".

* Because changes in static pressure.



Axial Flow Fan:



* It have mainly three types They are;
  * Tube axial
  * vane axial
  * propeller.

Tubeaxial Fans:

- These fans have a wheel inside a cylindrical housing B/W blade & housing to improve air flow efficiency.
- The wheel turn faster than propeller.
- Operation under high pressure 250 - 400mm
- The efficiency upto 65%.

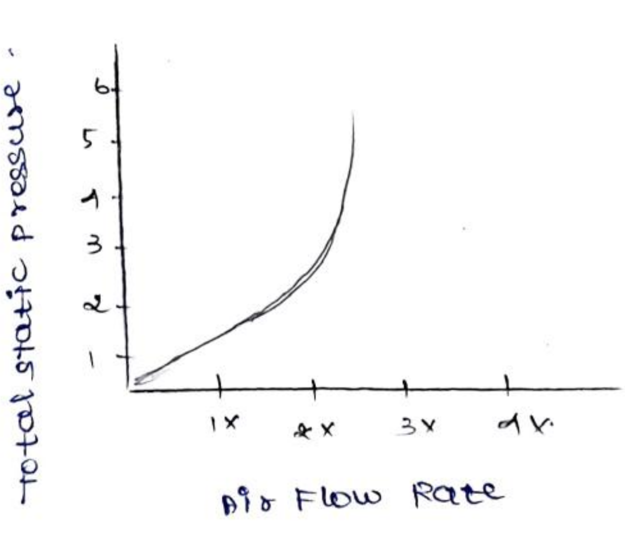
Vaneaxial Fans:

- These fans are similar to tubeaxial.
- In addition of improve efficiency by directing & straightening the flow.
- These fans are pressure up to 500 mmwc

Propeller Fans:

- These fans are run at low speeds & moderate temperature.
- They handle large volumes of air at low pressure.
- Propeller fans are often used in indoors.
- Efficiency is low at 50% or less.

System characteristics:



Fan Laws:

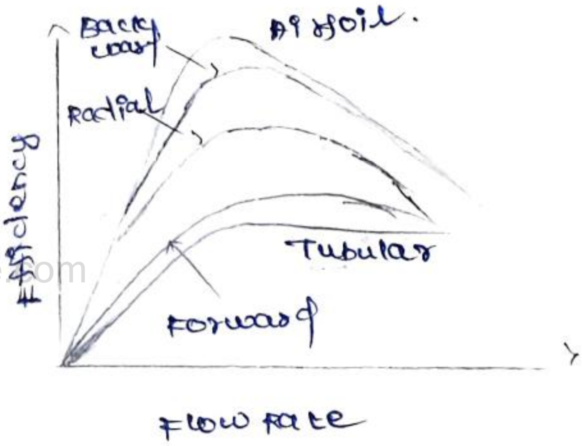
Flow ∝ speed ⇒ $\frac{Q_1}{Q_2} = \frac{N_1}{N_2}$.

Pressure ∝ (speed)^2 ⇒ $\frac{SP_1}{SP_2} = \left(\frac{N_1}{N_2}\right)^2$

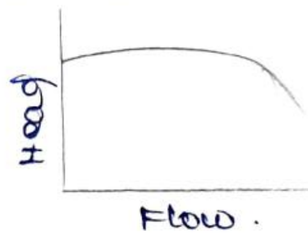
Power ∝ (speed)^3 ⇒ $\frac{KW_1}{KW_2} = \left(\frac{N_1}{N_2}\right)^3$

Fan performance characteristics

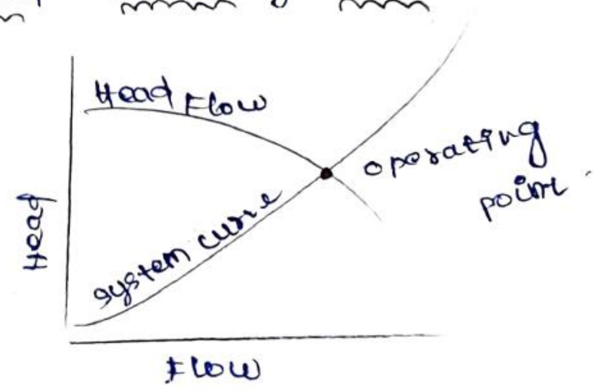
Based on fans/ Impellers.



System characteristics (or) pump flow:



Pump operating point.



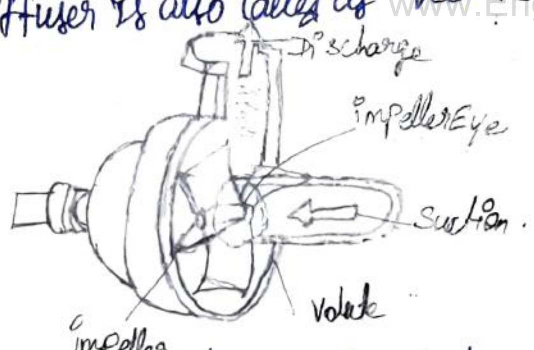
Pumps And Pumping System

1. Pump Types

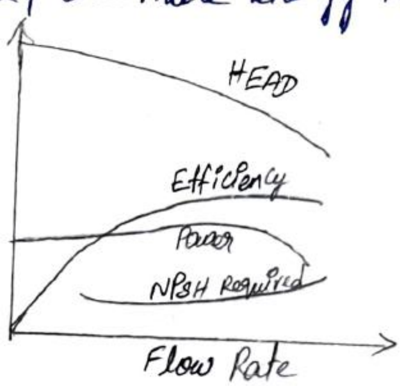
* Pumps come in a variety of sizes for a wide range of applications.
* They can be classified according to their basic operating principles as dynamic or displacement pumps.
* Dynamic pumps can be sub-classified as centrifugal and special effect pumps.

Centrifugal Pumps:-

* A centrifugal pump is a very simple design.
* The two main parts of the pump are the impeller and the diffuser.
* The diffuser is also called as volute.



* The more quality of water to be pumped, the more energy is required.

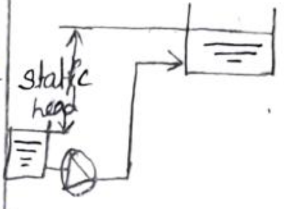


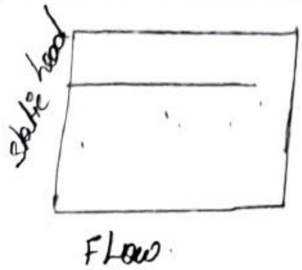
2. System Characteristics

* In a pumping system the objects in most cases.
* It is either to transfer a liquid from a source of required destination.

E.g: filling a high level reservoir or circulate liquid around a system.

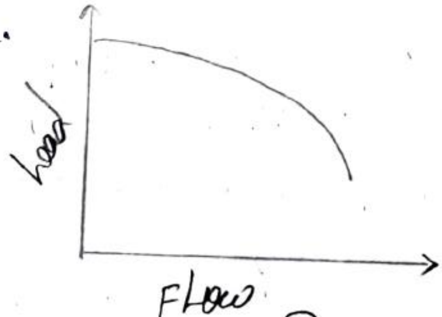
* A pressure is need to make the liquid flow rate is must over come head losses.





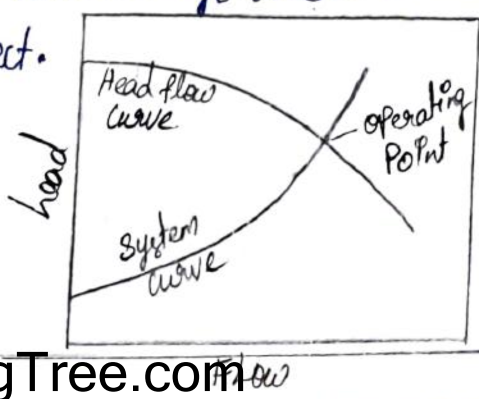
3. Pump Curves.

* The performance of a pump can expressed graphically as head against flow.
* Centrifugal pump has a curve where the head falls gradually increasing flow.
* This is called the pump characteristic curve.



Pump Operating Point:-

* When a pump is installed in a system effect can be illustrated graphically by superimposing pump and system curves.
* It will always where two curves intersect.



4. Factors Affecting Pump Performance

* Centrifugal Pumps are characterized by the relationship between flow rate (Q).
* They Produce and the Pressure (H) at which flow is delivered.
* Pump efficiency varies flow and Pressure

* Effect of over Sizing the Pump:-
  * the Pressure losses to be over come by the Pumps are functions of flow - the system characteristics
  * It is also head-flow curves.

* Energy Loss in throttling:-
  * A case where need to Pump $68 m^3/hr$ of water at 47m head.
  * The Pump characteristics curves.

If we select Pump E, then efficiency is 60%

Hydraulic Power = Q(m^3/s) x Total Differential head $h_d - h_s$ (m) x ρ (kg/m^3) x g (m/s^2)/1000

5. Municipal Water Pumping System.

* municipal water Pumping are centrifugal Pumps and Vertical turbine Pumps. (MLD) - Million Liters Per Day.

a) Raw water Pump house, intake water/river
b) Pure water Pump house and filtration plant
c) Booster station as Per the requirements
d) Elevated storage Reservoirs in the distribution system.

Vertical Turbine Pumps:-

* Vertical turbine Pump deep well turbine Pump is vertical axis centrifugal or mixed flow type Pump comprising of stag.
* It rotating impellers and stationary bowls Possessing guide vanes.

1. Pump element
2. Discharge column.

6) Energy Conservation Opportunities in Pumping System:-

* Ensure adequate NPSH at site of installation
* Ensure availability of basic instruments at Pumps like Pressure gauges, flowmeters
* Operate Pumps near Best Efficiency Point.
* Modify Pumping system and pumps losses to minimize throttling.
* Repair Seals and Packing to minimize water loss by dripping
* Balance the system to minimize flow and reduce Pump Power requirements.
* Replace old Pump for new energy efficient Pump.
* Separate High Pressure and low Pressure systems.

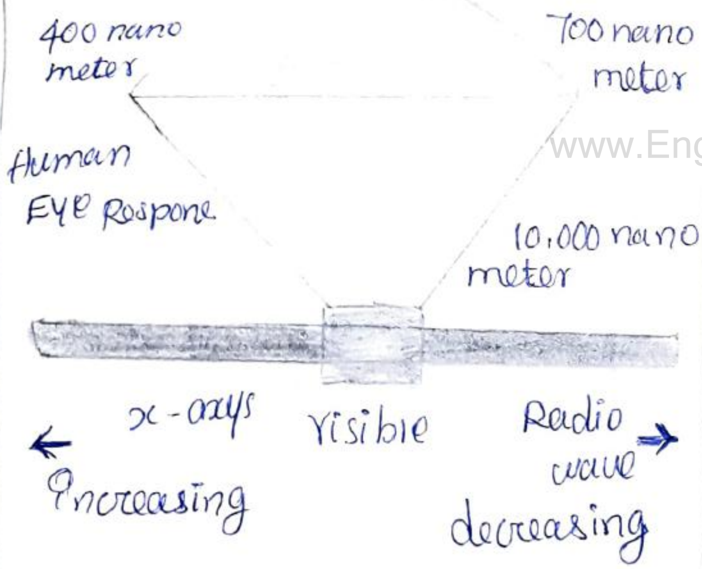
I. lighting System.

Introduction:-

* most natural light comes from the sun, including moon light.

* It's origin makes it completely clean and it consumes no natural Resources.

* light exists as tiny packets called photons and exhibits the properties of both wave.



1 watt = 683 lumens at 555 nm wavelength.

* Basic parameter and Terms in lighting System.

1. luminous flux:
2. Illuminance (E):
3. The inverse square law.

* light Source and lamp Type

1. lamp is equipment which produces light.

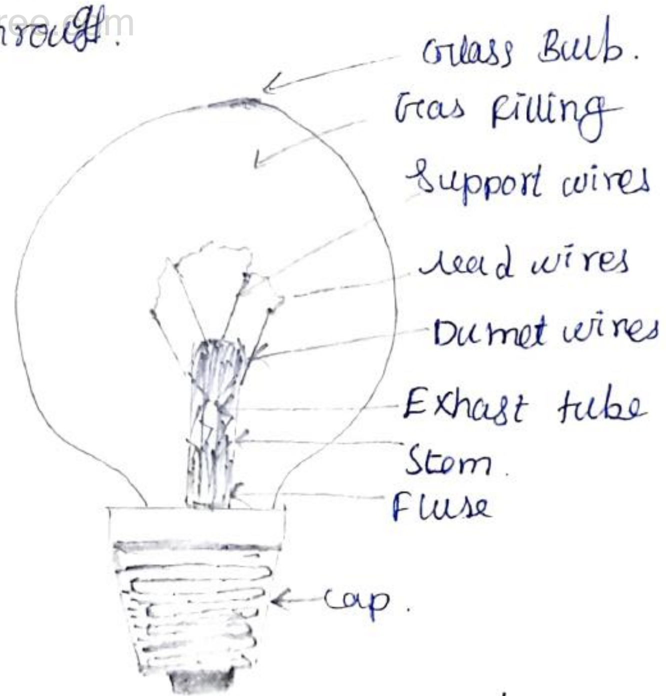
2. HID lamps can be further classified as Sodium vapour, mercury vapour and metal halide lamp.

* Incandescent lamp.

1. The principle parts of an incandescent lamp also known as GLS lamp.

2. General lighting service lamp (GLS).

3. Flow of electric current through.

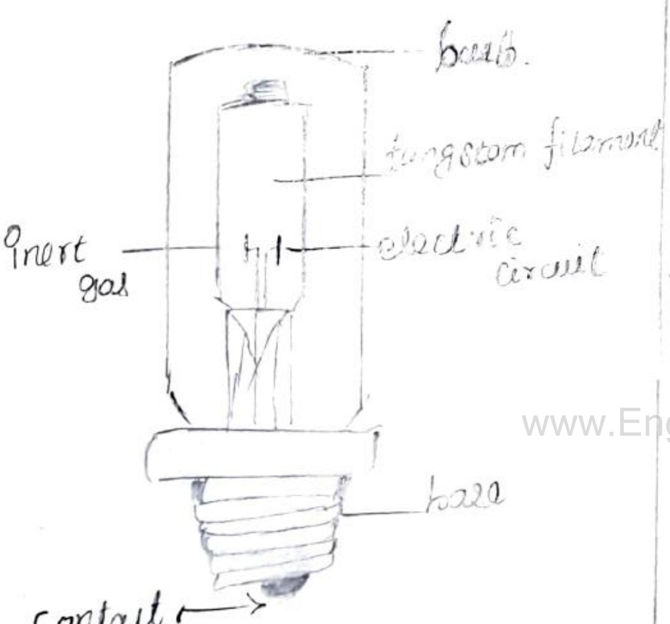


4 Reflector lamp are basically incandescent provided with a hight quality internal mirror exactly the parabolic shape of the lamp.

* Halogen lamp.

1. It has a tungsten filament and bulb filled with halogen gas.

2. Current flow throught filament and heats it up as in incandesent lamps.



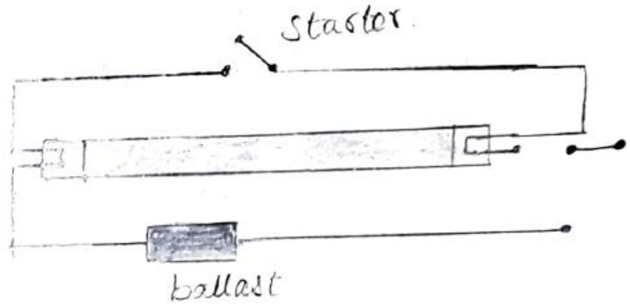
3. Tungsten atoms evaporate from the hot filament and move toward the cooler wall of the bulb.

4. The bulb-wall temperature keeps the tungsten oxyhalide molecules in the a vapor.

5. Filament and its molybdenum leads-in wires where the temperature drops sharply.

* Fluorescent tube lamp:

* It works by the fluorescene principle.
* This action provides a voltage across its electrodes that set off an electric discharge in the tube.



linear tube.

* T_{12} - 38 mm (1.5 diameter)

* T_8 - 25 mm (1 diameter)

U-bent tube.

* T_{12} - 38 mm (1.5 diameter)
* T_8 - 25 mm (1 diameter)

Circular tube.

* T_9 - 38 mm
* T_5 - 16 mm.

These four lamps vary in diameter (ranging form the 1.5 inches).

Fluoursent tube lamp into the type of the diameter in the tube.

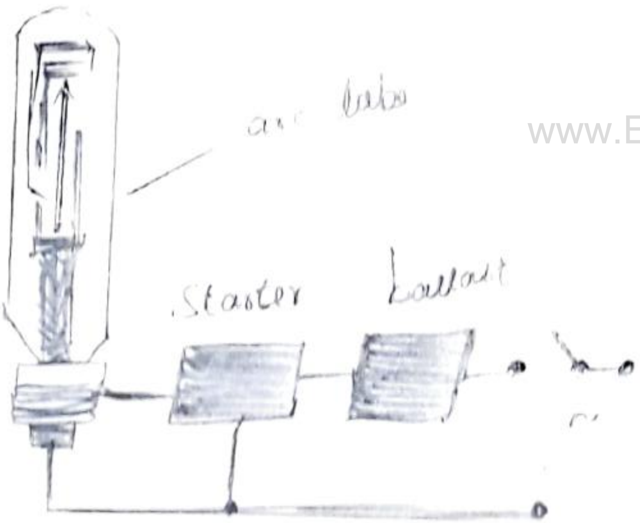
4. Compact fluorescent lamp.

* Compact fluorescent lamp are compact miniature versions of the linear or circular fluorescent lamps and operate in a very similar way.

5. Sodium Vapour lamp.

* Low pressure Sodium Vapour lamp.

* High pressure sodium vapour lamp.

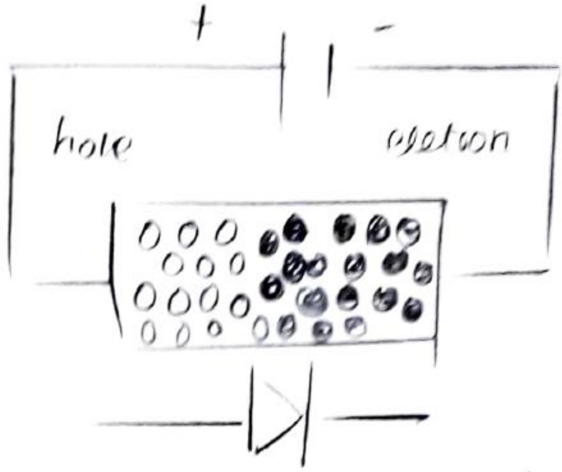


* to help start the arc as well as a Sodium-mercury gas mixture.

6. Mercury Vapour lamp.

7. Metal halide lamp.

8. light emitting diode. LED lamp.



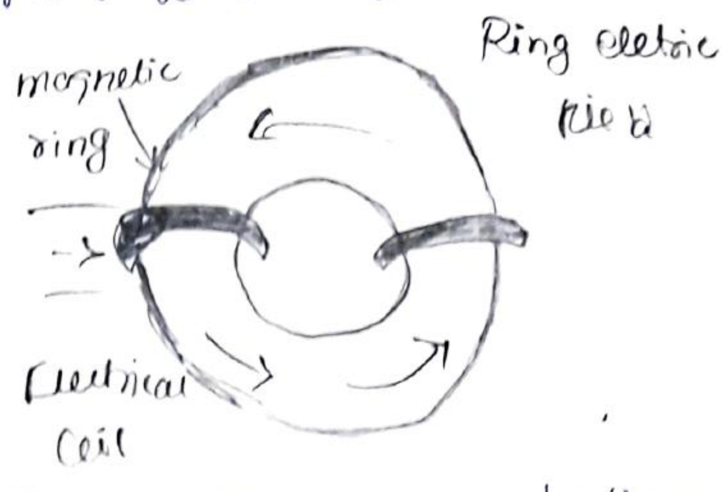
* The efficiency of LED's has now risen sharply and is currently up to 200 lumens per watt in the laboratory.

* Unlike incandescent and fluorescent lamps LED are not inherently white light source.

9. Induction lamp.

* Induction lamp is noted for crisp white light out put.

* Uses magnetic field to excite gases - has no lamp part to wear out.



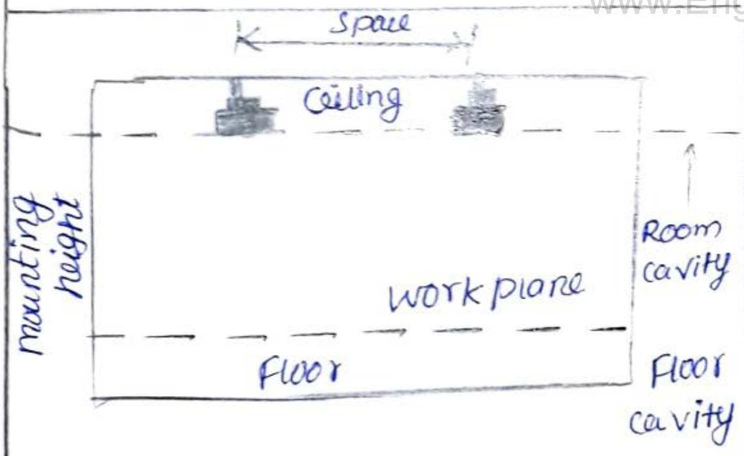
Representation of Induction lamp.

Methode of calculating illuminance - light design for Interiors.

1. For indoor lighting situations. the zonal cavity method is used with data from a coefficient of teable.

2. For outdoor lighting application a coefficient of utilization curve is provided the cu read directly forom the curve and standard lumen formula is used.

Zonal cavity methode indoor lighting calculations.



To calculate the number required the formula,

$$N = \frac{E \times A}{F \times UF \times LLF}.$$

LLF = lamp lumen MF × luminaire MF × Room Surface MF.

*Energy Efficiency lighting controles.

1. Occupancy sensors.
2. Timed Based control.
3. Type and features.
4. Daylight linked control
5. localized switched.
6. Street lighting system and control.

* Timer control (switch ON/OFF as per set timing.

* Day light control

* Selective switched / Altomate of street light

* Switching control based on lux levels.

* Installations of voltage control to be operated after midnight.

* Steet light / public light is one the major electrical.

* municipial area.