Energy is the possessed of the ability to produce a dynamic vital effect

Power - Rate of flow of energy

Power Plant - Unit built for prodn and delivery of a flow of mechanical and electrical energy.

World's most enlarged power resources
→ Nuclear Energy
→ 1 Kg of Uranium is equivalent to energy obtained by 4500 tonnes of high grade coal.

Sources of energy
→ 1 fuels → Solids → Coal, coke anth...
Liquids → Petroleum & deri...
Gases → Natural gas
blast furnace

Important

2. Energy stored in water 6) Tidal
3. Nuclear 7) Geothermal
4 Wind 8) Thermoelectric
5) Solar

Fuels → 1) chemical 2) Nuclear

chemical → which releases heat on combustion (C & H)

Fuels → Primary → occur in nature
secondary → prepared.

Type	Natural	Prepared.
solid	wood, peat, lignite	Coke, charcoal briquettes
liquid	Petroleum	Gasoline, Kerosene, fuel oil, Alcohol, Benzol etc
Gaseous	Natural Gas	Petroleum, gas; ~~Producer gas~~; Coal gas; Coke-oven gas; Blast furnace gas; carburetted gas; Sewer gas

Sunday 12

Important

13 Monday
JUNE

Wk 25

Coal →

Plant debris → Peat → Lignite, Brown Coal, → Sub Bituminous Coal → Semi Anthracite → Anthracite → Graphite

Peat → 1st stage → huge Amount of moisture & takes 2 months to dry
In India not used.

Lignite & Brown Coal → intermediate betn peat & coal. - burns with smoke
clay type, break easily

Bituminous Coal → burns with long yellow & smoky flames CV 31350 Kcal/Kg

SemiBituminous Coal → softer than Anthracite
10-20% volatile matter & breaks into small pieces

Semi Anthracite → less Carbon & less lustre than Anthracite, luminous flame

Coke → Consists of Carbon, mineral matter with 2% sulphur, & small qty of H_2, N_2 & P. It is smokeless & clean fuel. It is solid residue left after the destructive distillation of coals.

Briquettes → ~~produced~~ from fine coal or coke under high pr.

Analysis of Coal

→ 1) Proximate Analysis → individual elements are not determined only the p.c. of moisture, volatile matters, fixed carbon and ~~Asset~~ Ash are determined. → Moisture - 4.5% Volatile Matter - 5.5% Fixed carbon - 20% etc

2) Ultimate Analysis → the p.c. of individual elements are determined

Carbon - 90%. H_2 → 2%.

O_2 → 4%. S - 15%. N → 1% etc

Ranking of Coal -

→ ASME & ASTM →

higher Ranking on dry basis Fixed Carbon

Lower Ranking on ~~moist~~ basis heating value

... kcal/kg

↑ of Coal

→ Grading is on the basis

1) Size, 2) Heating Value, 3) Ash content

4) Ash softening temp, 5) Sulphur content

for eg. Grade written as 5-10 cm

500-A8-F24-S1.6

means

1) a size of - 5-10 cm

2) H.V. of 5000 Kcal/kg

3) 8-10 % ash

4) Ash softening temp - 2400-25...

5) Sulphur content - 1.4 - 1.6 %

So total Rank & grade as

(62-500), 5-10 cm, 500, A8-F24-S...

Gaseous Fuels

Natural gas — CH_4 and C_2H_6 — IC engines

Coal gas — H_2, CO, HC — Commercial

Coke oven gas — by heating the bituminous coal; major portion of the gas utilised for gas engines

Blast furnace gas — obtained from feeding ... in which air is forced through layers of coke and iron ore, and the gas is a byproduct of pig iron manufacture. CO_2, CO

Producer gas — obtained from partial oxidation of coal, coke or peat when they are burnt with insufficient quantity of air (open hearth furnace)

CV of fuels → The energy liberated by the complete oxidation of unit mass or volume of a fuel.
kJ/kg for solid fuel, kJ/m³ for gases

$LCV = HCV - 2465\, m_w$ → SI unit

where m_w = mass of water vapour produced in kg of fuel and 2465 kJ/kg is the latent heat corresponding to STP at 25°C

$LCV = HCV - 588.76\, m_w$ → MKS units

Dulong's formula (solid/liquid) fuels

$$GCV \text{ or } HCV = \frac{1}{100}\left[33800C + 144000\left(H - \frac{O}{8}\right) + 92705\right]$$ – SI unit

~~$$GCV \text{ or } HCV = \frac{1}{100}\left[8080C + 34500\left(H - \frac{O}{8}\right) + 2240S\right]$$~~ Kcal/kg

~~where C, H, O, and S are expressed in %~~

Energy stored in water →

~~→ hydroelectric power plants~~

Nuclear Energy →

1 Kg → 4500 tonnes of coal → 2000 tonnes of oil

Wind Energy →

~~Solar Energy~~ —

Tidal Power —

Geothermal Energy —

Thermoelectric power —

Power Plants —

Combustion of fuels

1. Carbon (complete combustion)

$$C + O_2 = CO_2$$
$$1\,Kg + \frac{8}{3}\,Kg = \frac{11}{3}\,Kg$$

2. Carbon (incomplete combustion)

$$2C + O_2 = 2CO$$
$$2\,mol + 1\,mol = 2\,mol$$
$$24 + 32 = 56$$
$$1\,Kg + \frac{4}{3}\,Kg = \frac{7}{3}\,Kg$$

3. Carbon monoxide

$$2CO + O_2 = 2CO_2$$
$$2\,vol + 1\,vol = 2\,vol$$
$$56 + 32 = 88$$
$$1\,Kg + \frac{4}{7}\,Kg = \frac{11}{7}\,Kg$$

4. Sulphur

$$S + O_2 = SO_2$$
$$1\,mol + 1\,mol = 1\,mol$$
$$32 + 32 = 64$$
$$1\,Kg + 1\,Kg = 2\,Kg$$

5. Hydrogen

$$2H + O_2 = 2H_2O$$
$$1\,vol + \frac{1}{2}\,vol = 1\,vol$$
$$4 + 32 = 36$$
$$1\,Kg + 8\,Kg = 9\,Kg$$

6. Methane (Marsh Gas)

$$CH_4 + 2O_2 = CO_2 + 2H_2O$$
$$1\,vol + 2\,vol = 1\,vol + 2\,vol$$
$$16 + 64 = 44 + 36$$

7. Ethylene

$$C_2H_4 + 3O_2 = 2CO_2 + 2H_2O$$
$$1\,vol + 3\,vol = 2\,vol + 2\,vol$$
$$28 + 96 = 88 + 36$$
$$1\,Kg + \frac{24}{7}\,Kg = \frac{22}{7} + \frac{9}{7}$$

Sunday 19

Important

JULY 2011

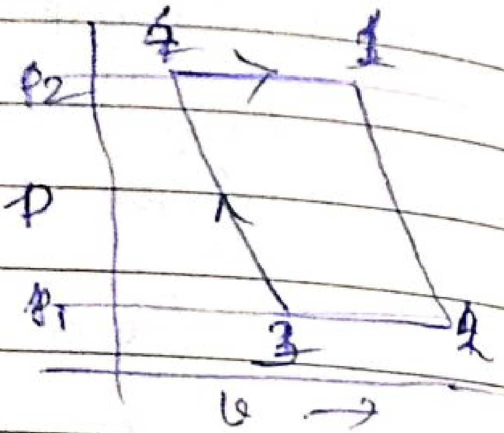
WK	M	T	W	T	F	S	S
27					1	2	3
28	4	5	6	7	8	9	10
29	11	12	13	14	15	16	17
30	18	19	20	21	22	23	24

Power Plant Cycles

Vapour Power cycles

1. Rankine cycle
2. Reheat cycle
3. Regenerative cycle
4. Binary vapour cycle

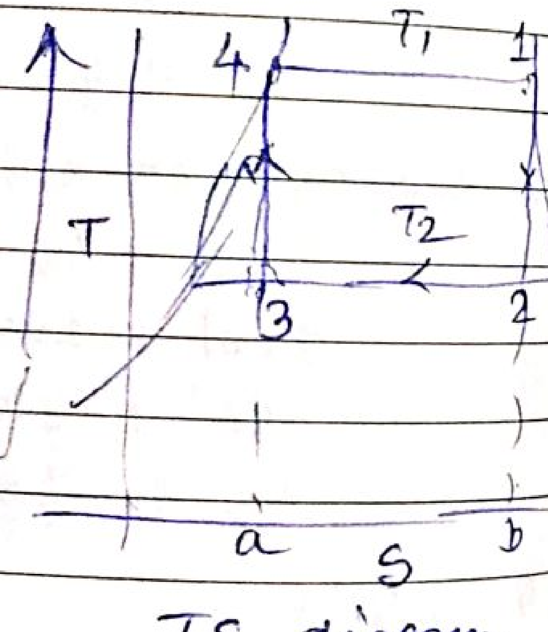
PV diagram



PV, diagram

Gas Power Cycles

1. Otto cycle
2. Diesel cycle
3. Dual combustion cycle
4. Gas turbine cycle
   a) open b) closed



Carnot cycle

op^n ⟶

TS diagram

Heat supplied at constant temp^r T_1

op^n 4-1 = area 4-1-b-a = $T_1(S_1-S_4)$ or $T_2(S_2-S_3)$

Heat rejected at constant temp^r T_2

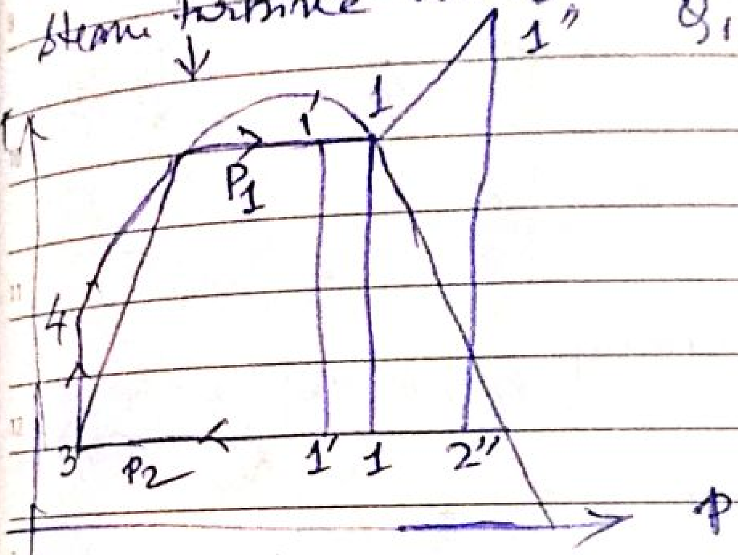
op^n 2-3 = area 2-3-a-b = $T_2(S_2-S_3)$

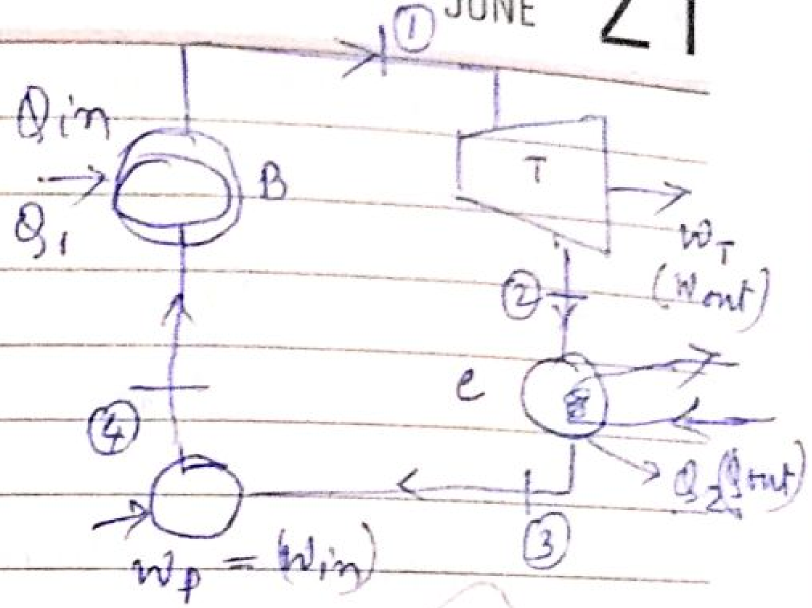
Rankine Cycle

↓

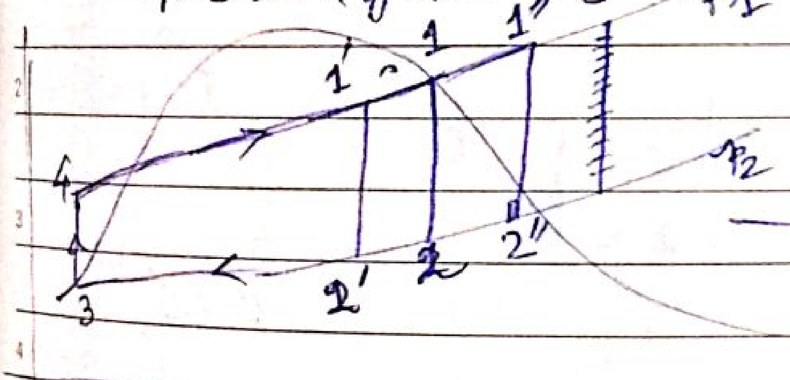
Steam turbine works

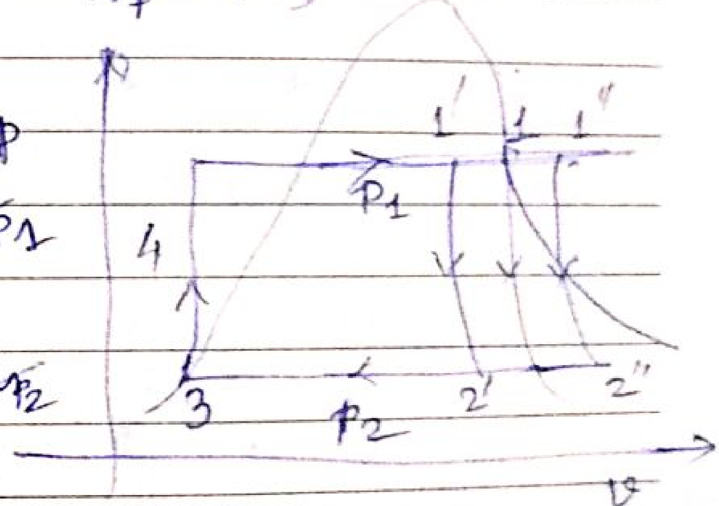
↓





T-S diagram





pv diagram

h-S diagram.

Process 1-2 — Reversible Adiabatic Exp^n in turbine

2-3 — Const p^r heat ~~addition~~ rejection in condenser

3-4 — Reversible Adiabatic Comp^n in feed pump

4-1 — constant p^r heat addition in boiler

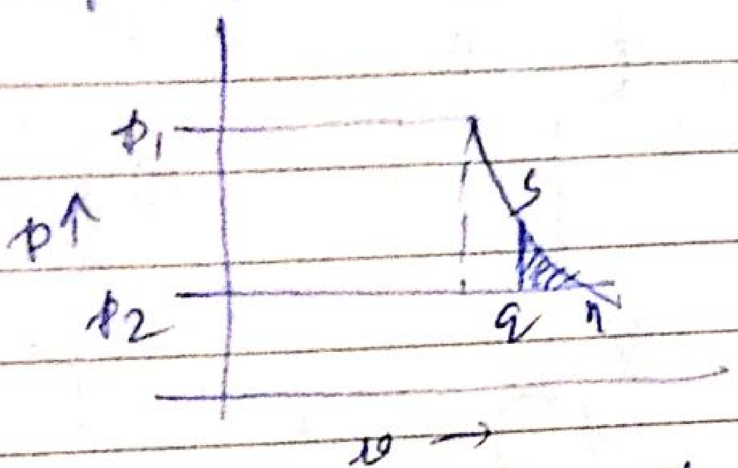
$Q_1 = h_1 - h_{f_4}$, $W_T = h_1 - h_2$, $Q_2 = h_2 - h_{f_3}$, $W_p = h_{f_4} - h_{f_3}$

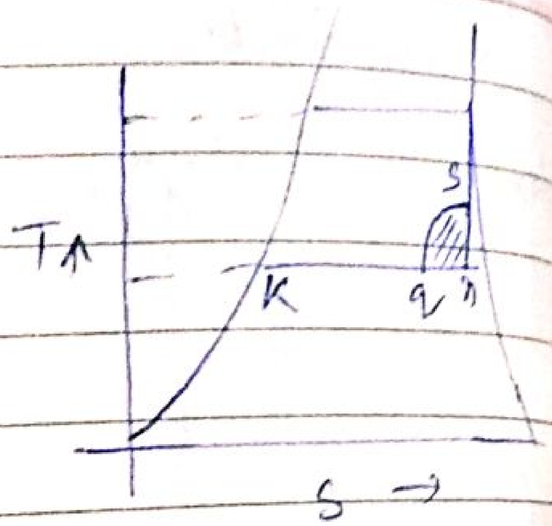
$$\eta_{Rankine} = \frac{W_{net}}{Q_1} = \frac{W_T - W_P}{Q_1} = \frac{(h_1 - h_2) - (h_{f_4} - h_{f_3})}{(h_1 - h_{f_4})}$$

$\boxed{\Delta h = v\Delta p \Rightarrow dh = v\,dp}$

$(h_{f_4} - h_{f_3}) = v_3(p_1 - p_2) \times 10^5$ J/kg

Modified Rankine Cycle





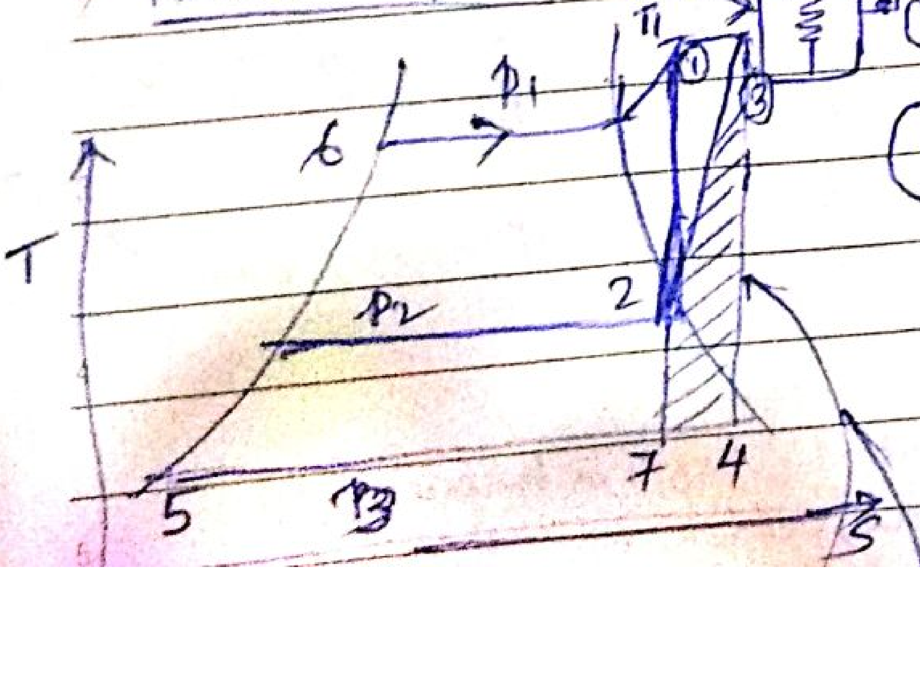
~~modified Rankine efficiency~~

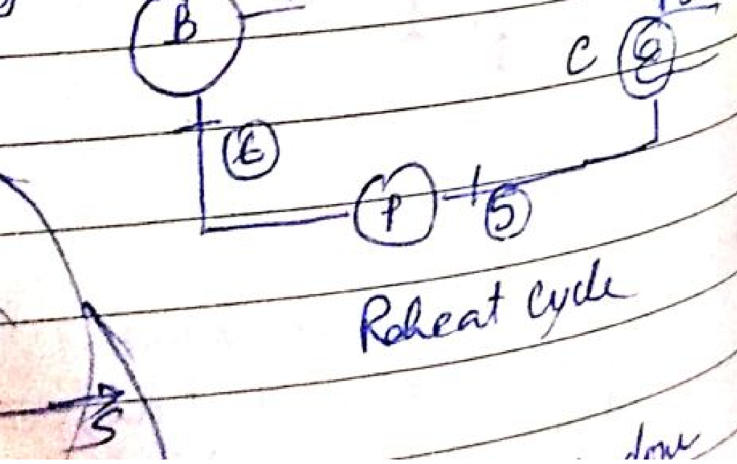
$$\eta_{mR} = \frac{WD}{Hs} = \frac{p_1v_1 + (u_1 - u_2) - p_3v_2}{h_1 - h_{f_3}}$$

or

$$\eta_{mR} = \frac{(h_1 - h_2) + (p_2 - p_3)v_2}{h_1 - h_{f_3}}$$

Reheat cycle





Reheat cycle

work done $= (h_1 - h_2) + (h_3 - h_4)$

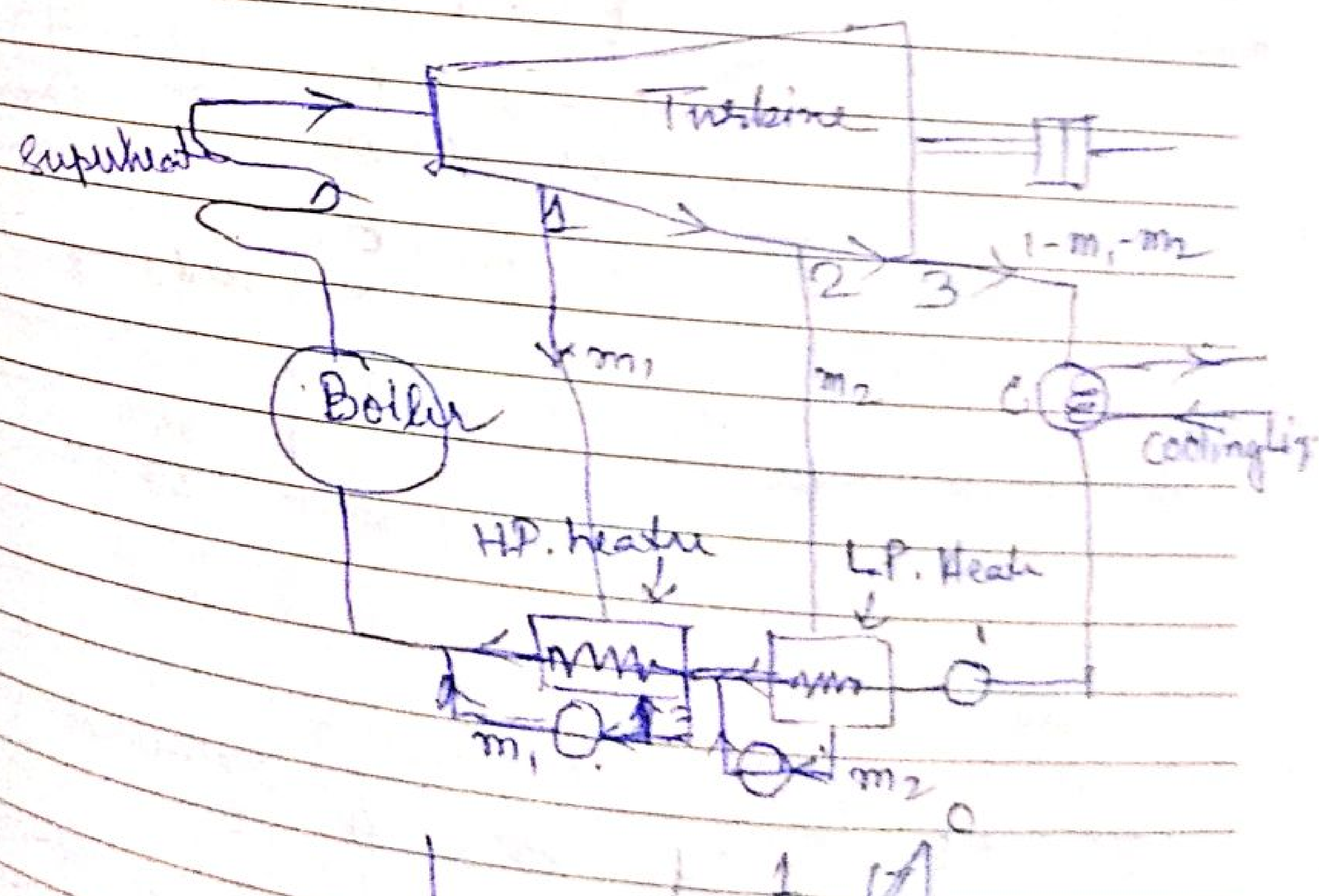
$$\eta_{thermal} = \frac{(h_1 - h_2) + (h_3 - h_4)}{(h_1 - h_{f4}) + (h_3 - h_2)}$$

if W_p is considered.

$$\eta_{therm} = \frac{(h_1 - h_2) + (h_3 - h_4) - W_p}{(h_1 - h_{f4}) + (h_3 - h_2) - W_p}$$

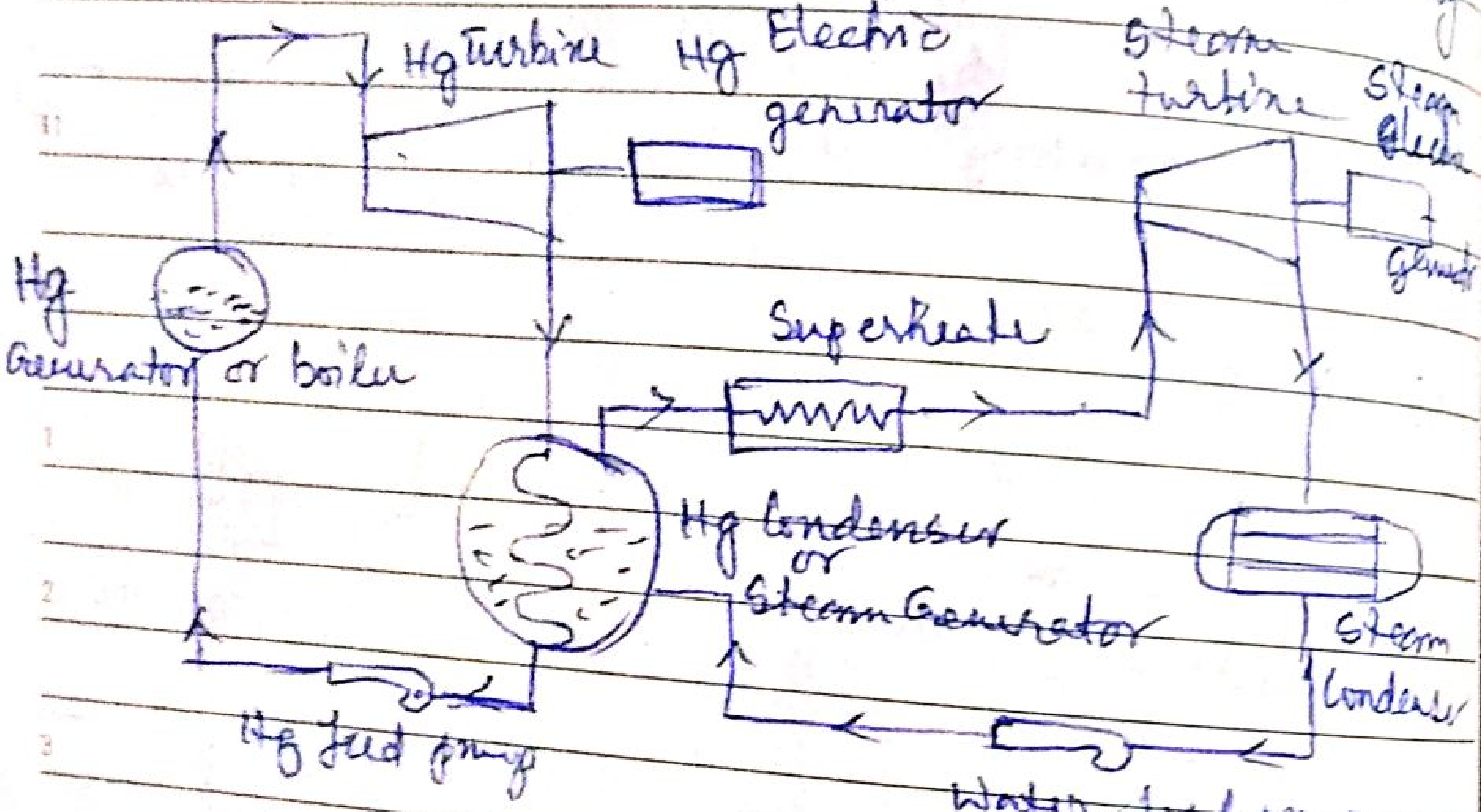
without reheating $\Rightarrow$ $\eta_{thermal} = \frac{h_1 - h_7}{h_1 - h_{f4}}$ $[h_7 = h_{f4}$

Regeneration cycle



Binary vapour Cycle

Two fluids Hg & Water are used in Cascade to produce power with high efficiency



~~Otto Cycle~~ Hg – freezing point −3.3°C
boiling point 354.4°C
Critical point 588.4°C

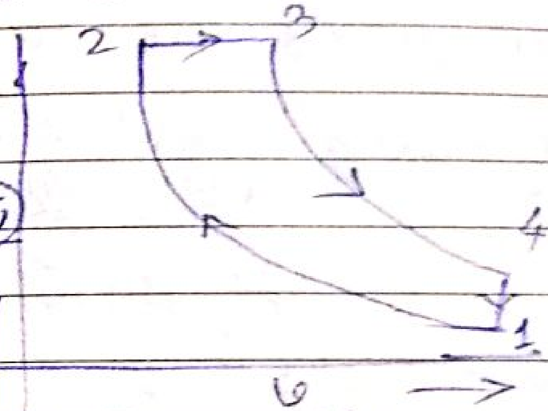
Gas Power Cycle

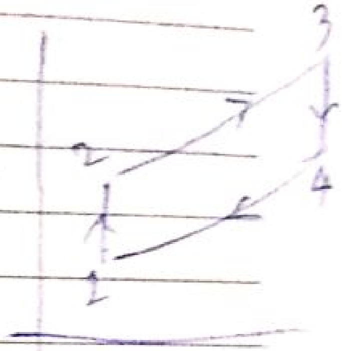
Otto Cycle (heat addition ? Adiabatic

$H_S = C_p(T_3 - T_2)$ $\quad H_r = C_v(T_4 - T_1)$

$\eta = \frac{C_v(T_3 - T_2) - C_v(T_4 - T_1)}{C_v(T_3 - T_2)} = 1 - \frac{1}{r^{\gamma - 1}}$ $\quad \gamma$ = Adiabatic constant

Diesel cycle



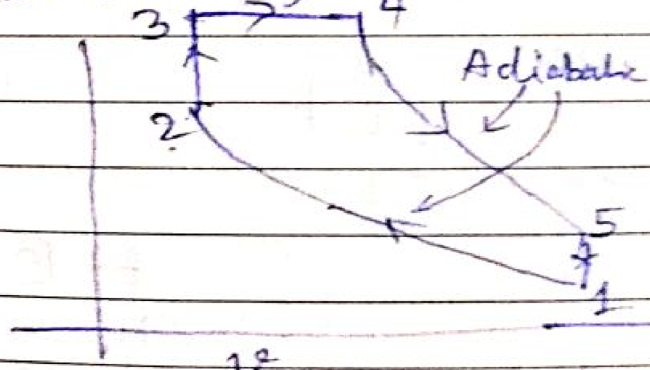


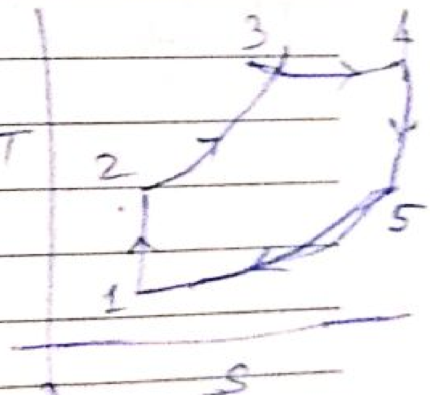
$\eta = \frac{C_p(T_3 - T_2) - C_v(T_4 - T_1)}{C_p(T_3 - T_2)}$

$= 1 - \frac{1}{\gamma (r)^{\gamma - 1}} \left[\frac{\rho^{\gamma} - 1}{\rho - 1} \right]$

cut off ratio, $\rho = \frac{v_3}{v_2}$ $\quad r = \frac{v_1}{v_2}$ = Expⁿ Ratio

Dual combustion cycle



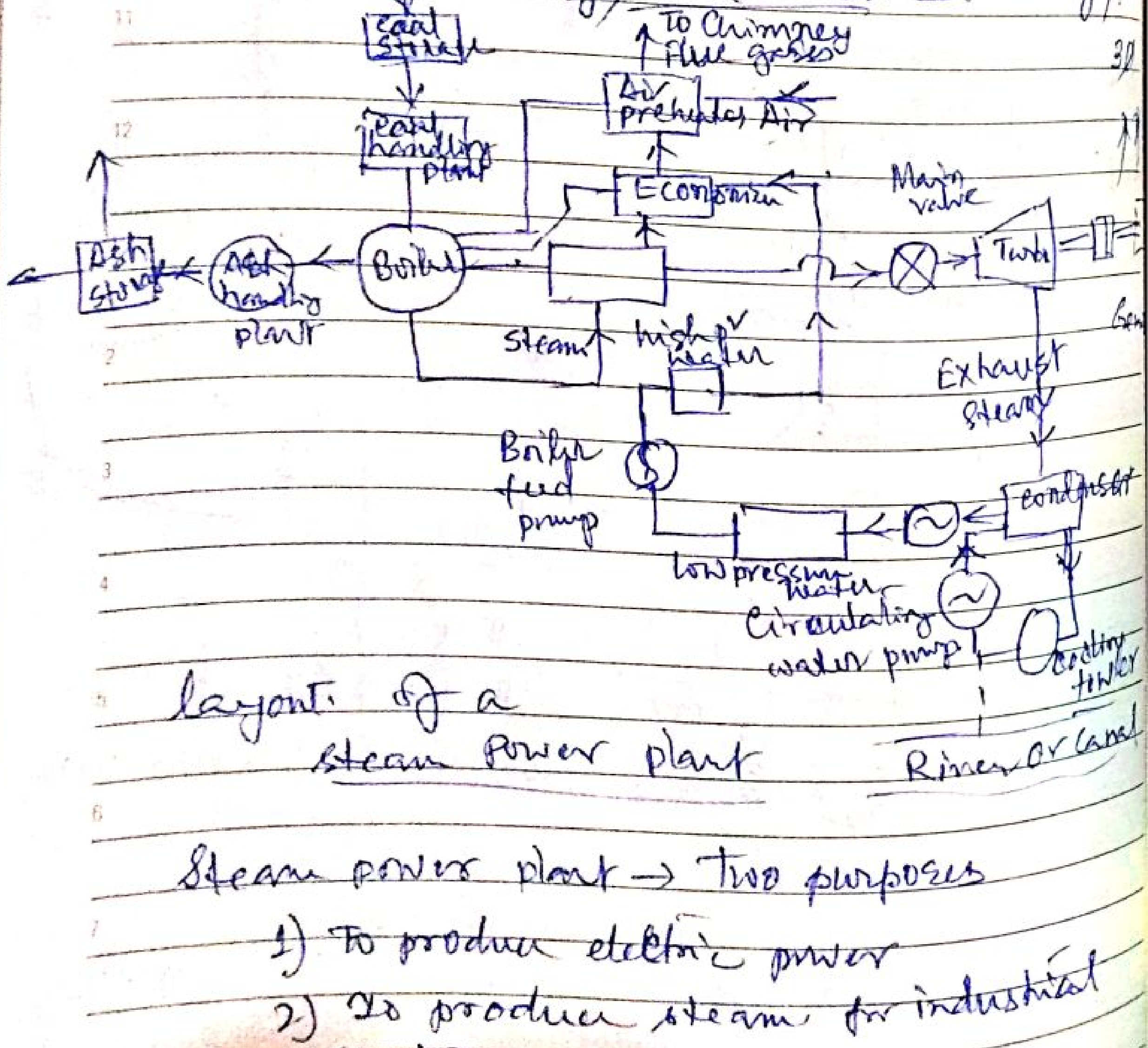


$\eta = 1 - \frac{1}{(r)^{\gamma - 1}} \times \left[\frac{\beta \rho^{\gamma} - 1}{(\beta - 1) + \beta \gamma (\rho - 1)} \right]$

$\frac{T_3}{T_2} = \frac{P_3}{P_2} = \beta$ = pressure or Explosion Ratio

Steam Power Plant

A steam power plant converts the chemical energy of the fossil fuels into mechanical energy and electrical energy.



layout of a steam power plant

Steam power plant → Two purposes
1) To produce electric power
2) To produce steam for industrial purpose

Classification (based on uses)

1) Central stations → all condensers
2) Industrial Power stations or Captive Power stations → large amount steam

Modern Steam Power Plant
→ four circuits
1) coal & ash circuit
2) Air & gas circuit
3. Feed water & steam flow circuit
4. cooling water circuit

Components
1. Boiler including Superheater & economizer Air preheater and Reheater (if available)
2. Steam turbine
3. Generator
4. condenser
5. Cooling Tower
6. Circulating water pump
7. Boiler feed pump
8. Wagon trippler
9. crusher house
10. coal mill
11. Induced draught fan
12. Ash precipitator
13. Boiler chimney
14. Forced draught fan
15. Water treatment plan
16. Control room
17. Switch yard.

Essential requirement
1. Reliability
2. Minm capital cost
3. Minm operating & Maintaining cost
4. Capacity to meet peak load effectively
5. Minm losses in energy in transmission
6. low cost energy supplied to consumers
7. Reserve capacity to maintain feature ...

Site selection

1) Availability of raw material
2) Nature of land
3) Cost of Land
4) Availability of water
5) Transport facilities
6) Ash disposable facilities
7) Availability of labour
8). Size of the plant
9) Load centre
10) Public problem
11) Future extensions.

Capacity of Steam Power Plant

Determined by studying the load duration curve and the anticipated future demand. The min^m capacity of the plant must be equal to at least the peak load.

1) Small loads → economical to install two units of equipment → capable of supplying the max^m demand independently.
At least one unit spare →
2) Medium power plants → no of units are more than two of the installed capacity
3) Large power plants → conservatively rated

Rating of Units

Normally the output of the units is classified under following heads

(i) Economical rating → 75-85% of full load

(ii) Max^m continuous rating → At max^m load it can run continuously for hours

The choice of steam conditions depends upon the following factors

1. Price of fuel (coal, gas etc)
2. Capital cost of the plant
3. Time available for erection
4. Thermal efficiency obtainable
5. The station 'load factor'