RENEVABLE ENERGY SYSTEM :-

UNIT - 4 :- GEOTHERMAL ENERGY :

Definition of Geothermal Energy :-

Geothermal energy is the thermal Energy produced and stored in the center of the Earth. Geothermal energy is a renewable energy source because heat is continuously produced inside the Earth.

Estimates of Geothermal power :-

→ The estimates vary vary widely. However the following give a rough estimate.

→ For a depth of 3 kms, the total stored energy of known fields in approximately 8×10^{21} Joules and for a depth of 10km the total stored energy is estimated to be about 4×10^{22} Joules.

→ The Energy stored in hot springs is about 10% of the above quantities.

→ If the above energy is extracted from a 3km belt with 1% thermal energy recovery factor at a uniform rate of over a 50 years period, thermal power of 50GW is obtained.

With the thermal electric conversion efficiency of 20% will yield only 10 GW of electric power.

→ For the estimate about based on a 10km depth on electric power of 50 GW. is predicted U.S.A has 5-10% geothermal fields and India much less.

Nature of Geothermal Fields :-

It is convinent to classify earth's surface into three broad groups

(1) Non thermal areas having a temperature gradient of 10-40°c per km depth.

(2) Semi Thermal areas having a temperature gradient of 70°c per km depth.

(3) Hyper Thermal areas where the temperature gradients are many times greater than in non-Thermal areas.

Geothermal fields may further be classified into three types:-

(A) Hyper-Thermal Fields :-

(1) Wet fields :- Where the water is pressurized and temperatures are above 100°c. when they are led to the surface a fraction will be splashed into steam and a major part remains as a boiling water

(2) Dry Fields :- They produce dry saturated stream or superheated steam at pressure above temperature.

(B) Semi-Thermal Fields :-

→ These are capable of producing hot water at temperature above 100°c.

→ Geothermal Sources:

Five General categories (or kinds) of geothermal resources have been identified

(1) Hydrothermal convective systems.

These are again subclassified as:

(a) vapour-dominated or dry steam fields

(b) Liquid-dominated system (or) wet steam fields.

(c) Hot water fields.

(2) Geopressure resources.

(3) petro-Thermal or Hot dry rocks (HDR)

(4) Magma resources

(5) Valconoes.

(1) Hydrothermal systems :-

Hydrothermal systems are those in which water is heated by contact with the hot rock.

(a) Vapour dominated systems :-

In these systems the water is vaporized into steam that reaches the surface in a relatively dry condition at about 200°c and rarely above 7 kg/cm³ (8 bar).

→ This steam is the most suitable for use in turbo electric power plants, with the least cost.

→ The Drawbacks of the system are the presence of corrosive gases and erosive material and environmental problems.

(b) liquid-dominated systems :-

→ In these systems the hot water circulating and trapped underground is at a temperature ranges of 175 to 315°c.

→ When tapped by wells drilled in the right places and to the right depths, the water flows naturally to the surface or is pumped up to it.

→ The drop in pressure, usually to 7kg/cm² (8 bar) or less, causes it to partially flash to a two-phase mixture of low Quality. i.e liquid dominated.

→ It contains relatively large concentration of dissolved solids ranging b/w 3000 to 25,000 ppm and sometimes higher.

→ liquid dominated systems, however, are much more plentiful than vapour-dominated systems. [PPM - Parts Per Million]

(2) Geopressure Resources :-

→ These resources occur in layer large, deep sedimentary basins, the reservoirs contain moderately high temperature water under very high pressure. They are of special interest because substantial amounts of methane CH_4 (natural gas) are dissolved in the pressurized water. and are released when the pressure is released.

→ Geopressured water is tapped in much deeper underground acquifers (it is a water-bearing stratum of permeable rock, gravel or sand), at depths b/w about 2400 to 9000 m.

→ The Geopressured resources are quite large: They could be used for the generation of electric Power and the recovery of natural gas.

(3) Hot Dry Rocks :-

Hot Dry Rocks (or) petrothermal systems.

→ These are very hot solid rocks occuring at moderate depths but to which water does not have access, either because of the absense of ground-water or the low permeability of the rock (or both).

→ In order to utilize this resource, means must be found for breaking up impermeable rock at depth, introducing cold water, and recovering the resulting hot water (or stream) for use at the surface.

→ The known temperatures of HDR vary b/w 150 to 290°c. This energy, called petrothermal energy, represents by far the largest resources of geothermal energy of any type, as it accounts for large percent of the geothermal resources.

4) Magma Resources :-

→ These consists of partially or completely molten-rock, with temperatures in excess of 650°c, which may be encountered at moderate depths, especially in recently active volcanic regions.

→ These resources have a large geothermal energy content, but they restricted to a relatively few locations.

→ Hydrothermal Resources (Convective) :-

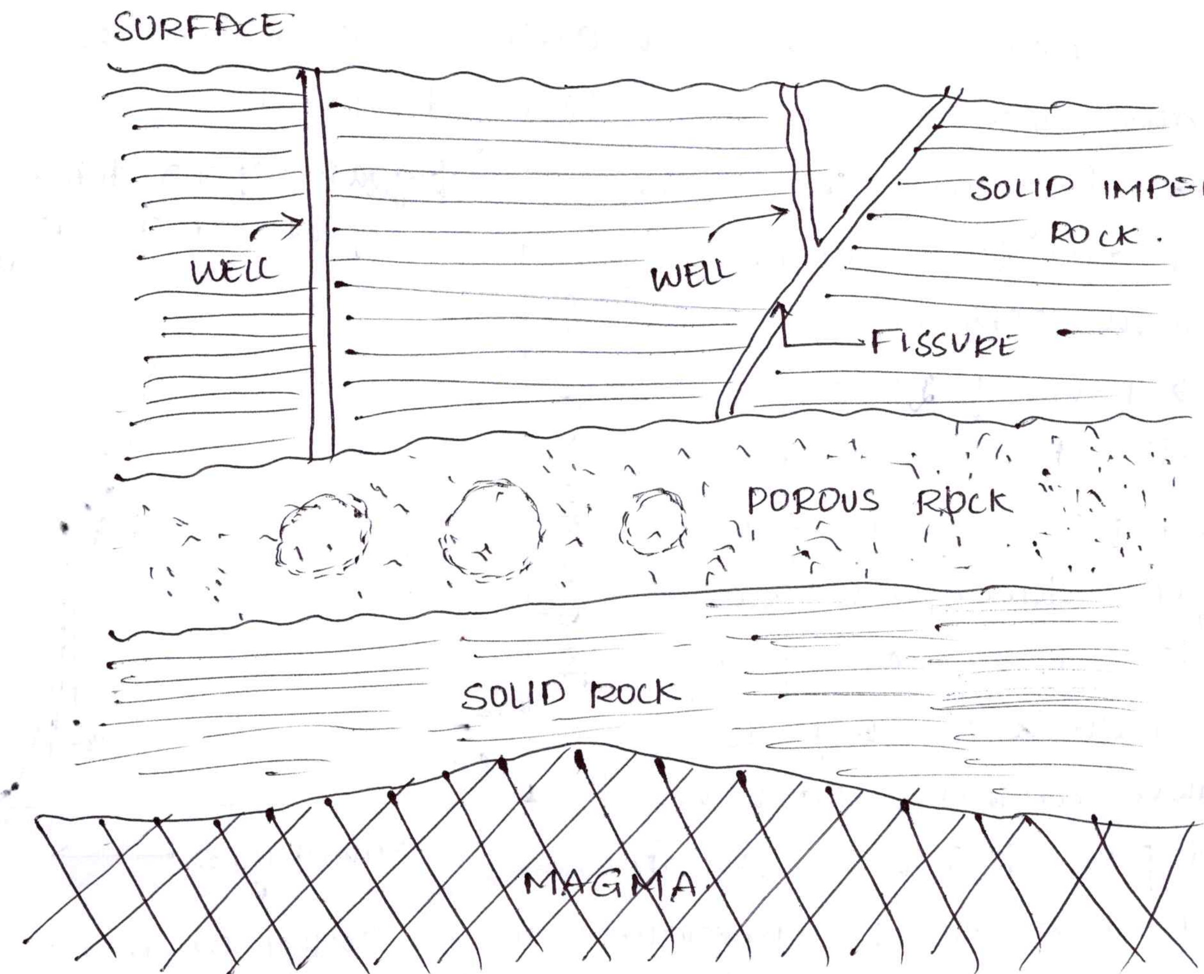
→ These are wet reservoirs at moderate depths containing system steam and/or hot water under pressure at temperatures upto about 350°C. These systems are further subdivided, depending upon whether steam or hot water is dominant.

→ If the temperature is high enough, the water or steam can be used to generate electricity, otherwise the geothermal energy is best supplied to process and space heating.

→ Hydrothermal resources arise when water has access to high temperature rocks, this accounts for the description as "Hydrothermal".

→ The Heat is transporated from the hot rocky by circulating movement
i.e., by convection of the water in a porous medium.

→ The general geological structure of a hydrothermal convective region is shown in simplified form in Fig (1).



Fig(1): Hydrothermal Convective region

→ The Molten rock (magma), raised by internal earth forces is overpaid by an impervious rock formation, Through which heat is conducted upward.

Above this is a permeable layer into which water has penetrated, often from a considerable distance.

→ The permeability could result from fractures or intergranular pores.

→ The heat taken up by the water from the rocks below, is transferred by a convection to a layer of impervious rocks.

Hot water or steam often escapes through fissures in the rock, Thus forming hot springs, geysers fumarols etc. In order to utilize the hydrothermal energy, wells are drilled either to intercept a fissure or more commonly, into the formation containg the water.

→ The Hydrothermal range wells in depth from above 600 to 2100m.

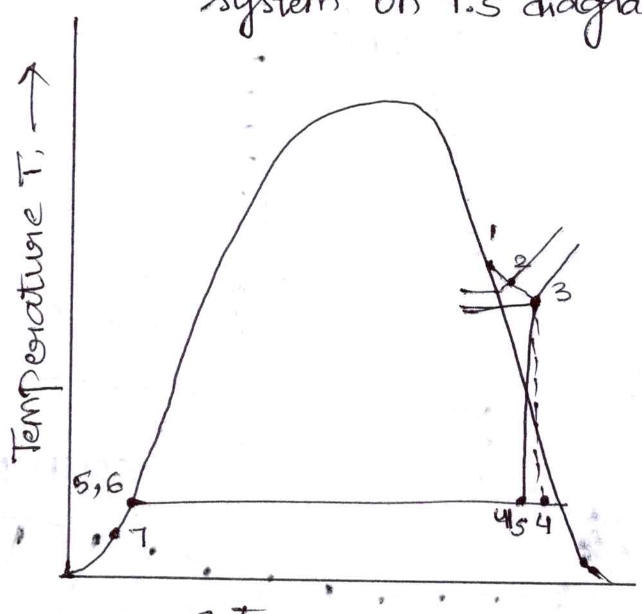
(i) Vapour Dominated systems :- (or) (Dry steam geothermal source) :-

These are the most attractive geothermal resources because They are the most easily developed.

→ They have the lowest cost and least number of serious problems.

→ From fig2(a) and fig (b) show an schematic and T.S. diagram of a vapour-dominated power system. Dry steam from the wells is collected to remove abrasive particles and passed Through turbines, which drive electric generators in the usual manner.

fig2a :- vapour dominated system on T.S diagram.



2) ~~Vapour~~ Liquid - Dominated system :-

→ In The liquid dominated reservoir, The water temperature is above The normal boiling point (100°c). However because the water in the reservoid is under pressure, it does not boil but remains in The liquid state.

When The water comes to The surface The pressure is reduced; rapid boiling Then occurs and The liquid water "flashes" into a mixtures of hot water and steam. The steam can be separated and used to generate electric power in The usual manner.

→ The Methods of Liquid Dominated systems :-

(a) The flashed - steam system, suitable for water in The higher temperature range, and.

(b) The binary - cycle, system, suitable for water at moderate temperature.

(c) A Third method called, The total flow system, concepts of it is also covered, but this approach awaits further development.

(a) The Flashed - Steam System :-

→ This is illustrated by The flow and T.S diagram of figs3(a and b). water from The under ground reservoir at 1 reaches as well head at 2 at a lower pressure.

→ Process 1-2 is essentially a constant enthalphy Throttling process That results in a two-phase mixture of low Quality at 2.

→ This is throttled further in a flash separator resulting in a still low but slightly to higher quality at 3.

→ This mixture is now separated into dry saturated brine at 5. The latter is reinjected into The ground.

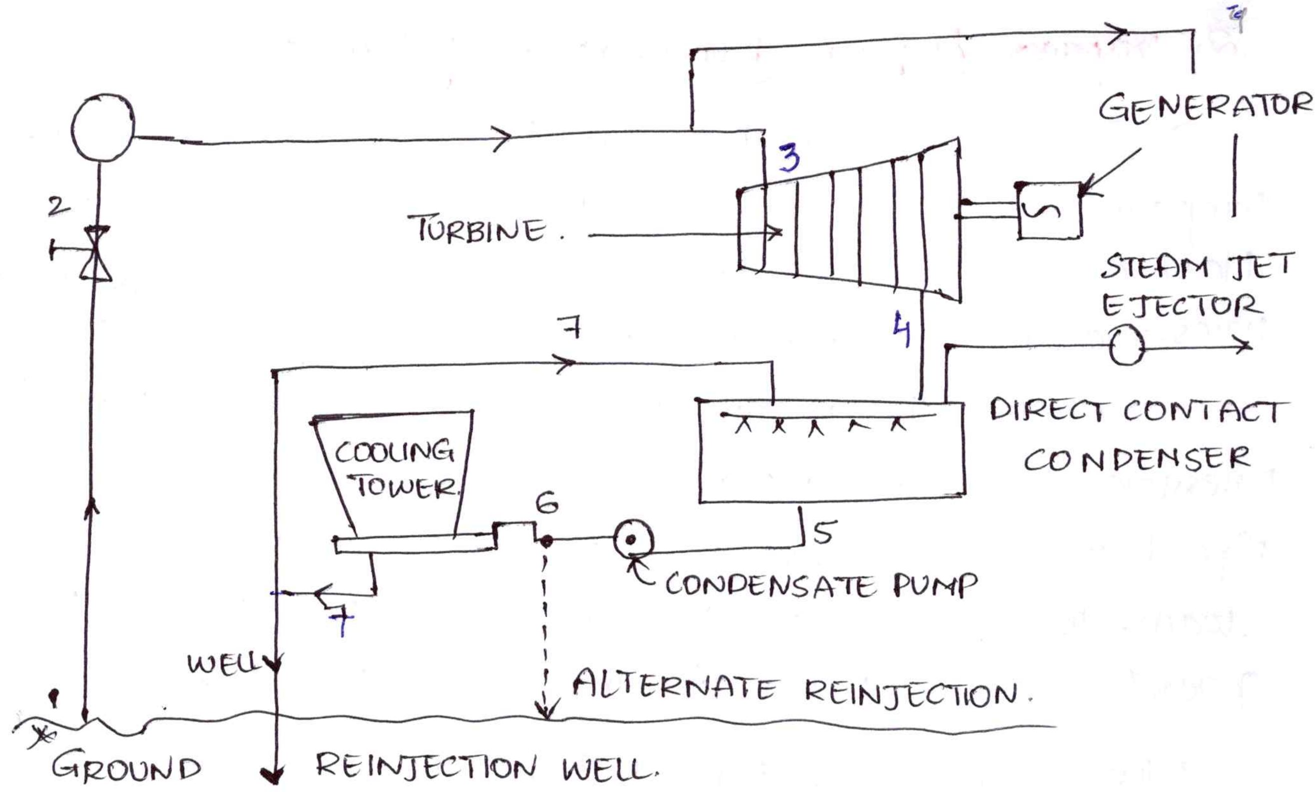


fig 2b :- Scheme of a vapour-dominated power plant

→ The Dry steam from the well (1) at perhaps 200°c is used. It is simply saturated have a shut-off pressure upto about 35 kg/cm². is (≃ 35 bar).

→ Pressure drops through the well causes it to slightly super heat at the well head (2). The pressure there rarely exceeds 7kg/cm² (~7 bar). It them goes through a centrifugal separation and then enters turbine after additional pressure drop

→ The condensation of steam continuosly increases the volume of the cooling water. Part of this is lost by evaporation in the cooling towers (6), and the remainder by injected deep into the ground (7) for disposal.

→ The turbine exhaust steam at (4) mixes, with the cooling water (7) that comes from cooling water tower. The mixture of cooling water coming from the cooling tower and turbine exhaust is saturated vapour at (5) that is pumped to the cooling tower (6).

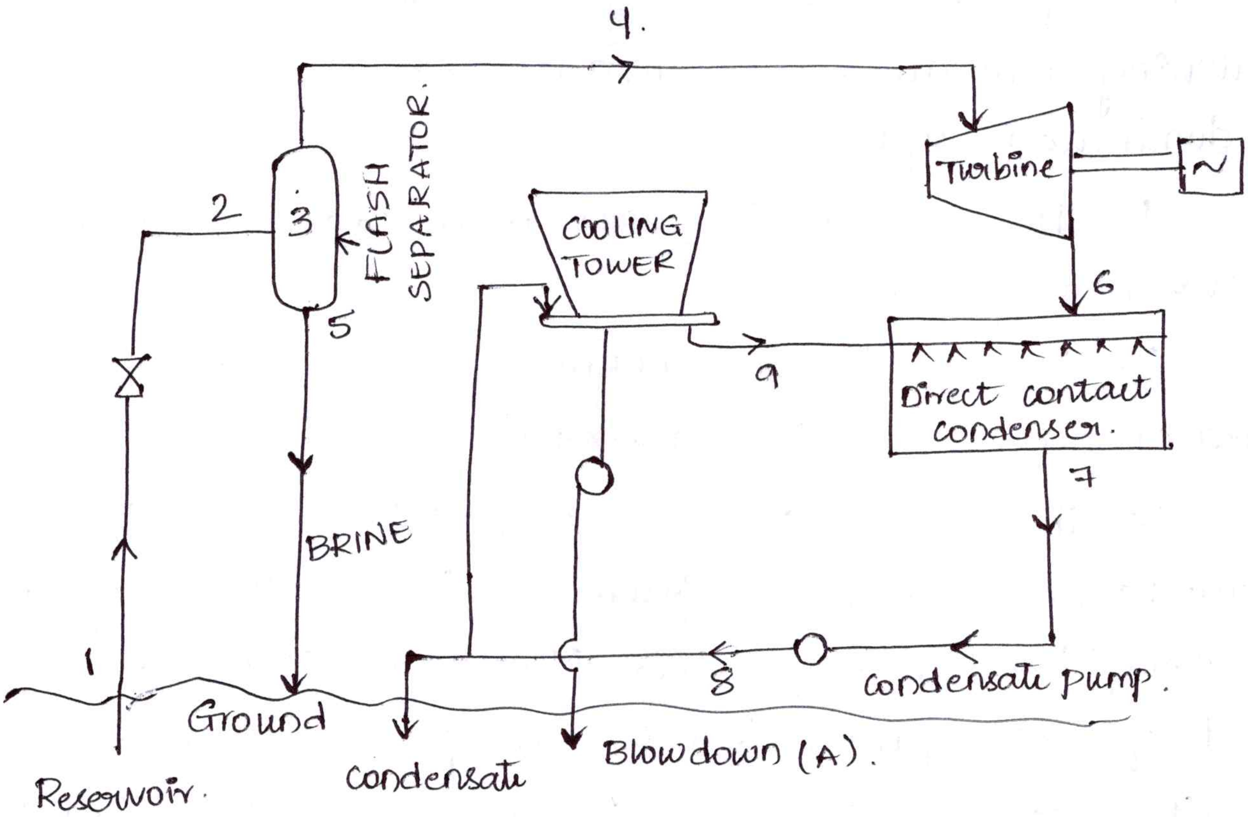


Fig: 3(a): Schematic of a liquid dominated single-flash steam.

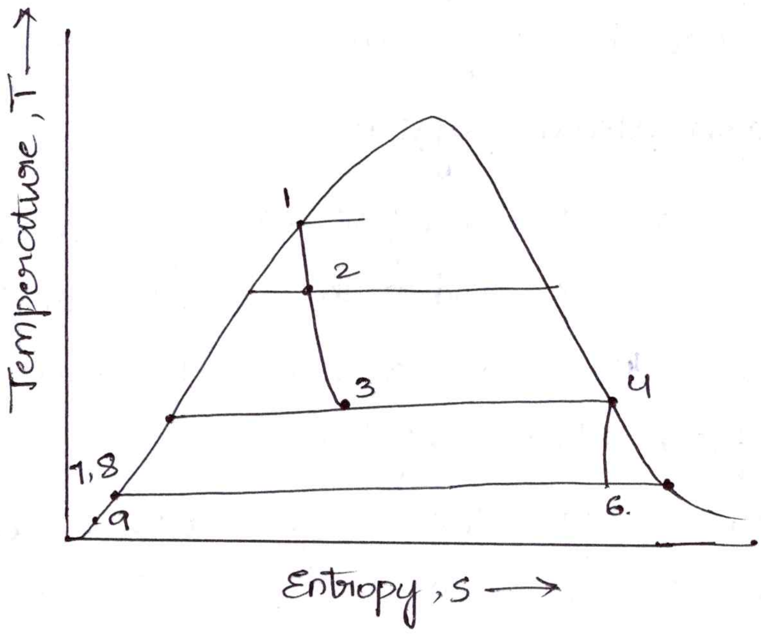


Fig 3(b): T-S diagram of a liquid dominated single flash steam system.

Fig(3)

The flashed-steam system described above has the following limitations as compared with a vapour-dominated system

(1) This system requires much larger total massflow rates through the well

(2) Due to large amount of flows, there is a greater degree of ground surface subsidence.

(3) The system provides a greater degree of percipitation of minerals from the brine, resulting in the necessity for design of valves, pumps, separator internals, and after equipment for operating under scaling.

(4) Greater corrosion of piping, well casing, and other conduits.

(5) Many times temperature and pressure of the water may not be sufficient to produce the flash steam.

Double Flash steam system :-

→ Double Mass Flash cycle can give more power than the single flash cycle under the same condition.

→ Fig4a and4b show a schematic flow and T-S diagram of a double flash steam system.

→ Depending upon the original water conditions, the brine at 5 in admitted to a second, lower-pressure separated where it flashes to a lower pressure steam(6) that would be admitted to a low pressure stage.

→ The remaining spent brine at 8 is in reinjected in to the ground.

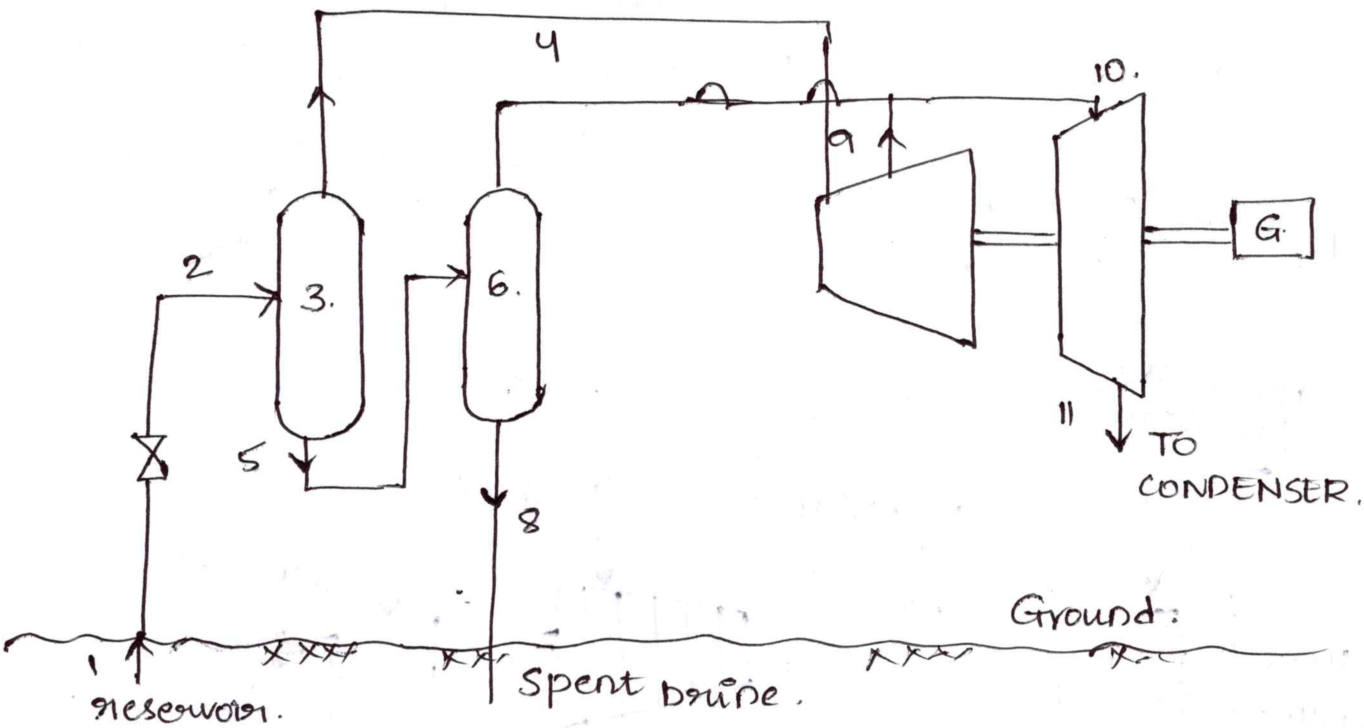


fig 4(a): Schematic of liquid-dominated double flash steam system.

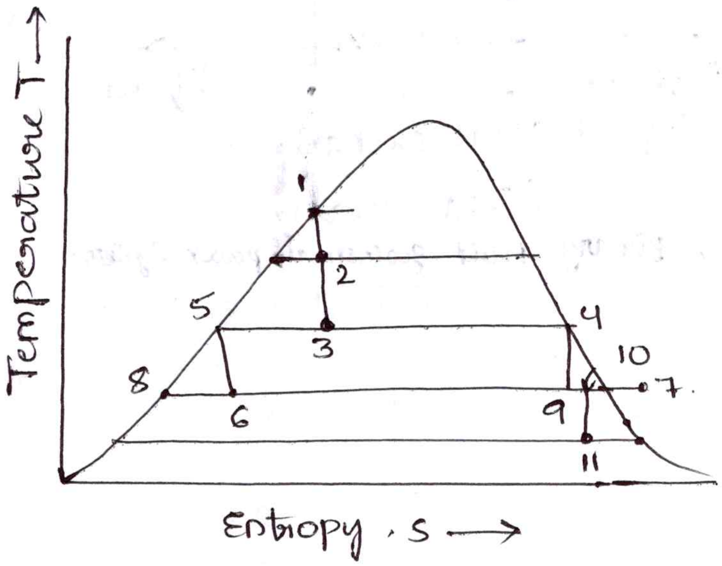


fig 4(b): T-S diagram of a liquid Dominated double flash.

(b) Liquid - Dominated system - Binary Cycle:

→ In order to isolate the turbine from corrosive or erosive materials and/or to accommodate higher concentration of noncondensable gases, the binary cycles concept is now receiving considerable attention as an alternate power cycle.

→ This is basically as Rankine cycle with an organic working fluid.

→ Flow diagram of a binary-cycle system is shown schematically in fig. Hot water or brine from the under ground reservoir either as unflashed liquid or as steam producing by flashing is circulated through a primary heat exchanger.

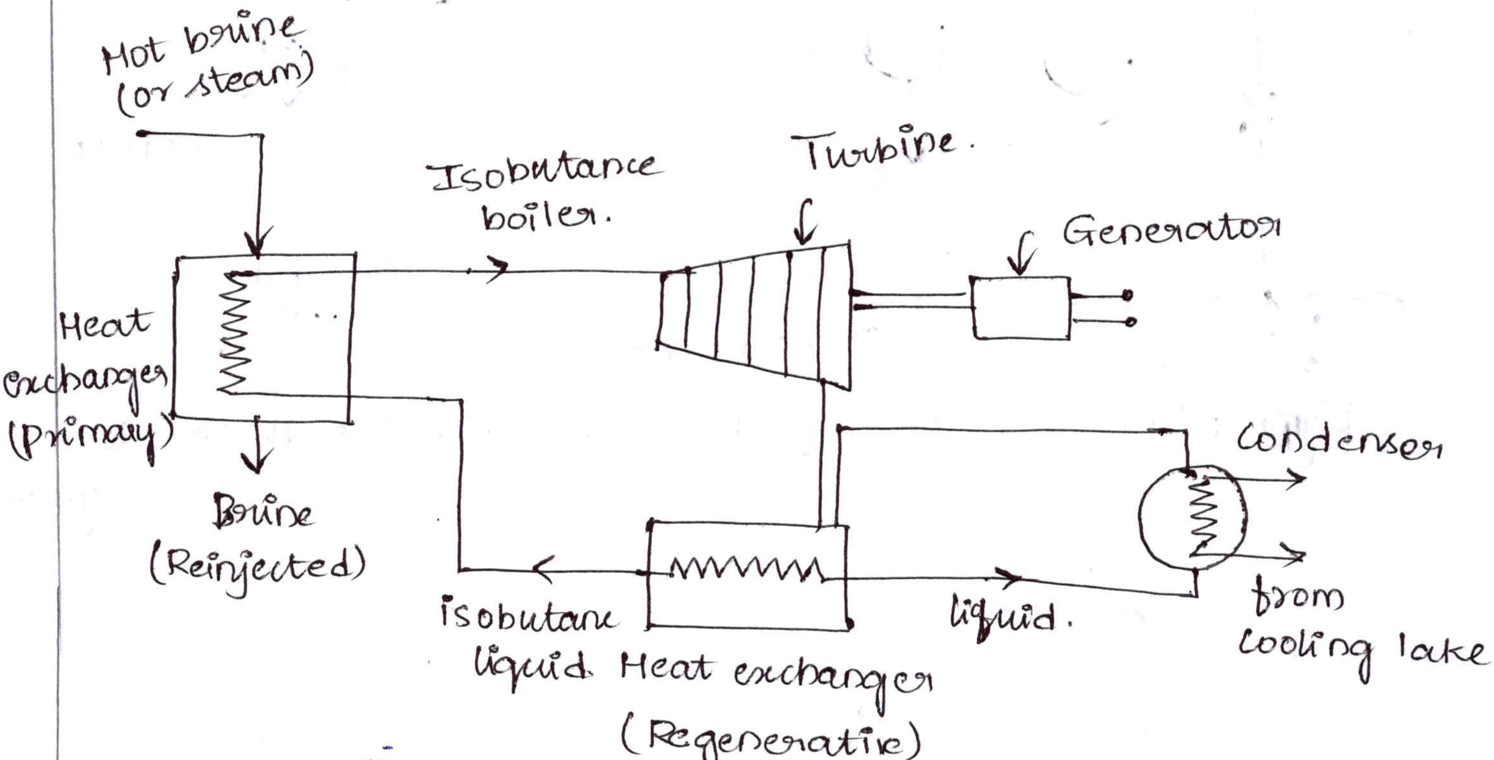


Fig 5 ; Binary fluid geothermal power system.

→ The condensed liquid organic ~~or~~ fluid is returned to the primary heat exchanger by way of the regenerative heat exchanger

→ The hot geothermal fluid and the organic fluid, constitute the two fluids of the binary-fluid system.

→ In the binary cycle there are no problems of corrosion or scaling in the working cycle components, such as the turbine and condenser.

→ The exhaust vapour from the turbine is cooled in the regenerative heat exchanger and then condensed, using either and air cooled condenser or a water-cooled condenser and cooling tower.

(c) Total Flow concept :-

→ A Third approach called The total flow concept would utilize both The kinetic energy and heat energy of The steam-liquid mixture produced by flashing The geothermal brine. The overall Efficiency for conversion into electrical energy should be greater than in The methods described above in which only The heat content of The brine is utilized.

→ The principle of The total flow concept is simple. The flow and T-S diagrams are show in fig a and b.

→ The hot brine from geothermal well at 1 is Throttled to 2, where it becomes a two-phase mixture of low quality.

→ The two phases at This point are not separated, The full flow is expanded to 3, condensed to 4.

→ Then The brine is reinjected into The ground at 5.

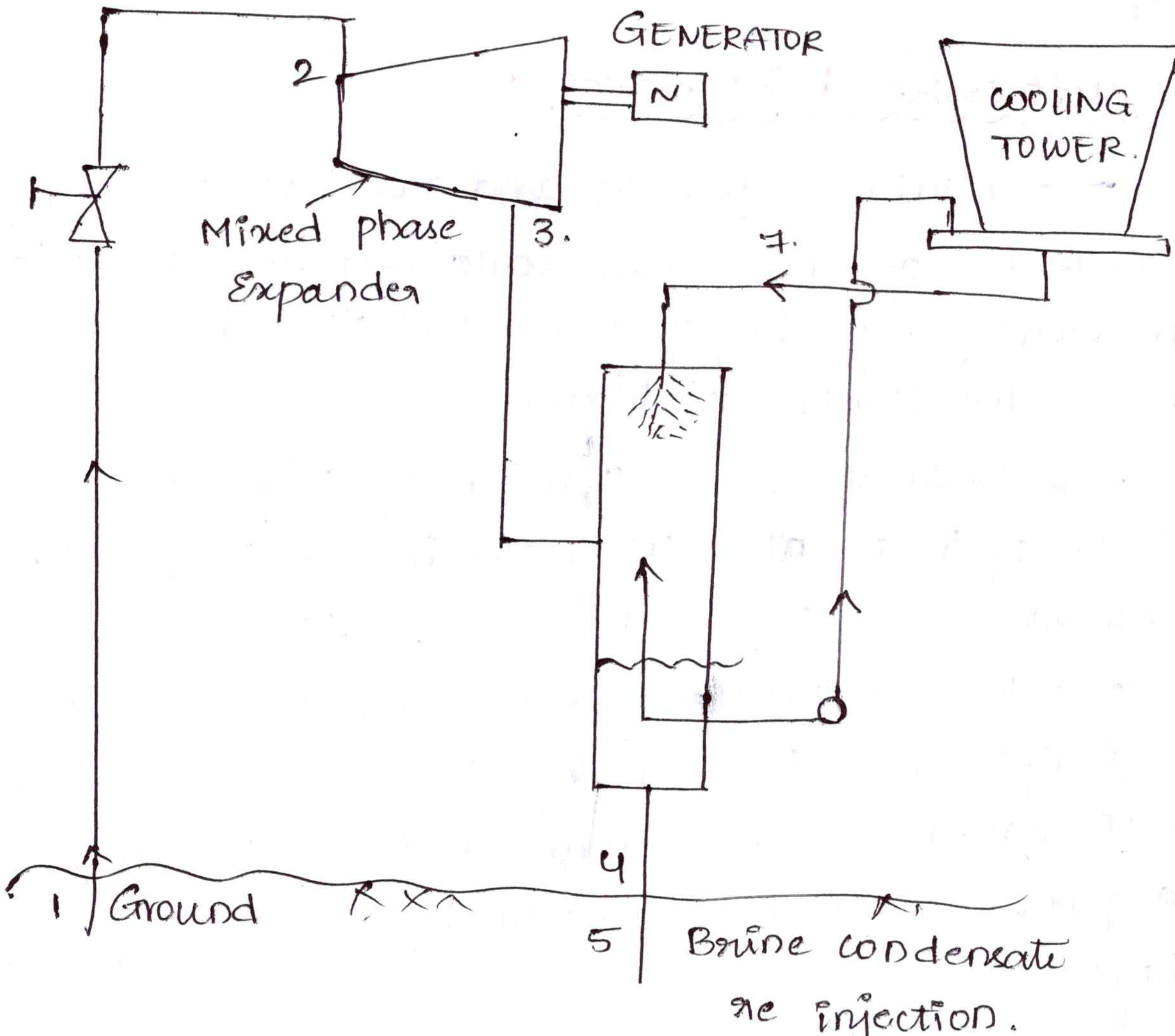
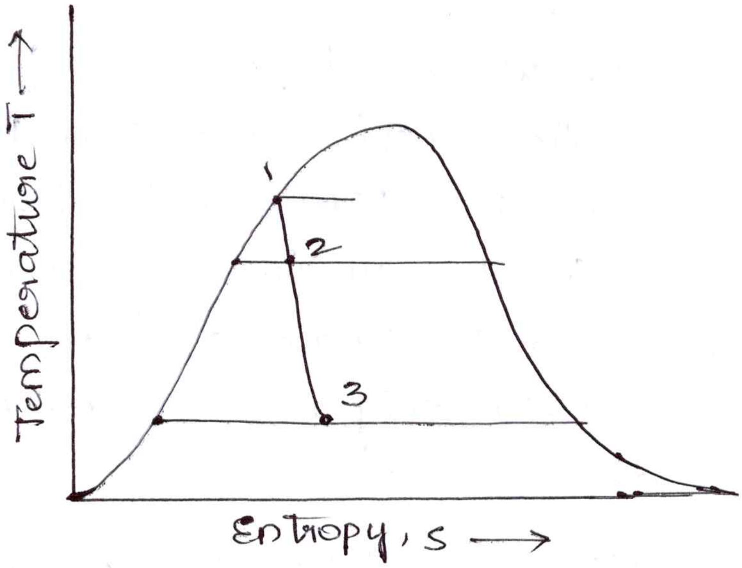


Fig 6(a): Schematic of a liquid-dominated total flow.



Fig(6): TS-diagram for liquid dominated total flow system

→ The requirements of mixed phase expanders are that they should be able to overcome the losses associated with the impingement of liquid droplets on blades.

→ They must also be able to withstand the corrosive and erosive effects of the significant quantities of dissolved solids in the brine.

Geo Pressured Resources :-

→ Drilling for oil and gas has revealed the existance of reservoirs containing salt water at moderately high temperatures and very high pressures in a belt some 1200 km in length.

→ Because of the abnormally high pressure of the water, up to 1350 atm. (137 MPa) in the deepest layers, the reservoirs are referred to as geopressured.

→ The Geopressured hot water (or brine) reservoirs were apparently formed by accumulation of geothermal heat stored over several million years, in water trapped in a porous sedimentary medium by the overlying impervious layers.

→ The upward loss of heat stored relatively small and there are no obvious surface indications of the deep, high temperature reservoirs.

→ A special feature of geopressured waters (or brines) is their content of methane.

→ The energy value of the brines thus depends on their temperature.

→ The solubility of Methane in water at normal pressure is quite low, but it is increased at the high pressures of the geothermal reservoirs.

→ when the water is brought to the surface and its pressure reduced, the methane gas is released from solution. The gas content of geopressured brine is usually about 1.9 to 3.8 cu m. gas per cu m. water.

Hot Dry Rocks Resources or Petrothermal systems :-

→ Petrothermal systems are those that are composed of hot dry Rock (HDR) but no underground water.

→ They represents by far the largest geothermal resource available

→ The rock, occuring at moderate depths, has very low permeability and needs to be fractured to increase its heat transfer surface.

→ The thermal energy of the HDR is extracted by pumping water through a well that has been drilled to the lower part of the fractured rock.

→ The water ~~removes~~ through the fractures, picking up heat. It is then travels up a second well that has been drilled to the upper part of the rock and finally back to the surface.

There, it is used in a power plant to produce electricity.

→ These types are not associated with hydro-thermal activity. Such resources, with rock temperatures exceeding about 200°c at depths upto 5 km are estimated to be significant and worthy of development as a source of energy.

→ In Principle, The recovery of heat from such hot dry rocks involves breaking up or cracking The rock to make it permeable and then introducing water from The surface. The water is heated up by The rock and is returned to The surface where The heat is utilized.

→ There are Two methods to tap This geothermal energy one possible method is to detonate a high explosive at The bottom of a well drilled into The rock.

→ water would be injected into This well, circulated Through The cavities so formed to extract heat from rock. The water or water-steam mixture is withdrawn Through another well. (fig).

→ Another method is to use hydraulic fracturing to Produce The heat transfer surface and permeability required to extract energy at a high rate from hot dry rock.

→ Hydraulic fracturing, which is performed by pumping water at high pressure into The rock formation, is commonly used in oil and gas fields to improve flow.

→ The Hot water or water steam mixture is utilized for generation of electricity with a binary liquid system using Freon (R-114) as The turbine working fluid.

→ It is believed That HDR systems offer more flexibility in operation and design That other geothermal systems.

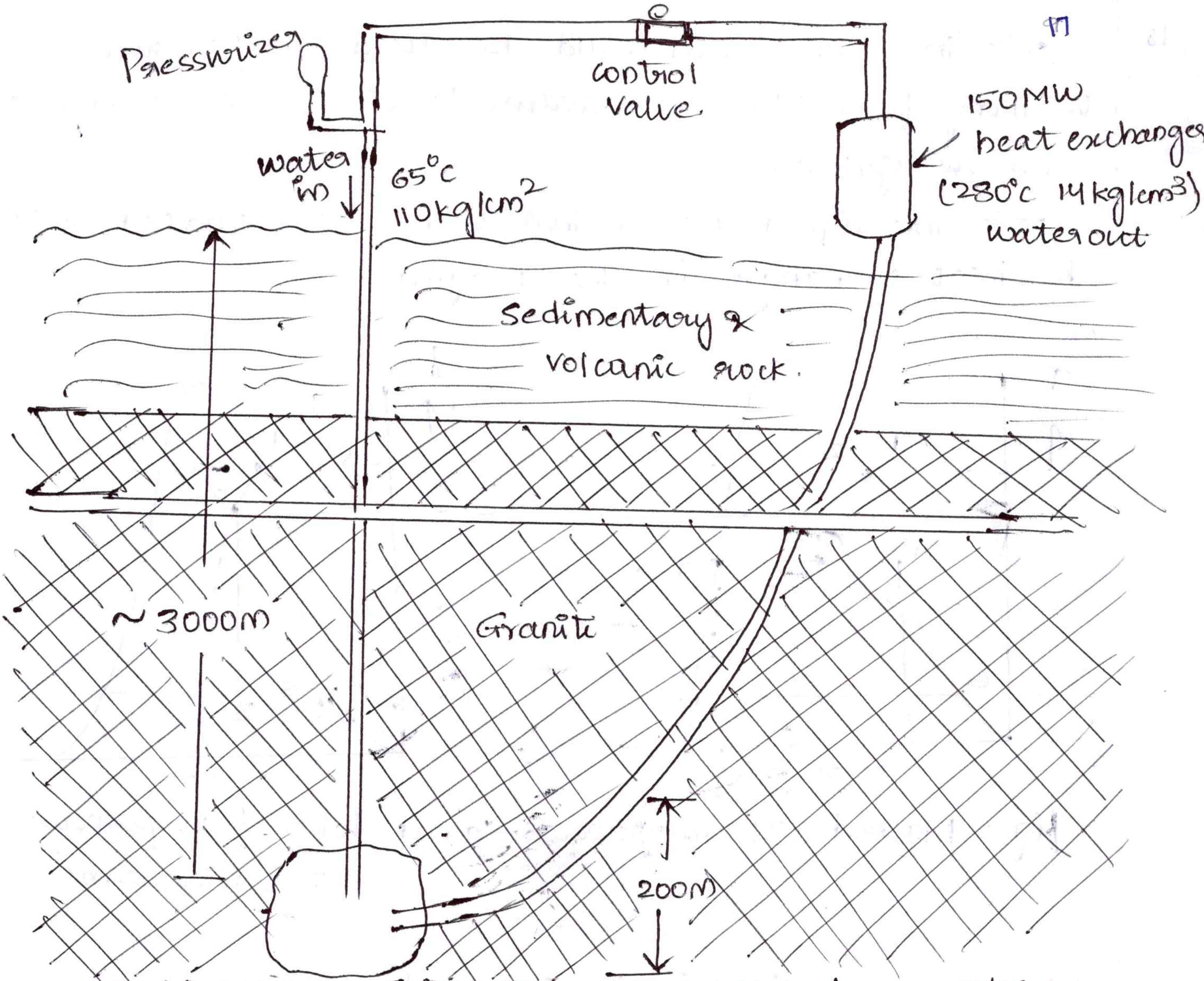


fig: Heat Extraction from Hot dry rocks.

→ **Magma Resources (Molten Rock - chamber systems) :-**

→ In some cases, especially in the victinity of relatively recent volcanic activity molten or partically molten rock (i.e magma). Occurs at moderate depths (eg. less than 5 km).

→ The very high temperature above 650°c and the large volume make magma a substantial geothermal resources.

→ A concept being studied for the U.s Department of energy by the sandia National laboratories to place a heat exchanger within the magma.

→ Heat would be transferred to a suitable liquid and brought to the surface.

→ The Hot liquid could be used to produce a working fluid, possible steam, to operate a turbine and electric generator.

→ The liquid would then to be recirculated through the heat exchanger in the Magma.

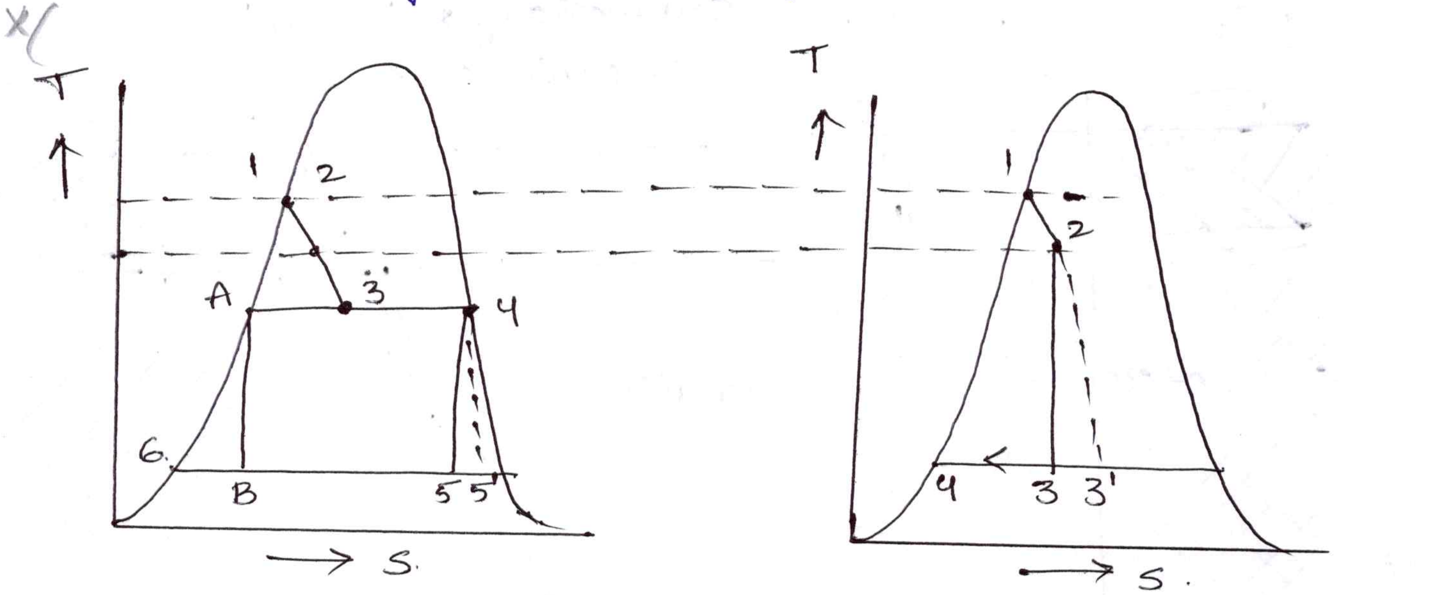


fig : Flashed steam process and total flow process on T-S diagrams.

Advantages and DisAdvantages of Geothermal Energy over other energy forms :-

This energy form posses distinct advantages over conventional and new energy form sources :

(1) Geothermal energy is versatile in its use.

(2) It is cheaper, compared to the energies obtained from other sources both zero fuels and fossil fuels.

(3) Geothermal energy delivers greater amount of net energy from its system then other alternative or conventional systems.

(4) Geothermal power plants have the highest annual load factors of 85% to 90% compared to 45% - 50% for fossil fuel plants.

(5) Geothermal energy is the least polluting compared to the other conventional energy sources.

(6) The greatest attraction of geothermal energy is the amenability for multiple uses from single resources.

(7) Geothermal energy is the least renewable resources that has practically no intermittency, has the highest energy density, and is economically.

This energy has also got the following Disadvantages:

(1) Overall efficiency for power production is low, about 15%, compared to 35-40% for fossil fuel plants.

(2) The withdrawl of large amounts of steam or water from a hydrothermal reservoir may result in surface subsidence

(3) The steam and hot water gushing out of the earth may contain H_2S, CO_2, NH_3 and radon gas etc.

(4) Drilling operation is Noisy.

(5) Large areas are needed for exploitation of geothermal energy as much of it is diffused.

Applications of Geothermal Energy :-

There are three main applications of the steam and hot water from the wet geothermal reservoirs:

(1) Generation of electric power,

(2) Industrial power process heat and

(3) Space heating for various kinds of buildings.

Other applications :-

(1) Desalination

(2) Many chemical industries including extraction of valuable minerals from geothermal fluids :

(3) Salt production from sea water.
(4) Heavy water production
(5) Paper Manufacture.
(6) protein and vitamin production
(7) Sulphur and sulphuric acid production.
(8) Timber seasoning
(9) Fruit and juice canning and bottling
(10) Sewerage heat treatment
(11) Anti-freeze for fire-fighting
(12) Sewerage heat treatment
(13) Sugar beet industry.

Potential of Geothermal Resources in India :-

There are about 340 known Thermal areas in India, each represented by hot or warm springs.

→ Many more areas are beings discovered and reported in the 12 well defined geothermal provinces.

→ The total stored heat potential of the 93 systems considered is 36.87×10^{18} calories, which is equivalent to the combustion energy of 5160 million tones of coal or 25440 million barrels of oil.

→ Off the remaining thermal areas, 49 are of intermediate temperature and 6 are of low temperature geothermal resources type which could best be used for non-electrical applications.

→ If the potentials of all 93 systems is cohesive considered for non-electrical applications the cummulative beneficial heat will be of the order of 2.185×10^{18} calories.

→ If this heat is to be supplied from electrical power 10,000 MW of electrically could be required for 30years. period.

Utilization Studies :- Several pilot projects were undertaken by Geological survey of India in collaboration with other agencies such as N.A.L Bangalore, IIT Delhi in the geothermal areas of North-West Himalayan province, which have conclusively proved the vast potentialities for exploitation.

→ A pilot projects for "space heating", at puga, in Ladakh in 1975 at attitude of 4500M, involved construction of a shed and using steam at 125°c, at 2.5 kg/cm^2 from a nearby geothermal well for heating the space.

→ The another project named "Green house pilot project". at chumathang, (Ladakh, 4400m altitude) in 1974, was commissioned. It utilizes hot water from a nearby geothermal well to heat the soil and environment of a green house separately.

→ A Third pilot project "cold storage" plant has been recently commissioned at Manikaran by the joint collaboration of Geological Survey of India, IIT Delhi, and Himachal pradesh Government.

→ Plants are being made to undertake further research and development studies in the area of geothermal energy.