# Geothermal Energy

3ME4-05: Renewable Energy Systems

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1

## Syllabus

Geothermal fields, estimates of geothermal power.

Basic geothermal steam power plant, binary fluid geothermal power plant and geothermal preheat hybrid power plant.

Advantages and disadvantages of geothermal energy.

Applications of geothermal energy.

Geothermal energy in India.

2



# Introduction

- Geothermal energy is primarily heat energy from earth's own interior.
- Volcanoes, geysers, hot springs and boiling mud pots are visible evidence of the great reservoirs of heat that lies within earth.

3

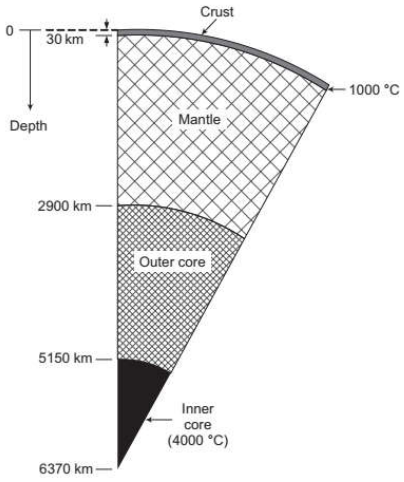
# Geothermal Fields

- Although the amount of thermal energy within the earth is very large, useful geothermal energy is limited to certain sites only, as it is not feasible to access and extract heat from a very deep location.
- The sites where it is available near the surface and is relatively more concentrated, its extraction and use may be considered feasible.
- These sites are known as geothermal fields.
- As per US Geological Survey, the entire heat content of the earth's crust up to a depth of 10 km above 15 °C is defined as geothermal resource.
- As such the geothermal resource is estimated to be more than $2.11 \times 10^{25}$ J, which is equivalent to $10^9$ MTOE (million tons of oil equivalent)

4

# Geothermal considered as renewable

- It is classified as renewable because the earth's interior is and will continue in the process of cooling for the indefinite future.
- Hence, geothermal energy from the earth's interior is almost inexhaustible as solar or wind energy, so long as its sources are actively sought and economically tapped.
- The heat occurs from a combination of two sources:
  - the original heat produced from the formation of the earth by gravitational collapse and
  - the heat produced by the radioactive decay of various isotopes.




5

# Important Aspects of Geothermal Energy

1. Form of energy
   - Thermal energy' in the form of hot water, steam, geothermal brine, mixture of these fluids.
2. Availability
   - Generally available deep inside the earth at a depth more than about 80 km. Hence, generally not possible to extract.
   - In a few locations in the world, deposits are at depths of 300 to 3000 m. Such locations are called Geothermal fields.
3. Method of extraction
   - Deep production wells are drilled in the geothermal fields.
   - The hot steam/water/brine is extracted from the geothermal deposits by production wells, by 'pumping' or by 'natural pressure'.

6

# Important Aspects of Geothermal Energy

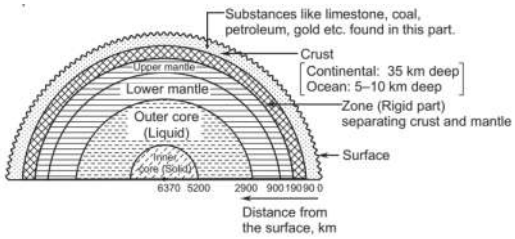
4. Geothermal fluids
   - Hot water;
   - Hot brine;
   - Wet steam;
   - Mixture of above
5. Range of geothermal power plants installed capacity
   - 5 MW to 400 MW
6. Average geothermal gradient
   - 30°C per 1000 m length
7. Geothermal energy released through earth's crust
   - About 0.06 W/$m^2$

7

# Structure of Earth's Interior

The earth consists of the following parts (concentric shells):

- **Crust**
  - It is the uppermost shell of earth that extends to variable depths below mountains, continents and oceans.
  - The thickness of crust is believed to be 0.90 km and several substances like limestone, coal, gold, petroleum etc. are found in the crust.
- Mantle
  - It is the second concentric shell of earth that lies below the crust.
  - The upper rigid part of the mantle extends up to 100 km below the separating crust and contains mainly iron and magnesium.
  - The crust and upper mantle form the 'lithosphere'.



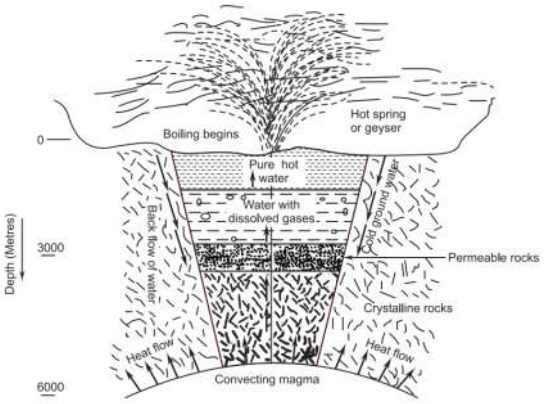

- **Core**
- It is the innermost concentric shell of the earth.
- The core boundary begins at a depth of 2900 km from the surface and extends to the centre of the earth at 6370 km.
- This layer is further subdivided into outer core and inner core.
- The outer core comprises the region from a depth of 2900 km to 5200 km below the earth's surface and behaves mere like a liquid.
- The inner core with a thickness of around 1170 km is believed to be a solid metallic body, containing nickel-iron alloy.

**The hot molten rock of the mantle is called Magma**

8

# Geothermal System – Hot Spring Structure

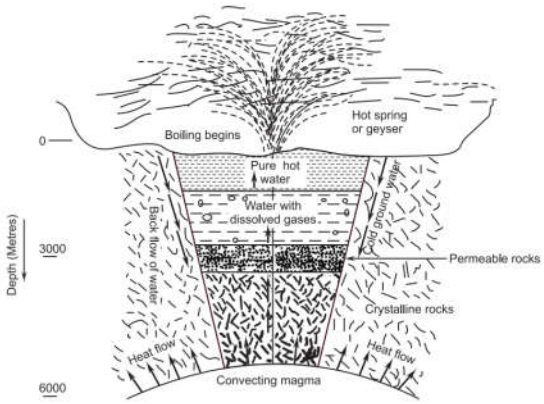
- "Hot springs (geysers)" are produced through hot magma (molten mass), the fractured crystalline rocks, the permeable rocks and percolating ground water.
- At a depth of 5000 m or so lies an impermeable magma.
- Above the magma are the 'impermeable rocks' which are overlain by localised pockets of 'permeable rocks'.




9

# Geothermal System – Hot Spring Structure

- The localised pockets are bounded by fracture zones or faults along which some relative motion of rocks has occurred.
- Water circulates along the fault lines.
- As it goes down and moves in earth's interior it is heated by the permeable layer which is in turn heated by conduction of heat from the magma.
- The hot water comes out through another fault and forms a hot spring.




10

# Geothermal Resources

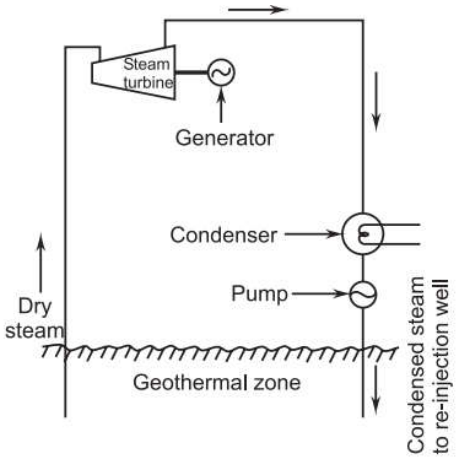
*Geothermal resources are of following five types:*

1. Hydrothermal or hydro-geothermal energy resources:
   - Vapour-dominated or dry steam fields;
   - Liquid-dominated system or wet steam fields;
   - Hot-water fields.
2. Geopressured resources.
3. Petro-thermal systems or hot dry rocks (HDR) resources.
4. Magma resources (Molten-rock-chamber systems).
   - The "hydro-thermal convective systems" are best resources for geothermal energy exploitation at present.

11

# Hydrothermal

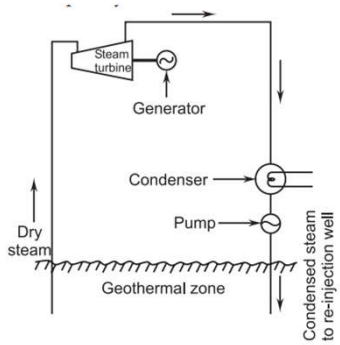
- In hydrothermal convective system water is heated by contact with hot rocks.
- These are wet reservoirs containing steam and hot water or only hot water.
- If the temperature is high enough then 'steam' generates electricity, otherwise 'hot water' is used for space heating and process heating.
- The water present in the porous medium is heated by convection process and convective heat flow occurs across hot rocks to water present in porous rock.




12

## Hydrothermal: Vapour-dominated or dry steam fields

- The vapour-dominated reservoirs produce dry saturated steam of pressure above atmosphere and at high temperature about 350°C.
- Steam extracted from the well is cleaned in centrifugal separator which removes solid matters.
- The cleaned steam is used to generate electricity
- The condenser condenses wet steam into water (through a cooling tower).
- The non-condensable gases present in wet steam are removed by 'steam jet injection method'.
- The condensed steam is reinjected deep into the ground/well.




13

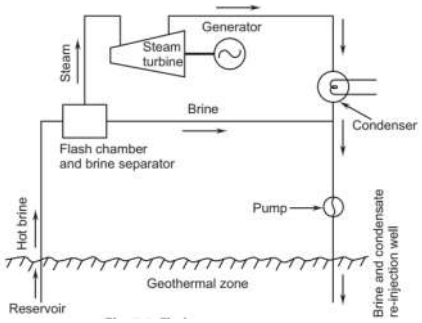
## Hydrothermal: Liquid-dominated systems or wet steam fields

- Water temperature is above the normal boiling point (100°C).
- Due to the pressure inside the reservoir, water does not boil but remains in liquid state.
- When the water comes on the earth surface its pressure reduces resulting in rapid boiling and the liquid water 'flashes into a mixture of hot-water and steam'.
- The steam is separated from mixture and used to generate electricity.
- Liquid-dominated high temperature systems:
- For such systems, the following two methods are used :
  - The flash steam open system.
  - The binary cycle system.

14

# Hydrothermal: Liquid-dominated systems
## Flash Steam Open System

- Hot brine from the reservoir reaches the well head at lower pressure by throttling process.
- This low quality mixture is then throttled in flash separator which improves the quality of mixture.
- Now steam is separated as a dry saturated steam and supplied to the 'steam turbine', which produces electric power through a 'generator'.
- The 'power generation' from such system can be made more economical by associating chemical industry with power plant to make use of brine and gases effluent.

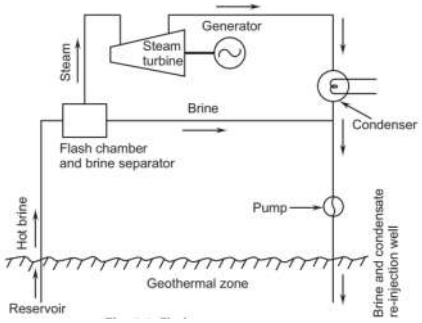



15

# Hydrothermal: Liquid-dominated systems
## Flash Steam Open System

Following are the limitations of flash steam open system as compared to vapour-dominated system:

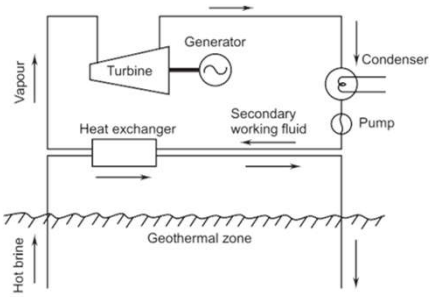
- Much larger total mass flow rates through the well required.
- Owing to large amount of flows, there is a great degree of ground surface subsidence.
- A greater degree of precipitation of minerals from the brine results in the necessity for design of valves, pumps, separator internals, and other equipment for operation under scaling conditions.



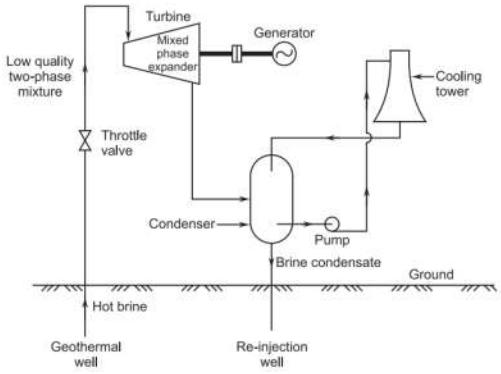

16

# Hydrothermal: Liquid-dominated systems
## Binary Cycle System

- The binary cycle concept isolates the steam turbine from corrosive or non-corrosive materials and/or to accommodate higher concentration of non-condensable gases.
- This is basically a Rankine cycle with an organic working fluid.
- About 50 per cent of hydrothermal water is in the temperature range of 153°C to 205°C.
- A 'heat exchanger' is used to transfer a fraction of the brine enthalpy to vaporize the secondary working fluid.
- Expansion through a 'turbine' to a lower pressure is fixed by the heat rejection temperature which provides the means for power generation.




17




# Hydrothermal: Liquid-dominated systems
## Total flow concept system

- In such a system, both 'kinetic energy' and 'heat energy of the steam-liquid mixture, produced by flashing the geothermal brine, are utilized.
- The overall efficiency for conversion into 'electrical energy' should be greater than other methods (described earlier) in which only the heat content of the brine is utilized.
- This system utilizes the principle of the 'Lysholm machine', known in this connection as the helical (or screw) expander or mixed phase expander.

18

## Advantages of Geothermal Energy

- Geothermal energy is cheaper.
- It is versatile in its use.
- It is the least polluting as compared to other conventional energy sources.
- It is amenable for multiple uses from a single resource.
- Geothermal power plants have the highest annual load factors of 85 per cent to 90 per cent compared to 45 per cent to 50 per cent for fossil fuel plants.
- It delivers greater amount of net energy from its system as compared to other alternative or conventional systems.
- Geothermal energy from the earth's interior is almost as inexhaustible as solar or wind energy, so long as its sources are actively sought and economically tapped.

19

## Advantages And Disadvantages of Geothermal Energy

- Low overall power production efficiency (about 15% as compared to 35 to 40% for fossil fuel plants).
- Drilling operation is noisy.
- Large areas are needed for exploitation of geothermal energy.
- The withdrawal of large amounts of steam or water from a hydro-thermal reservoir may result in surface subsidence or settlement.

20

# Applications of Geothermal Energy

- Generation of electric power.
- Space heating for buildings.
- Industrial process heat
- Crop drying.
- Plastic manufacture.
- Paper manufacture.
- Mushroom culture.
- Timber seasoning.
- Production of salt from sea.
- Sewage heat treatment
- Greenhouse cultivation using discharge from a geothermal field.

21

# Geothermal in India

- India is still at nascent stage of geothermal energy utilization with no geothermal power plant set up in the country so far due to
  - High upfront cost of Rs 30 Cr/MW
  - Indicative Tariff in range of Rs 10 per KWh,
  - Site specific deployment,
  - Lack of load center and power evacuation facility nearby,
  - High risk involved in exploration, etc.
- Geological Survey of India (GSI) with CSIR - National Geophysical Research Institute (NGRI) carried out preliminary resource assessment for the exploration and utilization of geothermal resources in 1970s & 1980s in the country.

22

# Geothermal in India

- Some progress has been made in India on tapping geothermal energy on a commercial scale.
- Engineers from the Geological Survey of India have drilled about 50 shallow wells for steam in the Puga valley of the Ladakh region in Jammu and Kashmir.
  - It may be possible to operate a 5 MW power station at the site.
  - The Puga valley at an altitude of 4500 metres above sea level has the most promising geothermal field.
  - The area extends to about 40 square kilometres out of which 5 sq. km is active.
  - A combination of wet and dry steam to the tune of 170 tonnes of hot water per hour and 20 tonnes/hour of dry steam (superheated steam suitable for running steam turbines) is available.
  - The geothermal heat can also be used for space heating in the Puga valley

23

# Thank You

24