

POWER GENERATION FROM LOW-ENTHALPY GEOTHERMAL RESOURCES

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INTRODUCTION

After a briefly presentation of power generation from geothermal energy, this paper presents the binary power plant at the University of Oradea as an example of geothermal low-enthalpy utilization for power generation.

POWER GENERATION FROM GEOTHERMAL ENERGY

The total worldwide installed electric power capacity exceeds 8 GW as far as geothermal sources are concerned (Sanner, 1998). This installed capacity is not equally distributed around the world. The United States is first, followed by the Philippines, Mexico and Italy. Japan, New Zealand and El Salvador are others worth mentioning as places of geothermal electricity production. Certain geological locations provide high enthalpy resources that are best adapted for power production. These are the so-called plate boundaries which take the form of subduction zones, spreading zones, or rift zones. These zones will remain the main areas of interest until the time when HDR (hot dry rock) technology might allow geothermal production virtually everywhere in the world. Consequently, the countries that are positioned within these zones may become more independent from oil import because of the possibility of using indigenous energy.

The technology of geothermal binary fluid has been researched and developed for the purpose of generating electricity from low-to-medium temperature resources and of utilizing the thermal resources through the recovery of waste heat. A well known source of waste heat in geothermal fields is the waste water from flash separators (Hudson, 1998).

The Figure 1 presents a simplified schematic of a binary system. A secondary working fluid has a low boiling point and a high vapor pressure at low temperatures when compared to steam and this is the fluid that the binary system utilizes. This secondary fluid is operated through a conventional Rankine cycle. Temperatures in the range of 85 to 170°C (185 to 338°F) are the values at which the binary system can be designed to operate through the selection of appropriate working fluid. The upper temperature limit is restricted by the thermal stability of the organic binary fluids.

The lower temperature limit is restricted by practical and economic considerations, as the heat exchanger size for a given capacity becomes impractical and the parasitic loads (from well and circulating pumps for example) requires a large percentage of the output. Before being expanded through a turbine to some lower pressure temperature, heat is transferred from the geothermal brine to the binary cycle via heat exchangers where the binary fluid (or working fluid) is heated and vaporized.

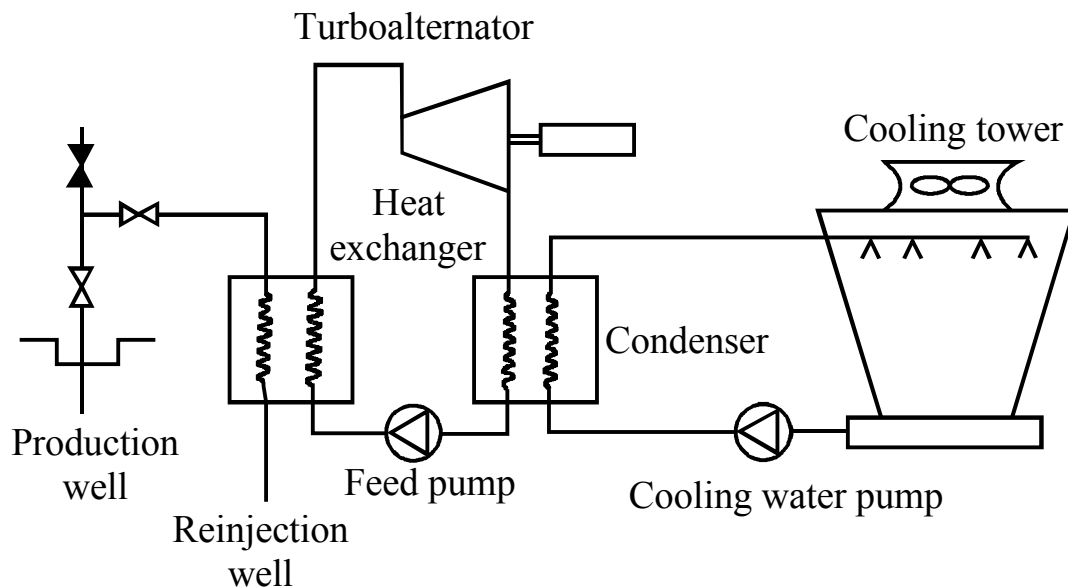


Figure 1. Simplified scheme of a binary system.

The binary plants have been small modular units varying in size from hundreds of kilowatts to several megawatts. The small development linked to modular construction is cost effective and facilitates short manufacturing and installation times. The problem of larger power project in the 10 to 50 MW range, is solved by bringing a number of modular units together in a common development.

Down hole pumps may be used where wells do not flow spontaneously, or where it is advantageous to prevent flashing of the geothermal fluid (to prevent calciting for example), in order to keep the fluid in a pressurized liquid state. Binary units can then be used to extract energy from the circulating fluid.

THE BINARY POWER PLANT FROM THE UNIVERSITY OF ORADEA

The University of Oradea initiated a research program for producing electricity by using geothermal energy. Due to the fact that the geothermal water temperature is less than 100°C (212°F), only a binary cycle could be considered for power generation. According to Maghiar (1995), the first pilot power plant was completed and tested in 1984 and had an installed capacity of 100 kW. The research program continued and two other pilot power plants were designed and completed: one 2 x 250 kW in 1986 and the other 1MW in 1988. Based on the experience gained and the encouraging results obtained with these pilot plants, the research program has been increased and, at present, a team of researchers and teachers have implementing a new pilot power plant with increasing output capacity, estimated at under 2 MW. A programmable logic controller (PLC 2), connected to the SCADA system controls and monitors the operation.

The binary power plant transforms the thermal energy of the water into mechanical energy and then, by a generator, into electric energy. Basically, the working fluid runs in a closed circuit according to a thermodynamic motor cycle, between two heat sources, water at high temperature and cooling water. Usually, the working fluid is hydrocarbon, such as isopentane, or refrigerant, such as R12. For environmental reasons, the working fluid used at this binary power plant is carbon dioxide. There are some advantages in using it, such as no explosion danger, it is non-inflammable, non-toxic and available at low cost. In Figure 2, the thermodynamic cycle of CO₂ in a pressure-enthalpy diagram is presented. Line 1-2 corresponds to the flow of the working fluid in the engine; line 2'-3 is the evolution for transferring heat from CO₂ to the cold water; line 3'-4 shows the passage of the working fluid through the piston pump for increasing the pressure of CO₂; and, line 4-1 shows the flow through the shell and tube heat exchangers where geothermal water transfers heat to the working fluid.

In order to obtain the maximum rated power, it is necessary to maintain the optimal thermodynamic cycle for every operation regime of the power plant and it is necessary to maintain optimal CO₂ parameters when disturbances occur. In a certain steady-state operation regime of the power plant, some disturbances may occur resulting in changing of CO₂ parameters. These changes can be due to fluctuations in

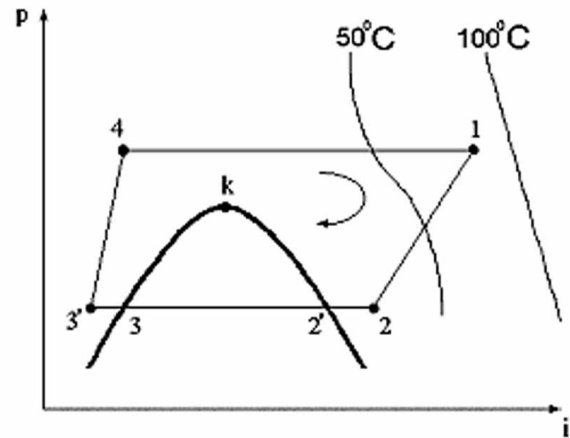


Figure 2. The carbon dioxide thermodynamic cycle in pressure-enthalpy diagram.

geothermal and cold water parameters and geothermal engine parameters (i.e. pressure and temperature fluctuations of CO₂, flows and temperature fluctuations of the geothermal water and cooling water and variations of geothermal engine speed, etc.). To maintain this optimal thermodynamic cycle, the automation of the power plant is required. As mentioned above, this will be accomplished by using a programmable logic controller, PLC2 (Antal, 1995).

The schematic diagram of the binary power plant is presented in Figure 3. Corresponding to the thermodynamic cycle presented above, it comprises a turbine (engine), a condenser with a buffer tank, a CO₂ liquid pump and an evaporator. In order to maintain the optimal thermodynamic cycle, sensors and devices were installed, such as pressure transmitters, temperature transmitters, flow transmitters and control valves (CV). A general view of the binary power plant is shown in Figure 4.

CONCLUSION

The technology of geothermal binary power plant has been researched and developed in the purpose of generating electricity from low-to-medium temperature resources and of utilizing the thermal resources through the recovery of waste heat.

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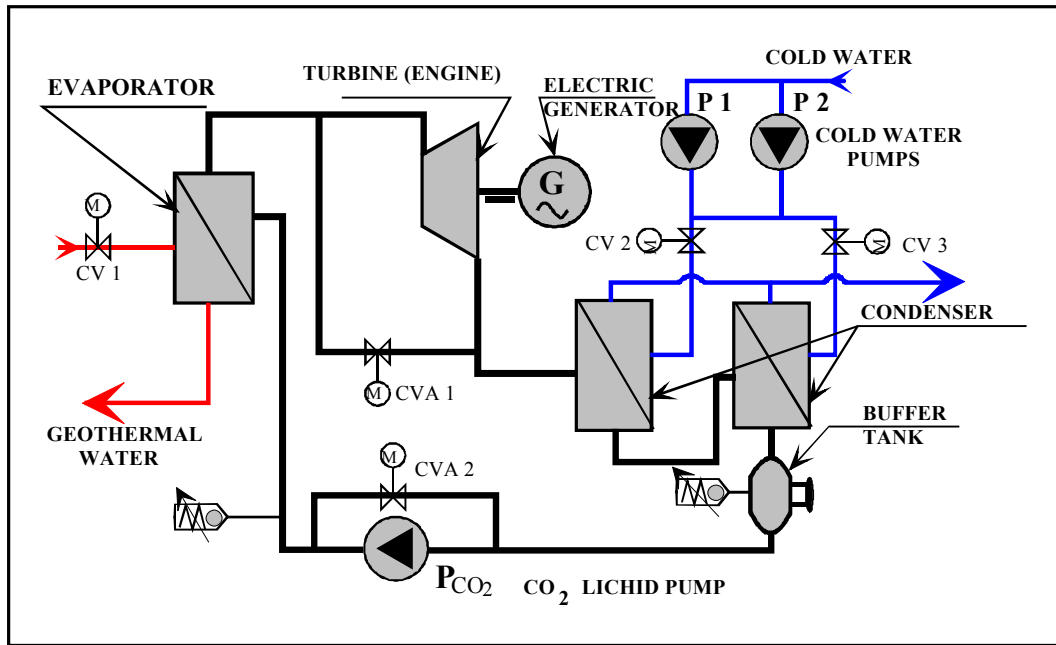


Figure 3. Diagram showing the binary power plant.

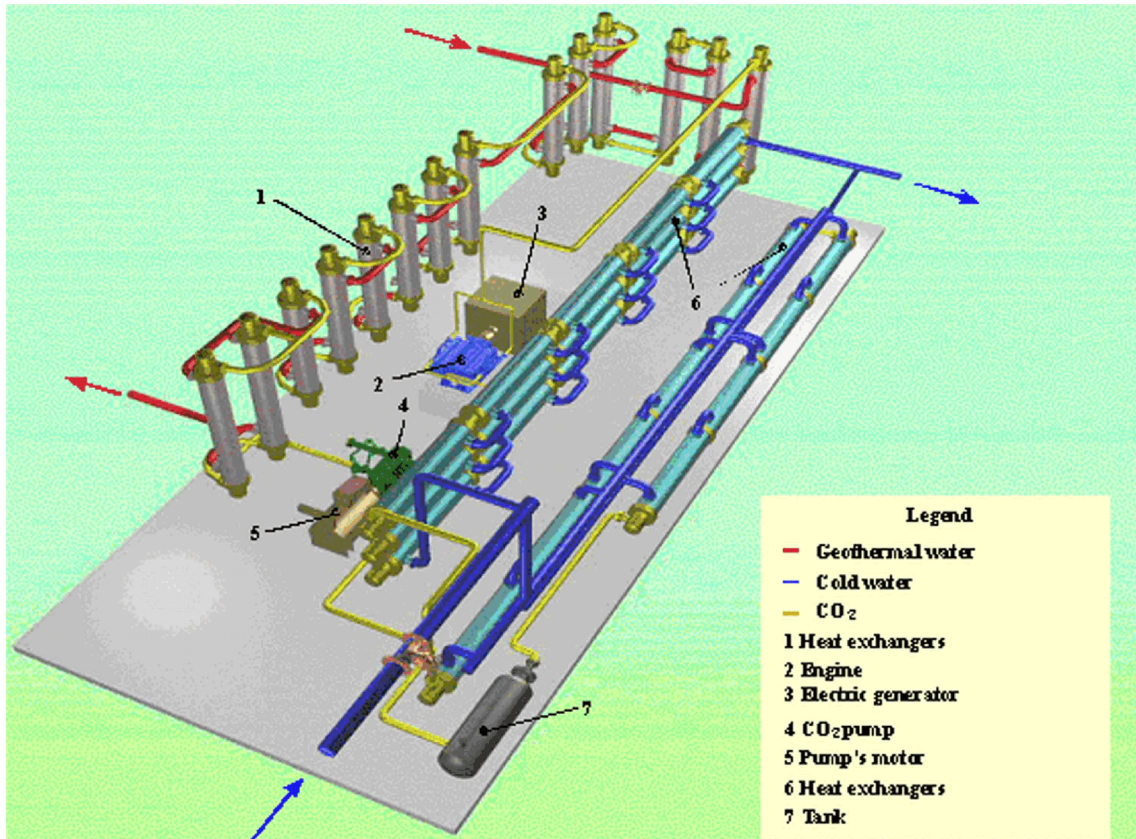


Figure 4. Binary power plant – general view.