Part 8

RENEWABLE ENERGY SOURCES

8.1. Geothermal power plants (GPPs)

8.1.4. Geothermal power plants with application of volatile clear or mix working substances

V.A. Vasilyev, B.V. Tarnizhevskiy, OJSC "ENIN"

In order to avoid the scales, which occur at evaporation of geothermal brines in schemes with expanders, a scheme using volatile working substances is applied (fig.8.4). Geothermal brine from the lifting hole *1* flows into heat exchanger-steam generator *2* (which is usually implemented in the form of two shell-and-tube apparatuses –vaporizer and heater (economizer)). After its cooling up to the limiting temperature, estimated under condition of scale absence, the brine returns to stratum by a pressure hole *3*. In accordance with high cost of holes, for increasing in geothermal brine consumption, sinking pumps are sometimes applied, located at the depth of 200 m inside the lifting hole, and for backfilling a pressure pump is almost always applied before the reinjecting hole *3*. Electricity consumption for the pump drive sometimes reaches 20% of electricity generation.

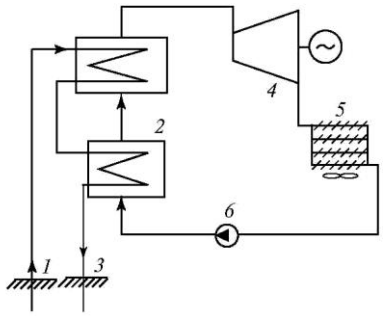

Fig. 8.4. Flow diagram of GPP with application of volatile working substances:
1 — lifting hole; *2* — heat exchanger – steam generator; *3* — pressure hole; *4* — turbine; *5* — condenser; *6* — circulating pump

As the working substances of similar GPPs, coolants (hydrocarbons: propane, butane, freons, recently a possibility of using water-ammonia mix is considered) are used. Liquid working substance is heated and evaporated in the steam generator *2* and enters the turbine *4*. Expansion of steam of volatile working substances occurs (contrary to water steam) in the turbine in a dry steam area. This is connected with abnormal form of the right branch of their saturation curves in *T*,s-diagram - the entropy decreases at condensing temperature drop, hence, it is dry steam going out from the turbine. If its temperature is considerably higher than the condensing temperature, usually estimated by the air temperature, it is reasonable to return the excess heat into the cycle. For this purpose a regenerative heat-exchanger, which is not shown in the diagram, is applied. It is installed before the condenser *5*, which is usually air-cooled, because of a lack of cooling water. The condensed working substance is fed to the inlet of the steam generator by a circulating pump *6* (if recuperator is available, it is used).

The world's first geothermal power installation under the similar scheme with freon-22 as the working substance was produced in 1956 and tested at Paratunskoe field of thermal water at Kamchatka. Equipment for similar GPPs with different working substances was produced by a number of firms in the U.S., Japan, Italy, and Austria. Presently, industrial production of power modules with capacity of 0,5…3 MW with volatile working substances is made by the firm "Ormat" (Israel). The total capacity of GPPs, constructed in many countries, using these power modules, exceeds 350 MW. In our country a power module of 1,5 MW with ozone-safe freon-42b at Kirovskiy factory was designed. Nowadays works on creation of special turbine are conducted in the OJSC "Nauka".

Power modules of the firm "Ormat" are supplied at the average price of 1000 dollars per 1 kW.

Recently special attention is paid to use of water-ammonia mix as the working substances. This interest is explained by temperature change during the mix vaporizing process. Firstly, at a lower temperature ammonia is, mainly, vaporized and in the process of ammonia concentration decrease, a temperature of the boiling mix increases. This results in approaching the curves of geothermal brine cooling and its heating, and also vaporization of water-ammonia mix in *I*, t-diagram. That leads to decrease in irreversible losses of exergy at heat exchange and increase in efficiency of GPP cycle. In addition, changing the ammonia concentration in the mix, the same turbine can be efficiently applied at geothermal fields with the brine temperatures from 80 to 200^0C.