PROSPECTS OF HORIZONTAL DRILLING
WHEN CONSTRUCTING GEOTHERMAL POWER PLANTS

A.B. Alkhasov, R.M. Aliyev, G.A. Azizov

The Institute for Geothermal problems of the Daghestan Scientific Centre of the RAS
Kalinina, 39a, Makhachkala, Daghestan, 367030, Russia

ABSTRACT

The most prospective direction of utilization of thermal water heat is transformation of it in electric power. Existing geothermal electric power plants (GPP) are based in the most cases on natural vapour, obtained from fields in regions of modern volcanism. But the potential of vapour fields in many countries is almost fully depleted. In Russia the works are carried out in construction of the first turn of Mutnovka GPP in Kamchatka with total capacity 200 MWt. Relative independence from consumers, economy of temperate power and special valuability of electrical power caused the prior development of GPP as the principal direction in geothermal resources development.

Enormous geothermal reserves with temperature 100-200 °C are concentrated in stratal hydrostatic head systems of sedimental basins. Characteristic peculiarities of thermal waters in stratal systems are high salinity, heightened gas content, tendency for saline deposition when changing thermobar conditions and high corrosion activity to construction materials. Utilization of that kind of resources for electrical power production connected with using of technology of two-contour GPP with low boiling working medium. That GPP includes a geothermal circulating system (GCS), in contour of which thermal water circulates and a cycle of steam-turbine unit (STU), in which low boiling secondary heat-carrier circulates. Application of GPP of that sort permits to increase significantly number of regions, prospective for geothermal power engineering development. One of them is the North Caucasus, where Central, Kajasula fields in Stavropol Territory and Tarumovka, Kumukh, Jushnosukhokumsk, Jubileiny, Talovka fields in Daghestan are immediate.

The first in the world and unique in Russia two-contour experimental GPP on freon R-12 was constructed in 1967 on Paratun geothermal field in Kamchatka. In 1974 this power plant was put out of action. The main purpose when creating the GPP is production of maximal usable electrical power. Increasing of capacity is reached by increasing of discharge of primary heat-carrier, circulating in contour of GPP and optimization of thermodynamical cycle of secondary contour. For working medium, circulating in contour of STU, the optimal temperature of evaporation exists, when usable electrical capacity on unit of discharge of thermal water reaches maximum. The optimal evaporation temperature depends on the temperature of thermal water, the temperature of condensation of secondary heat-carrier and the least temperature head in heat-exchanger-evaporator [1].

At the same time sharp rise in the cost of production when the plant capacity decreases, typical for fuel and atom electrical power engineering, do not spread to geothermal power plants. Beginning from 10-30 MWt further growth of their capacity do not lead to noticeable improvement of their economical indices, i.e. it demands increasing of quantity of wells and lengthening of surface pipelines [2].

For improvement of economical indices of GPP it is necessary to create GCS with high productive wells with increased diameter. One of ways of intensification of thermal water extraction is creation of additional channels in stratum for significant increasing of filtration surface and draining zone. It reaches by creation of horizontal borehole, which spreads to hundreds meter through stratum. That kind of formation exposing permits of the hole in the stratum and to raise the productivity of well many times.

At present the barge experience is accumulated of borehole drilling in oil production. Due to longitudinal formation exposing the hydrodynamical perfection of a well grows. Practive of horizontal wells operation shows, that their productivity is tens times higher than productivity of usual vertical wells. Drilling of horizontal wells is characterized by
deceleration of penetration rate and by rise in the cost of drilling. Owing to increasing of well length due to lengthening of borehole in productive formation, growth of number of limitations, put on technology of well drilling, and so complication of drilling and geophysical works, the cost and duration of drilling of horizontal wells is higher than usual wells. But because of more significant increase of well productivity, drilling of horizontal wells is economically profitable from point of view of ultimate aim of well construction. economical effectiveness when horizontal drilling - is retrieved as result of obtaining the given level of production by significant less number of wells. Comparison of change dynamic of the wells cost with their production growth dynamic shows, that productivity of horizontal wells grows more intensive than their cost.

In scientific literature number of formulae are given for determination of single horizontal well output [3, 4, 5]. For estimating calculations it the approximately formula by V.G. Griguletzky [3] may be used

\[
G = \frac{2\pi \sqrt{k_h k_v \beta h \Delta P}}{\mu B_0 \left[ \frac{R_k}{L} + \frac{\beta h}{L} \ln \frac{\beta h}{2\pi R_c} \right]}
\]

(1)

where \( B_0 \) is the stratal volumetric factor of fluid; \( \mu \) is the viscosity of stratal fluid; \( \beta = \frac{k_h}{k_v} \); \( L \) is the length of horizontal part of borehole; \( R_k \) is the radius of a well; \( R_c \) is the radius of circular external reservoir boundary; \( k_h \) and \( k_v \) are horizontal and vertical penetrations, correspondingly; \( h \) is the width off productive reservoir; \( \Delta P \) is pressure drop between pressure on boundary of circular external reservoir \( P_k \) and on wall of a well \( P_c \); \( \rho \) is density of obtained thermal water.

In fig.1 the technological scheme of GPP with horizontal wells is given. When constructing the horizontal well, dropping from top to subface, as shown in fig.1, the stratum is the most full included in filtrational flow.

Fig.1 Technological scheme of GPP with horizontal wells. 1 - producing well; 2- injection well; 3- pump house of GCS; 4- heat-exchanger; 5- evaporator; 6- pump of secondary contour; 7- turbine; 8- generator; 9- condensator; 10- aquifer.

When constructing the GPP with vertical wells (from condition of minimum specific capital expenses) the most optimal the technological scheme is with three equidistant production wells from central injection well with increased diameter [6].

The comparative analysis of GPP has been carried out for three (1,2,3) technological schemes of GCS construction: 1-one producing and one injection vertical wells; 2- three producing vertical wells and one injection vertical well of increased diameter; 3- one production horizontal and one injection horizontal wells. As low-boiling working medium isobutan is used.

As the optimum criterium it may be used the minimum of specific capital expenses, which are determined by formula

\[
f = \frac{S}{W_I}
\]

(2)

where \( f \) is specific capital expenses, \$/kWt; \( S \) is capital investment; \( S \); \( W_I \) is usable capacity of GPP; kWt

\[
W_I = W_h - W_l, \quad W_h = GN, \quad W_l = GP/\rho _I
\]

(3)

where \( W_h \) is the total capacity, producing by power unit; \( W_l \) is the capacity, consumed to own needs; \( G \) is the mass flowrate of thermal water, circulating in contour of GCS, kg/s; \( N \) - the specific capacity (Net) of power unit, kWt/kg$s; \( \rho _I \) is the density of injection water, kg/m$^3$. The pressure of injection, Pa; \( \rho _I \) is the density of injection water , kg/m$^3$. The mass flow rate of the secondary heat carrier \( m \) and capacity \( N \), developed by turbine on 1 kg/s of thermal water discharge, are determined by formula:

\[
m( h_3 - h_2 ) = c_4 [ t_5 - ( t_4 + \Delta t ) ]
\]

\[
m( h_2 - h_1 ) = c_4 [ ( t_5 + \Delta t ) - t_4 ]
\]

\[
N = \left[ \eta _m ( h_3 - h_4 ) - ( P_e - P_v ) \nu _e /\eta _p \right] m
\]

(4)
where $h_1$ is the enthalpy of condensat, KJ/kg; $h_2$ is the enthalpy of steam in point of evaporation; $h_3$ and $h_4$ are the enthalpies of steam before and after turbine; $c_4$ is heat capacity of thermal water, KJ/kg°C; $t_1$ is the temperature of thermal water; $t_s$ is the temperature of secondary heat carrier evaporation; $\Delta t$ is the least temperature head in heat-exchanger-evaporator; $t_H$ is the temperature of waste thermal water; $\eta_{oi}$ is relative inside efficiency of a turbine; $P_S$ is the pressure of evaporation; $P_k$ is the pressure of condensation; $\nu_k$ is the specific volume of condensate, m$^3$/kg; $\eta_p$ is pump efficiency.

Equation of movement of heat-carrier in circulating contour of GCS may be wrote down in the following form:

$$P = \Delta P_1 + \Delta P_a + \Delta P_6 + \Delta P_9 + (\rho_a - \rho_i)gH$$  \hspace{1cm} (5)

where $\Delta P_1$, $\Delta P_a$, $\Delta P_6$, $\Delta P_9$ are correspondingly hydraulic losses of pressure in injection, produinting wells and surface pipelines; $\Delta P_9$ is filtrational losses of pressure in formation; $\rho_i$ is the density of thermal water in producing well; $H$ is the depth of well, m.

Optimization calculations for three variants of GPP building is binded with Kumukh field of thermal water. In the field at depth 4850m effectiv width 65m. The temperature of stratal water 180°C, the salinity 140-160 g/l, the stratal pressure 53,3Mpa; the porozity 16%, the permeability $0.5 \cdot 10^{-12}$ m$^2$. On field two wells are drilled with deameter 0.146m, which are shut down at present.

When considering the variant with horizontal wells, the length of perforated horizontal part of well, dropping along the stratum is assumed equal to 250m.

In tabl.1 the basic parameters for three variants of GPP are given.

<table>
<thead>
<tr>
<th>N</th>
<th>Name</th>
<th>Technological scheme of GPP</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Depth of well, m</td>
<td></td>
<td>4850</td>
<td>4850</td>
<td>4850</td>
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<tr>
<td>2</td>
<td>Diameter of producing well, m</td>
<td></td>
<td>0.298</td>
<td>0.2458</td>
<td>0.3423</td>
</tr>
<tr>
<td>3</td>
<td>Diameter of injection well, m</td>
<td></td>
<td>0.298</td>
<td>0.3423</td>
<td>0.3423</td>
</tr>
<tr>
<td>4</td>
<td>Distance between wells, m</td>
<td></td>
<td>2720</td>
<td>2534</td>
<td>2750</td>
</tr>
<tr>
<td>5</td>
<td>Output of GCS, kg/s.</td>
<td></td>
<td>260</td>
<td>468</td>
<td>500</td>
</tr>
<tr>
<td>6</td>
<td>Pressure of injection, MPa</td>
<td></td>
<td>19,0</td>
<td>24,0</td>
<td>21,5</td>
</tr>
<tr>
<td>7</td>
<td>Capacity of injection pump, MWt</td>
<td></td>
<td>5.24</td>
<td>11.9</td>
<td>11.5</td>
</tr>
<tr>
<td>8</td>
<td>Usable capacity of</td>
<td></td>
<td>13.6</td>
<td>22.0</td>
<td>24.7</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>GPP, MWt.</th>
<th>9 Specific capital expenses, $/KWt</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1050</td>
</tr>
</tbody>
</table>

From given data the conclusion follows, that when further developing the geothermal power it is necessary to construction horizontal wells, using experience of oilmen, that will improve technical and economical indices of geothermal brunch and will raise its competitivenees in comparizon with traditional power brunch.

REFERENCES