SOLUTION OF SOME QUESTIONS RELATED TO THE REPLENISHMENT OF RESOURCES OF UNDERGROUND THERMAL WATERS, USING THE TEREK-SUNZHA OIL-AND-GAS-BEARING REGION AS AN EXAMPLE

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SOLUTION OF SOME QUESTIONS RELATED TO THE REPLENISHMENT OF RESOURCES OF UNDERGROUND THERMAL WATERS, USING THE TEREK–SUNZHA OIL-AND-GAS-BEARING REGION AS AN EXAMPLE

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The hydrodynamic system of the Terek–Sunzha oil-and-gas-bearing region is one of the most thoroughly studied in the Caucasus: oil deposits confined to the sandy beds of the Karagan–Chokrak deposits have been exploited for 40–50 years. Many productive beds of the fields of this region have been almost completely depleted, which creates favorable conditions for the use of the thermal waters of these beds for the heat supply of the city of Grozny.

It is known that the recharge area of the Middle Miocene deposits lies within the Northern monocline (the Black Mountains), where they crop out at absolute elevations of $+600 \div 950$ m. From the recharge area the waters move northward, north-northeastward, and northeastward in the direction of the dip of the aquifer complex. The excellent reservoir properties of the sandy beds have led to the occurrence, in the Middle Miocene deposits of the Terek–Sunzha region, of weakly mineralized waters of the hydrocarbonate-sodium type.

The main drainage area of the Middle Miocene aquifers is located within the Front Ranges (the Terek and Sunzha ranges), where powerful sources of thermal waters have long been known—the Sernovodsk, Mamakai-Yurt, Goryachevodsk, Bragun, Gudermes, and others.

In the first years of development of the Karagan–Chokrak deposits, withdrawals of fluid from the productive beds of the oil fields were small, and the yields of the water springs remained almost unchanged. A sharp increase in production led to a fall in hydrostatic levels and the spread of depression cones for tens of kilometers, which caused a reduction in the yields of spring waters, up to their complete drying up.

The authors have generalized temperature measurements in wells that had been idle for a long time, studied the thermophysical properties of rocks, and calcu-

Fig. 1. Geothermal section with thermophysical parameters for well 50/25 of the Oktyabr' skoe field. 1—sandstones, 2—clayey sandstones, 3—clays, 4—sandy clays.

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Fig. 2. Schematic geological profile section of the Terek-Sunzha oil-and-gas-bearing region. 1—injection wells, 2—production wells. L—the distance between injection and production wells, equal to 5500 m.

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lated the magnitude of the heat flux coming from the depths within the Oktyabrskoye field, located on the southern outskirts of the city of Grozny. The geothermal investigations carried out confirmed the great reliability of the hydrodynamic system.

The values of the coefficients characterizing the thermophysical parameters of the lithologic-stratigraphic section were determined by regular-regime methods. Several dozen samples of various sedimentary rocks were investigated in air-dry and moist states, over a temperature range from 15-20 to 90-100°. Thermophysical parameters were determined for sandstones, siltstones, and clays (Fig. 1).

The mean harmonic value of the thermal conductivity of the rocks for the section of the Middle Miocene deposits is 1.99 kcal/m • h • deg. The mean value of the geothermal gradient is 15.7 m/deg, and the mean value of the heat flux is $12.64 \cdot 10^{-2}$ kcal/m^2 • h.

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The above-indicated magnitude of the heat flow is due to the influence on the temperature conditions of the subsurface of hot waters entering the field from the recharge area through the deep Sunzha syncline (Fig. 2).

By drilling production wells about 4000 m deep in the Petropavlovsk syncline at a distance of 5.5 km to the north-northeast of the Oktyabr' skoe field, water with a temperature of up to 160° can be obtained from the Karagan-Chokrak deposits.

Fig. 3. Graphs of the dependence of reservoir-temperature change on time during withdrawals and injection of water in quantities of 100,000 (a), 50,000 (b), and 25,000 (c) m^3/day: when water is injected at the reservoir inlet with a temperature of 50° (solid curves) and 20° (dashed curves). 5500 m is the distance between injection and production wells. 4000, 3000, and 2000 m are the linear distances from the injection wells.

Figure 3: Fig. 3. Graphs of the dependence of reservoir-temperature change on time during withdrawals and injection of water in quantities of 100,000 (a), 50,000 (b), and 25,000 (c) m^3/day: when water is injected at the reservoir inlet with a temperature of 50° (solid curves) and 20° (dashed curves). 5500 m is the distance between injection and production wells. 4000, 3000, and 2000 m are the linear distances from the injection wells.

For replenishing the resources of thermal waters, some wells of the Oktyabr' skoe field may be used as injection wells (Fig. 2).

To establish the permissible withdrawals of thermal water and to determine the quantity of water that must be injected into the reservoir in order to restore the resources of thermal waters, certain thermal calculations were carried out, connected with determining the character of the change in reservoir temperature during water injection. The calculations were performed according to the scheme of H. A. Lauwerier, which takes into account convective heat transfer in the reservoir and the thermal conductivity of the surrounding rocks in the vertical direction (1).

Experimental studies carried out by G. E. Malofeev at the Institute of Geology and Development of Combustible Minerals on the propagation of heat in a reservoir during the injection of hot water into it showed agreement between the results of the experiments and calculations by the formula of H. A. Lauwerier (2).

Fig. 3. Graphs of the dependence of reservoir-temperature change on time during withdrawals and injection of water in quantities of 100,000 (*a*), 50,000 (*b*), and 25,000 (*c*) m^3/day: when water is injected at the reservoir inlet with a temperature of 50° (solid curves) and 20° (dashed curves). 5500 m is the distance between injection and production wells. 4000, 3000, and 2000 m are the linear distances from the injection wells.

The calculations were made for the assumed withdrawals of thermal water from the system in quantities of 25,000, 50,000, and 100,000 m^3/day, for points located at distances of 2000, 3000, 4000, and 5500 m from the injection wells. It is assumed that the hydrodynamic system operates under a rigid regime, when the quantity of injected water is equal to the quantity withdrawn. Replenishment of water losses in the reservoir occurs through natural recharge from the recharge area. The temperature of the injected water at the reservoir inlet was taken to be 20 and 50°, and the initial reservoir temperature at a depth of 4000 m was

160°.

The total effective thickness of the XIII and XVI beds of the Oktyabr' skoe field, whose waters are proposed for use, is 100 m; the coefficient of thermal conductivity of the rocks surrounding the beds is equal to 1.2 kcal/m • h • deg.; the volumetric heat capacity of the water injected into the beds, of the water saturating the beds, and of the surrounding rocks is equal, respectively, to 1000, 1000, and 550 kcal/m^3 • deg.

The filtration velocity of water through the beds at withdrawals of 100,000, 50,000

and 25,000 m^3/day is equal, respectively, to 0.01, 0.006, and 0.0035 m/hour. The results of the calculations are shown in Fig. 3. It is clear from the graphs that, under the given operating conditions of the system, the temperature of the subsurface will cool when 100,000 m^3 of water per day is injected into it. In this case, after only 15 years, the temperature for points located 2000 m from the injection wells will fall from 135° to 82.8 and 64.5° when water with a temperature of 50 and 20° is injected, respectively. For points located 3000, 4000, and 5500 m from the front of the injected water, the temperature drop will occur after 20, 25, and 35 years, respectively. In the subsequent years, the rate of temperature decrease will sharply diminish.

The most favorable operating conditions for the hydrodynamic system under consideration, consisting in an insignificant decrease in the temperature of the subsurface, can be obtained over a period of 30–50 years with withdrawal and injection of 100,000 or 50,000 m^3/day, provided that the linear distance between the injection and production wells is 5500 m. With injection of 25,000 m^3/day, the reservoir temperature will practically not decrease.

Continuous and comparatively simple restoration of thermal-water resources ensures the reliability of this hydrodynamic system over a very long period of time.

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Note: Figure translations are in progress. See original paper for figures.