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Geothermal Resources of Dagestan, the Experience and Technology of Their Development

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ABSTRACT

Dagestan is one of the pioneers in matter of analysis and industrial development of geothermal resources in Russia. Despite lacking obvious volcanism, mountain-filled Dagestan is rather rich in thermomineral sources and geothermal anomalies (Ahti, Hnov, Richalsy, Giljar, Berikey, Duzlak, Alchadjikent, Kayjakent, Adgi, Istisy, Miatli, Hzanor etc.). In premountain-flat Dagestan by drilling in gas-oil reservoirs and the thermal waters are reconnoitered with forecast estimation of resources of a field of low mineralized (3-15 g/l) thermal waters with temperature 50-105°C: Makhachkala, Izberbach, Kayjakent, Kizlar, Tarumovka, Jurkovka, Kargalinskoe, B.Areshevka, Rechninskoe, Kardonovka, Terekli-Mekteb and Chervlenie Buruni.

Since 1963, the thermal waters have been utilized widely with considerable economical and ecological effect for a central heating, ardent water facilities, sanatorium-balnealogical purposes and bottling of medical-restaurants mineral waters ("Deneb", "Richalsy", "Makhachkala-160", "Sarmatskaya", "Kardonovka" etc.).

Designs and methods of boring and exploitation of geothermal wells, including acclinal and horizontal drilling will fractionally be realised in production. The original minings on transforming a geothermal energy in calorific both electric and heat supply systems on the basis of geothermal circulating systems, original plutonic heat exchangers and with usage of heat pumps for low- and mean potential hydrothermal resources are executed.

1. NARRATIVE

The very favorable combination of contrast geological structures: Meganticlinorium of the Central Caucasian Range of Alpine tectogenesis, the Epihercynian Scythian Plate and the Caspian sublatitudinal through, the Earth's crust of which in its southern part is like an oceanic type caused formation in the Northern Caucasus and first of all in Daghestan the unique and rich thermomineral resources. The underground hydrosphere of a sedimentary section is distinctly subdivided into three structural hydrogeologic levels (SHGL).

The Mesozoic SHGL with the thickness 2 – 5 km embeds between a section of Maycop clays, argillites and the Paleozoic fundament and is represented by high thermal and parathermal rare-metal solutions. The natural resources on the area 12 thousand square km are 10,4 thousand cubic km with the technical and economical index (TEI) 200 billion tons of reference fuel (TRF). The forecasting commercial resources of the Mesozoic complex make up 1,2 million cubic m/day with TEI 20 thousand tons of reference fuel/day or 7 million TRF/year. These resources are explored by drilling of hundreds of gas and oil wells and nearly 10 special geothermal ones and are joined in Daghestan province of rare-metal vapor thermal springs with 55 potential deposits, containing valuable elements of commercial quality: lithium, rubidium, cesium, iodine, bromine, magnesium, strontium and a number of mineral salts. Berikeisky and Tarumovsky fields with initial output 70 and 7 thousand cubic m/day and also Yuzhnosukhokumsk group of gas and oil fields with simultaneous extraction of metal-bearing solutions in bulk 1,0 – 1,5 million cubic m/year are urgent for commercial production.

In 1980s a project of Tarumovsky geothermal power plant (GPP) with capacity 10 MWt and technical and economic ground of the largest GPP with capacity 400 MWt were created by Rizhsky division of the enterprise "Teploproekt" of the Ministry of power engineering of the USSR with participation of the Institute for geothermal research (IGR) and the Institute of geology of the Daghestan Brunch of the Academy of Sciences of the USSR (now DSC RAS). For realization of the plan the 5 deepest in the world geothermal wells (5500m) have been drilled with thermal power potential of the every one 10^9 Kcal/day or 3 – 4 MWt without taking into account the hydraulic power (100 – 120 atm on a wellhead) and the hydrocarbon gas factor (4 – 5 m^3 / m^3). But because of absence of geophysical and field equipment, designed for high stratal temperatures (200 – 210 ^{0}C) and very intensive processes of corrosion and salt deposition in pipelines and, mainly, beginning of reorganization (Perestroika) in the USSR, the project was not realized and wells are conserved.

The Neogene SHGL is deposited between waterproof sections of Sarmatian and Maycop clays, represented by the Middle Miocene thermal aquifer with the thickness 450 – 500 m containing low salt thermal waters with the temperatures 70 – 120^0 C and production of overflowing wells 1000 – 3000 m^3/day. The depth of aquifers bedding varies from 800 – 1000 m up to 3000 – 3500 m, the temperature and pressure on wellheads 70 – 120 ^{0}C and 3 – 35 atmospheres. The natural reserves of the Middle Miocene complex make up 1460 km^3 and Middle Maycop – 1620 km^3.

The Pliocene SHGL of low thermal (25 – 60^0 C) fresh waters occurs at depth 300 – 700 m, has the expected reserves more than 3 million m^3/day, is exploited in Daghestan for water supply through 3000 artesian wells. The development of alternative geothermal power engineering and rare-metal hydromineral industry in the Caucasian – Caspian region is connected with practically unexhausted power and mineral resources of the Mesozoic complex, which through seismogenerating tectonic faults hydraulically connected with deep (crust) hydrogeothermosphere. The latter, in its turn, feeds on deep fluids by degasification and defluidisation of undercrust and upper mantle layers. This is proved not only by geological (tectonic) and hydrogeologic-geothermal processes, but also by isotopic-geochemical analysis of the ratio of the isotopes helium 3 to helium 4, confirming mantle origin of fluids – a number of sources of salt waters in a zone of Alpine tectogenesis and deep wells on young Epihercynian Scythian platform.

Heat supply of towns, villages and agricultural industry, including commercial plant growing, pond fish-breeding, warm dropping irrigation of open ground and also development of the balneology complex and a number of factories on bottling of medicinal-table mineral waters are carried out by using thermomineral and fresh low thermal waters of Neogene and Pliocene structural-hydrogeological levels.

In the paper and the program all these questions are considered in details and high economic efficiency and profitableness of investments in geothermal production are shown – first of all it concerns the development of rare-metal brines and extraction from them lithium carbonate, magnesium, iodine, iodinated table salt, medicines etc., which have the great demand in our country and in the former USSR.

The most fast recoupment of capital investments is expected from construction of factories on bottling of medicinal-table waters, complex using low salt thermal waters for heat supply of green-houses and residential area, commercial plant cultivation, pond fish-breeding and growing protein mass. The fulfillment of all these measures practically do not need drilling new wells, because there are a large fund of conserved gas-oil and geothermal wells, development of which for thermal waters requires an order less expenditures.

The industrial technology of extraction of lithium carbonate from geothermal brines of Berikei field is worked out at the enterprise "Georesurs" Ltd with support of the Fund of assistance of development of enterprises of a small form in a scientific-technical sphere together with the IGR DSC RAS.

The ready resources in bulk 350 – 400 thousand m^3/year and elaborated technology allow to begin projecting and construction of a pilot plant on production of lithium carbonate, iodinated table salt, iodine, magnesium and simultaneously carbon dioxide and gas hydrocarbons with recoupment during 2 years.

The enormous resources of low-potential thermal waters of Daghestan do not use practically for heat power needs. The principal cause of it is the fact that such waters have not sufficient temperature parameters for heat and hot water supply. In comparison with middle- and high-potential thermal waters, the low-potential have a number of opportunities, such as small capital expenses for their output, low salinity and, accordingly, absence or minimal problems of salt deposition and corrosion and availability in the region of great number of wells, ready to exploitation. Under these conditions elaboration and introduction of technologies of heat pump systems is the most prospective direction of development of low-potential water. Using the low-potential waters as a primary source of heat in heat pumps will allow to escape the basic shortage of those waters, consisting of low start temperature, not providing temperature parameters of warm- and hot water supply.

Complete and economically efficient utilization of low-potential geothermal heat in systems of heat supply is practically impossible without involving the heat pumps.

Efficiency of low-potential water utilization in heat pump system (HPS) depends on its final temperature. It is necessary to be achieved the maximal temperature drop of water. It may be attained both in one heat pump installation (HPI) and in a scheme with consequent use of water in two and more HPI. Achievement of low final temperature of thermal water in one HPI is connected with lower temperature of working agent evaporation that leads to reduction of transformation factor and performance of the installation. If it is necessary to receive high temperature of condensation, the economic efficiency of such an installation becomes minimal. The consequent direction of thermal water through evaporators of two and more HPI allows to carry out process of evaporation of the working medium at different temperature levels that will result in economy of electric power due to increase of energy transformation factor from high value in the first installation to low value in a last installation. Depending on parameters of initial heat-carrier (flow rate, temperature) and consumer's demand to final temperature in HPS it may be included up to three HPI.

Potential opportunities of geothermal energy utilization in the region practically are not limited. However its effective use needs creation of new technologies and equipment, application of new materials, creation of economic interest in realization of projects.

In the Republic, especially in its flatland part, there is huge requirement in extraction and utilization both geothermal energy and resources of underground fresh waters. Now for maintenance of consumers with fresh water underground artesian cold or low-thermal waters are used.

The combination of favorable hydrogeothermal conditions in the region at simultaneous presence of a problem of fresh waters and escalating the volumes and rates of utilization of geothermal energy resources make lawful formulation of a problem on expediency of combination of low-thermal and thermal waters production. Under these conditions the role of geothermal technologies on combined-separate extraction of underground waters from different horizons sharply grows [2]. Integration of production of the artesian wells, obtaining fresh low-potential water in the areas, where disposition of hydrothermal wells is planned, obviously will promote to increase the efficiency of geotechnological complexes.

The technology of combined-separate extraction is widely and successfully applied when developing the oil deposits. It is necessary to note that conditions of application of such technology are much more favorable for output of thermal waters, than for oil wells.

Now some experience of practical use of the technology of combined-separate extraction of thermal waters from different horizons is accumulated. At the beginning of 1980s in Kizlyar field of thermal waters the well for combined-separate extraction of thermal salt (115 ^{0}C and 23 g/l) waters of Chockrak aquifer from depth 2900 m and low-thermal and low-salt (48 ^{0}C 2,1 g/l) waters of Apsheron horizon from depth 1000 m was constructed, which was successfully exploited for a number of years. In the annulus of the well the inflow almost fresh high temperature (up to 85 ^{0}C) water with output up to 2000 m^3/day was received. Because of breakdown the well was abandoned (inflow of fluid from a top layer). Operating experience of the combined well has shown that temperatures of the waters rising from both horizons to the wellhead are almost leveled. Thermal salt water of the bottom horizon with high temperature was disposed off that resulted in sharp decrease of use of thermal potential and deterioration of parameters of operation. Besides high requirements in preservation of the environment do not allow to dispose waste salt thermal waters on the surface. In these conditions the technological circuit is optimum, where thermal water from a bottom horizon circulates inside the closed contour "bed - producing well - surface pipeline – pump - injection well - bed", and low-thermal water from a top layer rises through annulus both producing and injecting wells. The part of a well from a bottom of the upper stratum up to a mouth of an injection well serves as countercurrent double-pipe heat exchanger. Arrangement of geothermal circulating system of two wells - heat exchangers most full will allow to transfer heat of thermal water rising from a lower horizon to fresh low–thermal water of an upper horizon. The used water after the consumer is injected through a separate well into upper aquifer.

When using the technological circuit of combined – separate extraction, from a top layer to a mouth of a well hot high quality water rises, which has much smaller corrosion activity and ability to salt sedimentation in contrast to the thermal water rising from a bottom layer. Submission of such water to consumers increases a between servicing cycle of systems of heating and hot water supply that essentially will lower expenses for repair and service of central heating systems. Technical and economic parameters of the system are improved 40 – 50 per cent in comparison with extraction of such waters by separate wells. Estimated calculations show that construction in Kizlyar field of thermal waters only one geotechnological system of two combined wells will allow, depending on technology of use of production of wells to save from 4 up to 10 thousand TRF per one year.

The most promising way of heat utilization of high-temperature salt thermal waters it is their transformation to electric energy. Electric power development of such resources is caused by use of technologies of binary geothermal power plant (GPP) with low-boiling working agents [3,4].

When constructing the GPP reception of the maximal useful electric capacity at optimum economic parameters is the main purpose. Increase of capacity is achieved by increase of a charge of initial heat-carrier, circulating in contour of a GPP and optimization of thermodynamic cycle of a secondary contour.

The choice of a working agent in a secondary contour is the most important point at construction of a GPP. The working agent chosen for geothermal installation should have favorable chemical, physical and operational properties under the given operating conditions that are to be stable, nonflammable, explosion-proof, nontoxic, inert in relation to constructional materials and cheap. It is desirable to choose a working medium with lower factor of dynamic viscosity (less hydraulic losses) and with higher factor of heat conductivity (heat exchange is improved). All these requirements simultaneously to meet it is practically impossible, therefore always it is necessary to optimize a choice of this or that working agent.

When selecting a low-boiling working agent the value of specific manufacture of the electric power on 1kg/s of the charge of a primary heat-carrier is determining, therefore an efficiency of heat transformation in such installations depends, first of all, on thermodynamic and heat-physical properties of low-boiling working agents, character of their change at input and output of heat.

For working agent circulating in a contour of steam-turbine installation there is the optimum temperature of evaporation, at which useful electric capacity on unite of discharge of thermal water reaches the maximal value. The optimum temperature depends on temperature of thermal water, temperature of condensation of the working agent and the least temperature head in a heat exchanger - evaporator. The essential influence on efficiency of a power plant the temperature of condensation is rendered. The most favorable for a binary GPP it is use of a condensation system designed for the lowest temperatures allowable on the surface.

When designing the GPP also it is necessary to optimize parameters of GCS: the output of a system, the number of wells and their diameters, the pattern of arrangement of wells and the distance between them. For improvement of the economic parameters of a GPP it is necessary creation of GCS with high-efficient wells of increased diameter. The technological circuit of a GPP with three equidistant producing wells from the central injection well of increased diameter is optimum. With increasing the quantity of wells in a ring battery the diameter and output of a single producing well decrease. Thus the diameter of an injection well is increased as total yield of GCS grows. With increasing the output of GCS there is an increase of useful capacity of GPP and it reaches a maximum at some optimal output. The further increase of the output results in reduction of useful capacity since power consumptions for back injection of the used thermal water into a stratum sharply grow.

For high-temperature waters (180 ^{0}C and more) the most effective it is supercritical isobutene cycle approached to a so-called "triangular" cycle. At a supercritical cycle owing to the minimal difference of temperatures between a heat-carrier and a working medium occurs the maximal drop of temperature potential of thermal water.

Comparison of a supercritical cycle with the pressure of evaporation P_e=5,0 MPa with subcritical (P_e=3,2 MPa) shows that capacity developed by a turbine at a supercritical cycle is 30 per cent increases and density of a stream of substance acting in the turbine 1,7 times is higher that results in improvement of transport properties of a heat-carrier and reduction of the sizes of an equipment (feeding pipelines and the turbine) of steam-turbine installations. Besides in a supercritical cycle the temperature of waste thermal water makes 42 ^{0}C whereas in a subcritical cycle 55 ^{0}C.

The growing role of ecology and rapid progress of gas-turbine installations (GTI) cause expediency of increase of a share of natural gas in power balance of the world. It is even more obvious for Russia having enormous resources of gas. Under these conditions combined geothermal steam-gas power installations having advantages both renewable sources and mineral fuel are prospective. In such installations on manufacture of electric power the temperature potential of thermal water and exhaust of GTI where carries out heating of low-boiling working agent in Rankine cycle is carried out by thermal water up to the temperature of saturation at the appropriate pressure and further evaporation and overheating of the agent is carried out due to recycling heat of the used gases in Brighton cycle.

The limiting temperature, lower of which traditional binary GPP it is inexpedient to create, the temperature of a geothermal heat-carrier close to 130 ^{0}C is considered. The advantage of steam-gas installations lies in the fact that for manufacture of electric power it can be involved thermal waters with the lower temperature (80 ^{0}C and higher) with a subsequent reduction of the temperature of used water up to 20 – 45 ^{0}C against 60 – 85 ^{0}C in a traditional GPP.

The geothermal steam-gas installations are rather promising for creation of the most effective supercritical cycles in a contour with a low-boiling agent.

High thermal rare-metal waters of the Mesozoic complex are complex minerals of multi-purpose use. Development and expansion of use of high-parametrical waters of deep bedding in the national economy will promote to increase of hydromineral raw material and geothermal potential of the country. On the basis of utilization of these waters it may be developed both geothermal heat and electric power engineering and a number of subbrunches of rare-metal industry for extraction of microelements, mineral salts and dissolved gases.

The complex utilization of high-parametrical industrial waters will allow: to exploit wells within all the year with extraction of chemical elements and dissolved gases at simultaneous reception of electric power and heat; to make maximal utilization of thermal potential of water with downturn of its temperature on disposal up to 30 ^{0} C; to provide needs of the industry of Russia in valuable rare-metal raw material; to improve significantly economic structure of the Republic due to realization of excessive rare-metal raw material and reception of additional kinds of energy for internal using; to transform the Republic of Daghestan into a demonstration zone of high power efficiency; to create additional workplaces and to improve social conditions of life of the population; to raise sharply efficiency and profitability of use of hydrothermal resources and considerably to reduce time of recoupment of capital investments.

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