ISSN: 0975-8585

Research Journal of Pharmaceutical, Biological and Chemical Sciences

The Results of the construction project design of a pilot geothermal station with a circulation loop of heat extraction at the Khankala deposit of the Chechen Republic.

Sh. Sh. Zaurbekov[1], M. Sh. Mintsaev[2], A.A. Shaipov[3], S. V. Cherkasov[4], and M. M. Labazanov[3].

[1]1st vice-rector of GSOTU, doctor of geographical sciences, professor Grozny State Oil Technical University by Academician M.D. Millionshtchikov, Grozny, Russian Federation
[2]vice-rector of research and innovation of GSOTU, doctor of technical sciences, associate professor, Grozny State Oil Technical University by Academician M.D. Millionshtchikov, Grozny, Russian Federation
[3]candidate of geological and mineralogical sciences, Grozny State Oil Technical University by Academician M.D. Millionshtchikov, Grozny, Russian Federation
[4]candidate of geological and mineralogical sciences, State Geological Museum by V.I. Vernadsky Russian Academy of Sciences (RAS), Moscow, Russian Federation

ABSTRACT

In the introductory part of the article, the issues concerning the relevance of the geothermal energy development in the world and Russia are discussed. It is noted that the Chechen Republic also has the prospects for its development. A brief description of the Khankala geothermal deposit in the Chechen Republic and the history of its development are presented. It is noted that the first geo-circulation loop established at this deposit revealed a number of shortcomings during its operation. Below is the information on the new stage of the Khankala deposit exploitation and implementation on its basis of a comprehensive construction project for designing an experimental-industrial geothermal station with a circulation loop of the geothermal heat extraction. The description of the station's engineering solution includes the information on the drilled wells, the thermomechanical and pumping equipment, and the automated control system. In conclusion, it is noted that the prospects for the development of geothermal energy in most regions of the South of Russia rich in geothermal resources are associated with the commissioning of a pilot geothermal station with a circulation loop at the Khankala deposit of the Chechen Republic. The conclusion of the article also suggests that the next stage of development should become a geothermal station with a circulation loop, which applies a multilevel principle of using the geothermal heat – for the electric power generation, the use for the purpose of heating, the extraction of useful components, etc.
Keywords: geothermal energy, geothermal heat, geothermal station, circulation loop, geothermal deposit

Corresponding Author

ISSN: 0975-8585

INTRODUCTION

Among the alternative energy sources, the geothermal heat originating from the Earth's interior is one of the inexhaustible and renewable sources.

More than 80 countries use the geothermal energy in varying degrees; in 60 countries, its industrial application has been mastered. The greatest progress in the development of geothermal energy has been reached by such countries as Iceland, Germany, Turkey, France, the USA, Japan, Italy, Israel, Kenya, etc. In 2014, about 530 MW of the geothermal stations (GS) were put into operation around the world, which has become the largest increase per year since 1997.

In the Russian Federation (RF), there are significant reserves of the geothermal resources. Currently, 65 deposits of thermal waters and 5 deposits of steam-water mixture are opened. They are located in two regions of Russia – the North Caucasus and the Far East. In the North Caucasus, 52 deposits are opened, in which about 75% of balance reserves of the whole country have been explored. In the Far East, there are 11 deposits of thermal waters and 5 deposits of steam-water mixtures [1, 2,3,4,5,6].

One of the most promising regions for the development of geothermal energy in the North Caucasus is the Chechen Republic (CR). According to the geothermal waters reserves, the CR occupies the third place among the regions of the Russian Federation after Kamchatka and Dagestan.

In the CR, there are 14 deposits of geothermal waters (Fig. 1), out of which the Khankala, Novogroznenskoye (East Gudermes), Chervlenskoe, and Kargalinskoe are relatively large ones.

The most studied and promising deposit of thermal waters is Khankala, due to its potential and geological structure as well as to the physicochemical characteristics of the thermal waters.

This deposit has a number of advantages as compared to others: the occurrence of producing horizons at shallow depths (up to 1,000 m); the high flow rates (up to 1 l/s m); the high temperatures (up to 1,000 ºC or more); the waters of the 13th horizon are almost fresh and with mineralization of 0.81-1.20 g/l, which contributes to their low corrosiveness.

In 1978-1979, in the Grozny State Oil Technical University, Sukharev G.M., Vlasova S.P., Taranukha Iu.K., and Kovel'skii E.V. substantiated the variants and provided a feasibility study of the possibility of recovery by artificial means of the thermal water resources in the middle Miocene sediments on the territory of Grozny. These works demonstrate a possibility of establishing a GCS (geo-circulation loop) within the Khankala valley for the production of 70 thousand m^3/per diem of thermal waters. On October 23, 1981, the first in the USSR Khankala geothermal system started functioning [2,3,4,5,6]. However, the exploitation of a GCS revealed a number of shortcomings:

- failed to completely solve the problem of discharging by reinjection; a part of the thermal waste water was discharged into the surface water bodies leading to the contamination of the environment;
- the absence of the heat exchange equipment that would "unleash" the main and consumer loops, and thus, solve the problem of the aggressive geothermal water negative influence on the pipelines, mechanical units, and pumping equipment of the consumer loop;
- the presence of linear pipelines extending up to 1-1.5 km for the transportation of geothermal water into the reinjection zone;
- the integrated use of the thermal energy followed by its conversion into the electrical energy was not achieved.

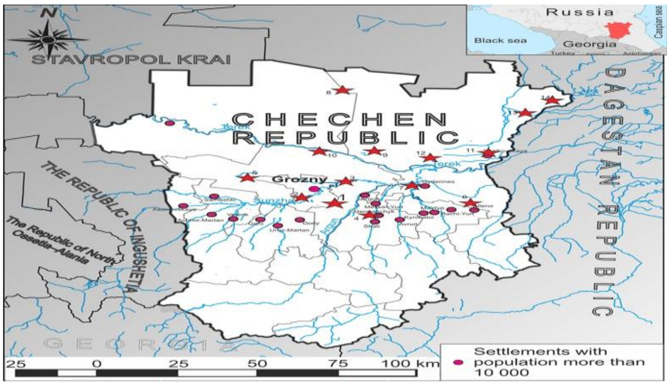

Fig.1. The geothermal water deposits of the Chechen Republic.

An asterisk on the map marks the following deposits: 1 – the Khankala deposit; 2 – the Goity deposit; 3 – the Petropavlovskoe deposit; 4 – the Germenchuk deposit; 5 – the Gunyushki deposit; 6 – the Novogroznenskoe deposit; 7 – the Gudermes deposit; 8 – the Central Burunnoe deposit; 9 – the Chervlyonnoe deposit; 10 – the Komsomolskoe deposit; 11 – the Schelkovskoe deposit; 12 – the Novoschedrinskoe deposit; 13 – the Kargalinskoe deposit; 14 – the Dubovskoe deposit.

The prospective projects

For more than 30 years, the geothermal stations have been effectively used in France exploiting the Dogger reservoir, which differs substantially from the reservoirs of the North Caucasus in the water intake capacity and the permeability.

The best geothermal stations of a circulatory type are the stations in Colomiers, where after 30 years of operation, the temperature at the head of the production well and the flow rate have not changed and are 72 ºC and 230 m^3/h, respectively, and the Orly airport station built in 2010 that ensures 30% in winter and 100% in summer of the airport demand for the heating and hot water supply [7,8,9].

The foreign experience in the construction of geothermal stations with circulation loops shows that the most effective engineering solutions are comprised of the well doublets – the water production and injection wells. At the same time, the modern drilling technologies allow spudding wells from a small platform of 0.4-0.5 ha in size, and the required distance between the bottom holes is achieved through directional drilling. Such geothermal stations, which are densely located in the heavily populated areas, are successfully operated in France, USA, Germany, Iceland, and many other countries.

In Russia, there are no working geothermal stations with circulation loops – all the examples of thermal water application known under conditions of sedimentary basins use artesian wells with further discharge to the relief or water bodies.

Currently, the Grozny State Oil Technical University by Academician M.D. Millionshtchikov (GSOTU) together with the State Geological Museum by V.I. Vernadsky of the Russian Academy of Sciences and the BRGM Company (France) resumed the study and use of the heat and power potential of the Chechen Republic. Since 2013, an integrated project has been being implemented on establishing an experimental and industrial geothermal station with a circulation loop (GSCL) of geothermal heat extraction on the basis of the XIII productive formation of the Khankala deposit. The project is funded by the Russian Ministry of Education within the framework of the Government Decision No. 218 dated from May 9, 2010; and in the end of 2015, the government tests and commissioning of an 8 MW geothermal station with a circulation loop are planned [10,11,12,13]. The GSCL consumers are the greenhouse complexes, the construction of which is carried out in parallel by the private investors. The novelty of the proposed geothermal station is associated with the use of the new technologies for optimizing the circulation loop, which consists of the water production and injection wells (CL). At the same time, the circulation loop of heat extraction with the reinjection of the waste water into a reservoir allows for the production of the environmentally friendly thermal energy.

The practical implementation of the project work results is provided as the implementation of heat and hot water for greenhouse complexes as well as the services on the development and personal construction of geothermal stations.

The description of the GSCL engineering solution

Fig. 2 demonstrates a generalized block diagram. The heating scheme is independent with the division of the thermal water and heating network loops through heat exchangers. The heating system is a closed double-pipe system (Fig. 3).

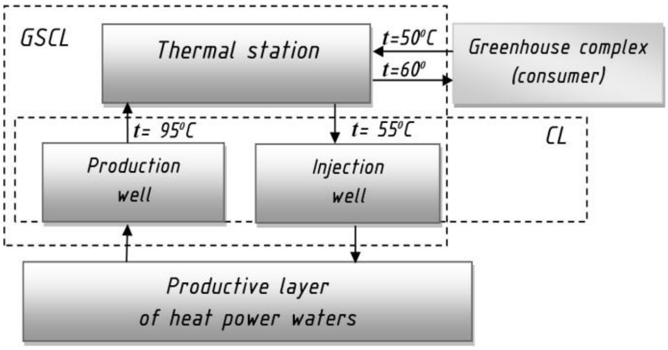

Fig.2. A generalized block diagram for GSCL: CL – a circulation loop of the geothermal heat extraction; GSCL – a geothermal station with a circulation loop.

As can be seen in Fig. 2-3, the waste thermal water is pumped in full through an injection well back into the formation.

The temperature loop charts – thermal water of a heating loop: 95/55 ºC (the output temperature is specified at the stage of designing and the experimental and industrial exploitation); the heating network – 60/50 ºC.

The circulatory system of heat extraction consists of a "doublet" (two wells: a water production well 1DGT and an injection well 2NGT) and ensures the maximum flow rate up to 200 m^3/h, from which an estimated thermal capacity of at least 8 MW results (Fig. 4).

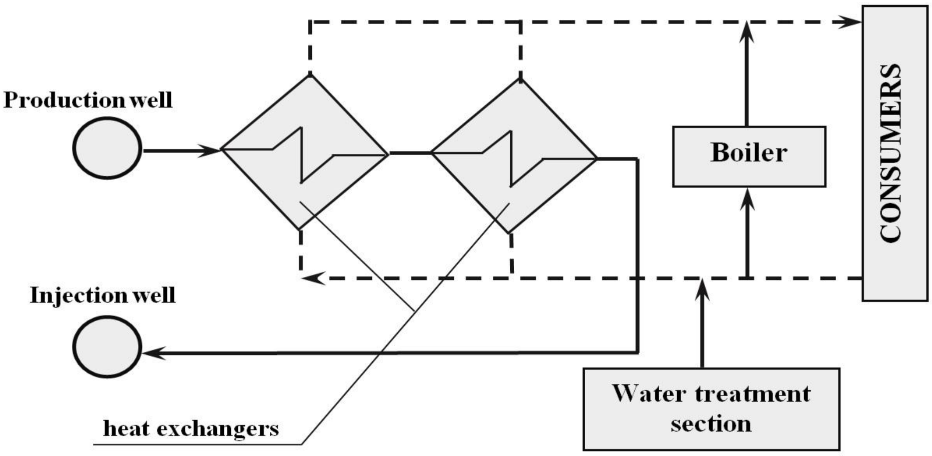

Fig.3. A simplified thermal diagram.

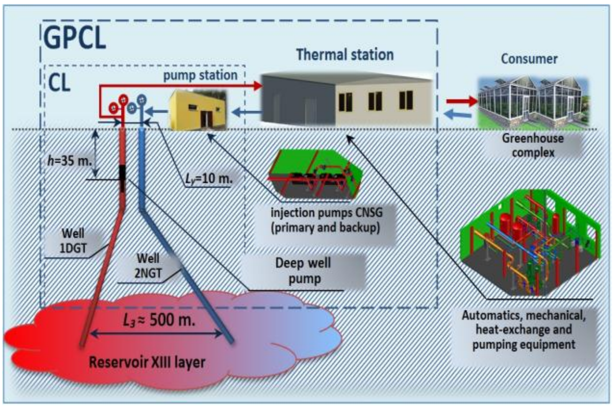

Fig.4. A geothermal station with a circulation loop of the geothermal heat extraction (GSCL): a well 1DGT – a water production (development) well, a well 2NGT – an injection well, CL – a circulation loop.

The preliminary performed 3D modelling of the XIII formation revealed that the spacing between the bottom holes of the water production and injection wells should be at least 500 m in order to prevent the cold front of the thermal water cooled down to 55 ºC from reaching the area of the bottom hole of the water production well. This condition must be met within 30 years from the start of its operation (the station's lifetime in accordance with the identification plate). The cooling of the thermal water during its lifetime from the production well is allowed by no more than 2 degrees. To fulfill this condition, taking into account the project distance not exceeding 10 meters between the wellheads, a directional drilling was for the first time applied in the North Caucasus under conditions of a complicated geological structure and two wells were successfully drilled, which formed the basis of a "doublet". Fig. 5 shows the equipped wellheads, distanced up to 10 m.

The heating scheme provides for the thermal water pumping in the volume of up to 200 m^3/h from the production well using a downhole submersible pump to the surface, then this water is pumped with the IL200 series pumps manufactured by the Wilo company (the main and the backup pumps) to the heat exchangers located in a heating unit. The heating unit has a modular design and consists of five modules 3×5 m in size.

Fig.5. The water production and injection wellheads.

The heating of the heating network water is carried out according to an independent scheme using 2 plate heat exchangers "Ridan" designed for a maximum capacity of 9 MW (Fig. 6).

Fig.6. The plate heat exchangers "Ridan" installed in the GSCL heating unit.

For the heat carrier circulation, the IL 250 series pumps manufactured by Wilo company (the main and the backup ones) are installed within the heating network on a supply line after the heat exchangers. All pumps installed on GSCL are equipped with the frequency converters.

The heating scheme also provides for an electric boiler with a capacity of 400 kW. The main task of this boiler is to ensure a minimum heating of the network water at the possible failures within the thermal water loops in order to prevent the heating networks and the consumers' heat supply systems from freezing. On the return line of the heating network, an expansion tank with a volume of 800 liters produced by the "Reflex" company (Germany) is installed for the compensation of the heat carrier's thermal growth.

The return of the cooled water from the heating unit is carried out through an accumulating tank with the volume of 2,000 liters. In order to prepare a makeup water of the network loop, an automatic plant of continuous action with the capacity of 1 m^3/h developed by the "Vodeko", LLC is used.

As can be seen from Fig. 7, an electric pump 180-340 of the centrifugal multistage sectional type for hot water with a gland seal (the main and the backup ones) is installed within the scheme for the reinjection of the thermal water into the injection well. The injection pumps are installed in the pump station and are designed as a separate module at a distance of 3 meters from the injection well.

Fig.7. The injection electric pumps 180-340 of the centrifugal multistage sectional type for hot water with a gland seal installed in the pump station.

A special attention should be given to the automated process control system (APCS) of the GSCL, which eliminates emergencies, ensures smooth operation of the station in the automated and, if necessary, in the manual modes with the possibility of smooth adjustment of the multiple parameters. The GSCL APCS is a classic three-tier system [14]: the lower level (field), the middle level (controller), and the upper level (dispatching).

The lower level includes sensors and actuators. The information from the sensors reaches the middle level that is a programmable logic controller (PLC) Siemens of the Simatic S7-1500 series performing the basic functions of the automatic logic control. The PLC outputs exercise a regulatory effect on the actuators in accordance with the control program developed on the basis of all technological requirements and settings.

Depending on the configuration in use, the PLC Simatic S7-1500 performs the following functions:

- collecting data from sensors and controlling actuators;
- processing data including scaling;
- maintaining the universal time within the system;
- arranging archives according to the selected parameters;
- exchanging information with the upper layer;
- working in a standalone mode when the connection with the upper level is failed;
- exchanging data with the database server;
- reserving data transfer channels, etc.

The APCS being developed has the following main tasks of the lower and middle levels: the collection and processing of the analog and digital signals; the provision of warnings, alarms and process messages and alarm signals; the control of the technological equipment, frequency converters, and stop valves; the information exchange with the higher-level systems of management.

From the middle level, the information is transmitted to the higher dispatching level, on which an operator's automated working place (AWP) is located with the specialized software of a SCADA type used for establishing a dispatching interface. These functions on the higher level of APCS are performed by the WinCC RT Advanced software from Siemens.

The database server functions in view of the process information volume are combined in a panel PC, at which an AWP is also implemented.

The main tasks of the upper level are as follows:

- the output of the current parameter values, process messages and reports, dynamics and history of the process to the video monitors and printers;
- the information exchange with the middle control level;
- the provision of the information to the operating personnel.

Inside the heating unit, the following boards are locates as a part of the APSC: a heating unit power distribution board (HUPDB); a heating unit regulating board (HURB); an automated circulatory system board (ACSB).

The programmable logic controller (PLC) Siemens of the Simatic S7-1500 series is a part of HURB, which is used to control the electric equipment of the heating unit. The PLC is comprised of a shared freely programmable controller with expansion modules, control circuit power supply units, automated control circuit power supply breakers, switches, indication elements, and a cellular GSM-modem.

One of the system's advantages is the possibility to view remotely the status of the technological processes on a mnemonic diagram using Internet resources.

The developed GSCL structure of a geothermal station and the employed modern hardware and software Siemens means on a basis of the Simatic S7-1500 PLC make it possible to implement a flexible automated system with the possibility of scaling that provides a high level of automation and dispatching.

It should be noted that Simatic S7-1500 is the PLC of a new generation and is based on the further development and improvement of the functionality of the widely used programmable controllers S7-300 and S7-400.

CONCLUSION

The application of the new technologies allows hoping for the high efficiency of the station as a whole and of the circulation loop in particular, especially for the Russian conditions.

As the technical parameters of this station are unparalleled in the Russian Federation, the construction cost of the first station increases by the amount of R&D. In future, the organization will be able to mount similar stations on a "turn-key" basis. However, due to the low operating costs of heat generation, the cost value of 1 Gcal of heat will be relatively low, which will make it possible to compete in the target market.

Furthermore, the stations of this type have a potential for the expansion of their beneficial effect due to the connectivity of a binary power plant.

For today, the prospects for the development of geothermal energy in most regions of the South of Russia rich in geothermal resources are associated with the commissioning of a pilot geothermal station with a circulation loop at the Khankala deposit of the Chechen Republic. The next stage of development should become a geothermal station with a circulation loop, which applies a multilevel principle of using the geothermal heat – for the electric power generation, the use for the purpose of heating, the extraction of useful components, etc.

However, as with any innovatively oriented project, all possible risks can be studied only after implementation of a pilot project, which, in case of a positive result, can change the structure of the energy consumption in the regions with geothermal reserves, increase the interest of the business community in using the geothermal heat having created conditions for the establishment of a new industry in the Russian federation – the geothermal energy.

ACKNOWLEDGMENT

In this paper, the authors have used the materials obtained during the execution of works under the Agreement No. 02.G25.31.0056 dated from February 12, 2013 within the framework of implementation of the Government Decision No. 218 on May 9, 2010.

The authors express their gratitude to the postgraduate student Farkhutdinov A.M. for his assistance in preparing the material.

REFERENCES

[1] O. Povarov. “Geothermal Power Engineering in Russia Today”, Proceeding of the World Geothermal Congress 2000, Kyushu Tohoku, Japan, May 28 – June 10, 2000.

[2] Sh.Sh. Zaurbekov, M.Sh. Mintsaev, A.A. Shaipov, F.I. Machigova, S.V. Cherkasov. “The Thermal Waters of the Chechen Republic and the Prospects for their Use. In Collection: Actual Problems of Environmental Protection and Technospheric Safety in the Changing Anthropogenic Conditions – White Nights-2014”, Proceedings of the International Scientific and Practical Conference, pp: 253-259, 2014.

[3] M.Kh. Dautkhadzhieva, M.Sh. Mintsaev, G.S. Taimaskhanov, “The Regional Production Clusters as the Key Factors of the Life Support of Depressive Territories”, Terra Economicus, vol. 10(2-2), pp. 171-174, 2012.

[4] A.M. Gareev, A.M. Farkhutdinov, I.M. Farkhutdinov, S.V. Cherkasov. “The Current State and Prospects of Use of the Thermal Waters of the Russian Federation (on an Example of the Khankala Deposit)”, Bulletin of the Bashkir University, vol. 19(3), pp. 887-892, 2014.

[5] A.M. Farkhutdinov, I.M. Farkhutdinov, R.A. Ismagilov. “The History of the Discovery and Development of the Khankala Thermal Water Deposit”, Bulletin of the Bashkir University, vol. 19(1), pp. 93-96, 2014.

[6] A.M. Farkhutdinov, I.M. Farkhutdinov, R.A. Ismagilov, S.V. Cherkasov. “The Prospects for Using Geothermal Waters in the Ciscaucasian Foothill Zone (the Khankala Deposit)”, Bulletin of the Academy of Sciences of the Republic of Bashkortostan, vol. 19(4), pp. 34-43, 2014.

[7] A.B. Alkhasov, R.M. Aliyev, Kh.G. Magornedbekov. “Prospects of Two-Contour Geothermal Power Station Construction”, Renewable Energy, vol. 10(2/3), pp. 363-366, 1997.

[8] J. Lund, T. Boyd. “Geothermal Direct-Use in the United States in 2000”, Geo-Heat Center Quarterly Bulletin, Klamath Falls, OR, vol. 21(1), pp. 15, 2000.

[9] G. Axelsson. “Sustainable Geothermal Utilization”, Proceedings of "Short Course on Geothermal Development and Geothermal Wells", organized by UNU-GTP and LaGeo, Santa Tecla, El Salvador, pp: 18, 2012.

[10] Iu.N. Malyshev, Kh.E. Taimaskhanov, Sh.Sh. Zaurbekov, M.Sh. Mintsaev. “The Prospects for the

Development of Geothermal Energy in the Chechen Republic", International Scientific Journal "Sustainable Development of Mountain Areas, vol. 1, 2014.

[11] M.Sh. Mintsaev, Kh.A. Taymaskanov, T.G. Churikova, S.V. Cherkasov, M.A. Shaipov, F.I. Machigova. "Khankala Thermal Water Deposit of the Chechen Republic and Resources for the Implementation of Geothermal Circulatory Systems", World of Mining – Surface & Underground, vol. 2(67), 2015.

[12] F.I. Machigova, A.A. Shaipov, L.R. Bekmurzaeva and S.V. Cherkasov. "The Geochemical Studies of the Khankala Deposit Thermal Waters of the Chechen Republic", Sustainable Development of Mountain Areas, vol. 2, pp. 61-63, 2014.

[13] A.A. Shaipov, et al. "An Integrated Project on the Establishment of a Pilot Geothermal Power Station on the Basis of the Implementation of a Circulatory System for Using Geothermal Heat", Report on R&D: the Grozny State Oil Technical University Named after Academician M.D. Millionshtchikov, Grozny, pp: 134, 2013.

[14] M.Sh. Mintsaev, A.V. Iliukhin, M.R. Isaeva, V.V. Pashaev, M.A. Labazanov. "The Automated Technological Process Control System of the Experimental and Industrial Geothermal Power Station with a Circulatory System of Heat Extraction at the Khankala Deposit of the Chechen Republic", The Proceedings of the International Scientific and Practical Conference on Geoenergy. Grozny: GGNTU, Makhachkala: ALEF, pp: 233-240, 2015.