GEOTHERMAL RESOURCES FOR LOCAL HEAT AND POWER SUPPLY IN RUSSIA

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ABSTRACT

Russia has unique geothermal resources located almost throughout the whole territory and these resources are well developed.

Construction of local systems for heat and power supply based on geothermal resources is an important trend in the Russian energy sector, which will ensure effective power supply to a number of regions such as Kamchatka, the Kuril Islands, Siberia and the Northern Caucuses.

Reliable district heating systems are of great need in several regions of Russia, that's why nowadays new technologies of geothermal heat utilization are being actively developed, and new geothermal power plants based on a binary cycle are being created.

Key Words: *geothermal resources, district heating system, geothermal power plants, binary cycle*

INTRODUCTION

Russia is well known not only for its huge resources of solid fuel but also for its large heat reserves. Heat reserves with the temperature of between 30-40 ^{0}C (Fig.1, see next page) can be found in several regions of Russia and some parts of it are known for geothermal reserves with the temperature of up to 300 ^{0}C [1].

The territory of Russia is well investigated and major heat resources have been already discovered, having large industrial and generating power capacity.

In 1983 a map of thermal water resources of USSR was prepared. Forty seven geothermal fields with the capacity over 240x10^3 м^3/day and two-phase fluid fields with the capacity 105x10^3 м^3/day had been explored on the territory of Russia [2].

Kamchatka is known not only for its 300 MW Mutnovsky high temperature geothermal field, but also for large geothermal resources of the Koshelyevsky, Bolshe-Banny steam fields located in the south of Kamchatka and the Kireunsky field located in the north of Kamchatka. The total capacity of such steam fields amounts to 2000 MW_e. Based on expert estimation, hot water heat reserves of Kamchatka equal to 5000 MW_{th} [3, 4, 6].

The Kuril Islands are also known for their rich heat reserves sufficient for their heat and power supply for the next 100-200 years. In the Northern Caucuses and the Magadan region geothermal reservoirs with temperatures of between 70° and 180°C, located at depths between 300 and 5000 м, are well explored. Geothermal fluid has been already utilized there for district heating for many years. The volume of geothermal water being extracted in Dagestan amounts to 6 mln m^3 per year. Almost 500,000.00 inhabitants of the Northern Caucuses are provided with geothermal water supply.

West-Siberian regions, the Far Eastern region, the Baikal also possess reserves of geothermal heat suitable for large-scale use in industry and agriculture.

Fig. 1. Geothermal resources of Russia
(yellow marked parts define low-enthalpy geothermal resources,
while red marked parts – high-enthalpy geothermal resources)

For the last years heat pumps have been widely used in district heating systems utilizing geothermal energy resources. International experts predict that Japan, China and other countries will greatly advance in developing this technology in the nearest future. Being a northern country with a wide territory, Russia should also, by all means, facilitate the development of local district heating systems based on heat pumps.

Application of heat pumps is proved highly efficient for local district heating systems and hot water supply to big cities. This concept is being actively developed in Europe and other countries all around the world.

The technology of heat pumps will be soon implemented in Moscow and other big cities of Russia. Thus, heat pumps will be used for aqua-park and some other buildings in Moscow to supply them with hot water and heat. However, the system of hot water supply to an 18-storey building is already in successful service in the south-west of Moscow.

Utilization of reservoir heat with heat pumps as well as utilization of ventilation emissions will provide cheaper, reliable and all-year-round hot water supply to buildings.

FULL HEAT AND POWER SUPPLY OF THE ELIZOVO REGION (KAMCHATKA) BASED ON GEOTHERMAL RESOURCES (A DEMONSTRATION PROJECT).

In recent years power supply in Kamchatka and particularly in the Elizovo district has been critical with power generation traditionally based on expensive imported fuel (mazut, coal and diesel fuel).

Particular significant is the Elizovo district heating problem caused by severe climatic conditions and long annual heating period (up to 260 days per year at minimal designed outdoor temperature –20 ^{0}C).

At present heat supply to Elizovo consumers is provided by 25 boiler-houses with a total heating capacity of 150 Gcal/h at temperatures of 70-95 ^{0}C. Greenhouse gas emissions from boiler-houses in Elizovo City amount to 2600 tons per year.

High cost of the imported solid fuel and delays in its delivery have resulted in a critical situation with power supply in Kamchatka. Still the Elizovo region possesses unique geothermal heat reserves, sufficient for completely satisfy energy and heat supply of the region.

In 1999 Geotherm SC completed the construction of the environmentally friendly 12 (3x4) MW Verkhne-Mutnovsky GeoPP at the Mutnovsky reservoir and put it into operation. At present the construction of the first 50 (2x25) MW phase of the Mutnovsky GeoPP is almost finished. The capacity of geothermal resources of the Mutnovsky field amounts to 300 MW_e and presently the business-plan for the second phase of the Mutnovsky GeoPP with 100 MW capacity is being prepared [3, 6].

Heat supply to consumers located 20-30 km away from Elizovo City (in Paratunka and Termalny settlements) is provided by direct utilization of geothermal heat. Hot water for the district heating system is delivered from the Paratunsky reservoir (its proved capacity is 23.3 thous. m^3/day with the average temperature of 77 ^{0}C), which has been operated by Kamchatburgeothermiya SC since 1969.

Utilization of geothermal water provides reliable heat supply to inhabitants, enterprises and medical centers located in the Paratunka river valley. Heat of the Earth is used in this area for heating and hot water supply, growth of vegetables, fruit and flowers, salmon fish rearing, in swimming pools, etc. (Fig. 2, see next page).

To transfer the existing Elizovo district heating system to local geothermal resources an environmentally friendly geothermal district heating system with a thermal pump station is offered to be constructed; the thermal pump station will provide heating of the water up to 95 ^{0}C as well as maximal benefit from geothermal heat-carrier utilization.

Power supply to the Elizovo district including power supply to heat pump compressors will be implemented based on geothermal resources. Electric power will be transmitted from the GeoPP complex located on the Mutnovsky steam field.

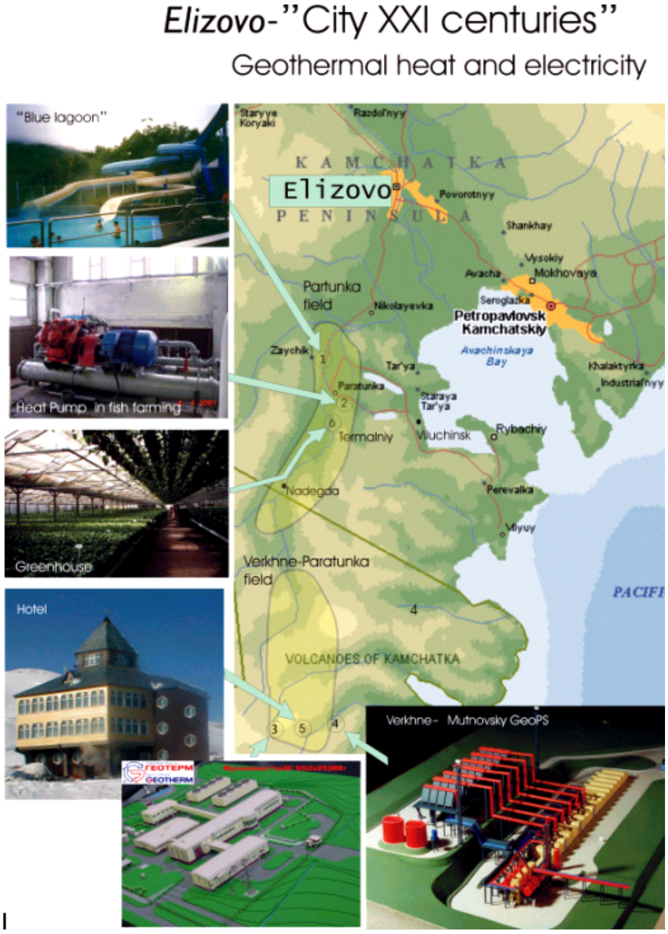

Fig. 2. Ways of utilizing geothermal resources in the Elizovo district (Kamchatka).

The scheme of a heat pump station (HPS) is presented in Figure 3 and comprises three circuits: circuit of geothermal water, intermediate circuit and circuit of the water in the Elizovo heating system. Water temperatures in three different circuits correspond to the required peak heat load.

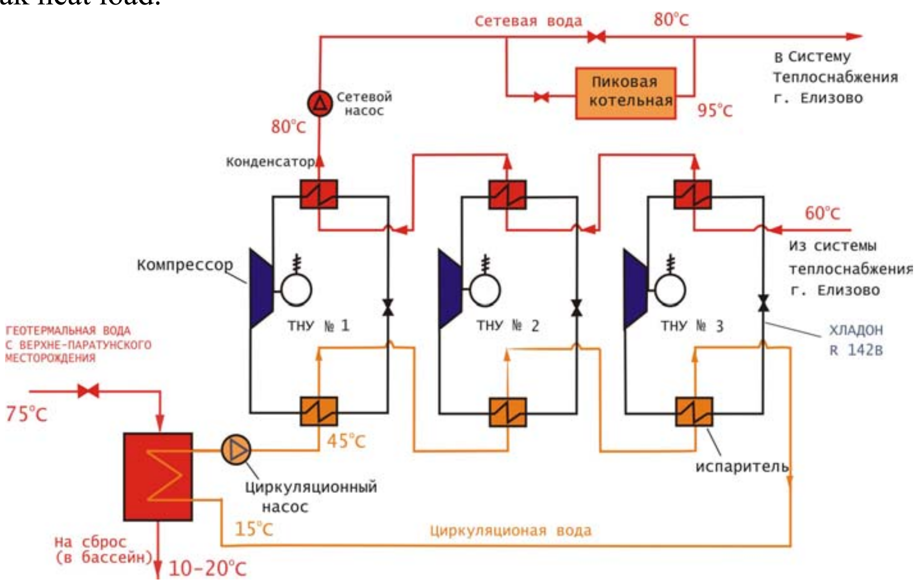

Fig. 3. The system of Elizovo geothermal heat supply utilizing heat pumps.

Geothermal water from the Verkhne-Paratunsky reservoir with the temperature of 75 ^{0}C (temperature drop in the pipeline can not be more than 3-5^0 C) is delivered to Elizovo City through the main pipeline. Maximal water flow rate is 300 l/s. The second circuit water, passing through a heat-exchanger, is heated by geothermal water up to 45^0 C, then comes into evaporators of three successively switched heat pumps (HPU), where it gives its heat to chladone, evaporating it, and then the water comes back to the heat-exchanger. From the heating system of with the temperature of 15 ^{0}C Elizovo the water comes into condensers of three heat pumps where it is heated up to 60^0 C - 80^0 C. Additional heating of the water is provided in a boiler house in accordance with temperature requirements for water flow in the heating system.

Maximal heat capacity of HPS with the coefficient of transformation equal to 3,2 (calculated as an average for three successively switched HPS) is approximately 86 Gcal/h.

Should the heat load be reduced, heat pumps will be switched off in succession. In summer period (July, August) the demand for hot water can be covered without heat pumps.

GEOTHERMAL HEAT AND POWER PLANTS (GeoHPP)

The major benefit from utilizing geothermal resources can be obtained by synchronous heat and power supply to small towns and settlements which are remote from the centralized power supply system.

It's often enough to have one production and one re-injection wells to supply the settlement (almost 1000 houses) with geothermal heat and electricity.

GeoHPPs will be most effective for Russia, particularly for its Northern areas, because GeoHPPs can operate all-year-round.

The efficiency of GeoHPP can be increased by using heat pumps utilizing "waste" heat of geothermal water as well as by modern heating systems such as warm floors and air radiators.

Should geothermal resources be located inside big cities, it's also justified to construct big (several dozens MW) GeoHPPs. Under the Kyoto Protocol to the United Nations Framework Convention on Climate Change dated 1997 Russia took the obligation not to exceed the level of greenhouse gases emissions fixed in 1990. The renewed growth of the Russian economy and a low level of the power efficiency require the development of environmentally friendly power technologies, including heat supply technologies [4].

Environmentally friendly geothermal technologies for power and heat generation favorably differ from technologies utilizing coal, mazut, diesel fuel.

Combined power and heat generation utilizing coal causes huge carbon dioxide emissions that can reach 1 kg/kW·h. Combined power and heat generation utilizing oil is a little bit better from an environmental point of view.

The concept of generating power in turbo-generators using working fluids with low-boiling temperatures has been appreciated for more than 50 years. The first geothermal binary cycle Paratunsky power plant, constructed in Kamchatka in 1965-1967, was a great achievement in this respect [5, 6]. Nowadays, this concept by Soviet scientists is utilized worldwide and about one thousand power units and power plants have been constructed in over 50 countries, which operate on a binary cycle technology with capacities ranging from a few kW up to 130

MW_e.

When the Paratunskaya geothermal power plant was being constructed and later in the Soviet period numerous thermophysical research works on low-boiling working fluids had been conducted at the Institute of Thermal Physics (Siberian branch of the Russian Academy of Sciences), VNIIkholodmash-Holding SC, etc. and as a result methods for intensifying heat exchange process were developed.

Recently in Russia the increase in prices for solid fuel (mazut, diesel oil) and its delivery to remote regions, as well as the tendency to use local renewable energy sources and establish local independent power systems have facilitated the development of afore mentioned plants.

Geotherm SC and Nauka SC with support from the Ministry of Industry and Sciences of the Russian Federation, RAO UES of Russia, and with assistance from MPEI and the Institute of Thermal Physics have been working on creation of a power unit based on a combined cycle. Such power units will include a geothermal installation with a 2.5 MW back-pressure turbine and a 4 MW binary cycle power plant [7]. Figure 4 illustrates a heat flow diagram for the 4th combined cycle power unit of the V-M GeoPP.

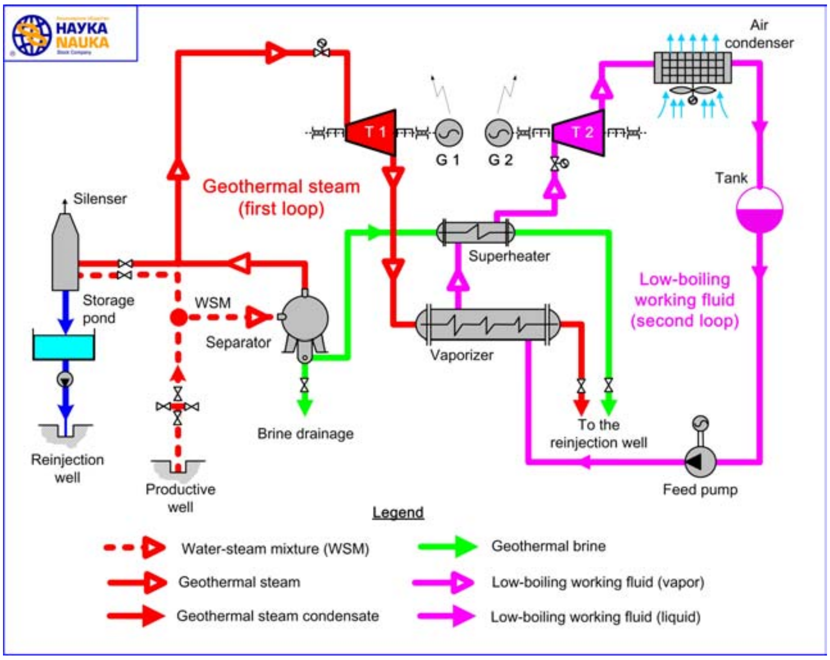

Fig. 4. Basic heat flow diagram for the 4th Unit of the V-M GeoPP

The first turbine (T1) operates on vapor produced after separation of two-phase fluid coming from wells. A backpressure turbo generator is manufactured at Kaluga Turbine Works SC by applying well-known technology and concepts.

Turbine exhaust vapor with the pressure of almost 1bar and the temperature of ~100 °C flows into a binary cycle power plant (BPP) steam generator, where it is heated up and causes evaporation of the working fluid for a 4 MW binary cycle turbo generator (T2).

Figure 5 shows BPP design and its main elements. This design was developed for climatic conditions of Kamchatka: snow depths can reach 6-8 m; winter temperatures can drop to minus 30 °C, wind speed can vary from 5 to 30 m/sec.

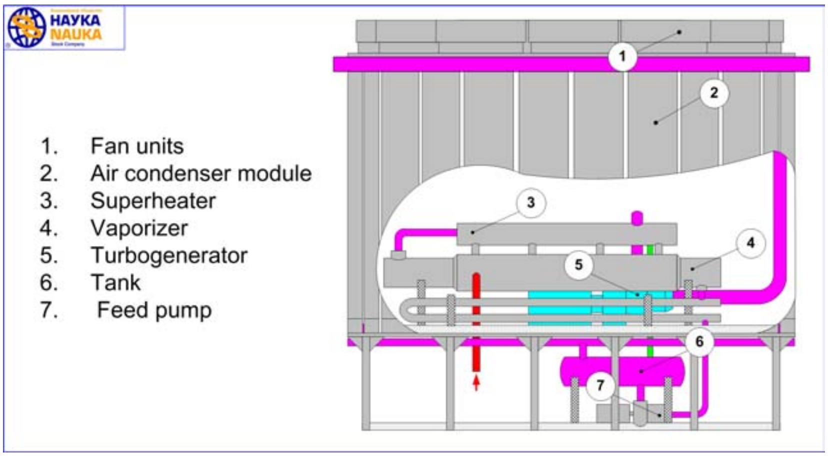

Fig. 5. Binary Cycle Power Plant Design

BPP could increase power generation by GeoPP based on a traditional cycle, should the heat of the brine and of the steam from substandard geothermal wells with temperatures of over 150 ^{0}C be utilised.

Construction of BPPs is one of the trends in the power saving program based on utilising waste heat from Nuclear Power Plants and Heat Power Plants, steel, cement, and similar plants. High electricity tariffs force industrial companies to create their own independent (local) power supply systems. BPP can either increase generating capacities of existing plants or supply power to large industrial companies.

Major energy saving benefits from binary units can be obtained by connecting them to local systems for heat and power supply, i.e. by creating binary cycle thermal power plants (BTPP) utilizing heat from nuclear water-heating boilers (Fig.6), from hot geothermal fluids with temperatures of over 90 °C, as well as from gas-fired waste heat boilers, etc.

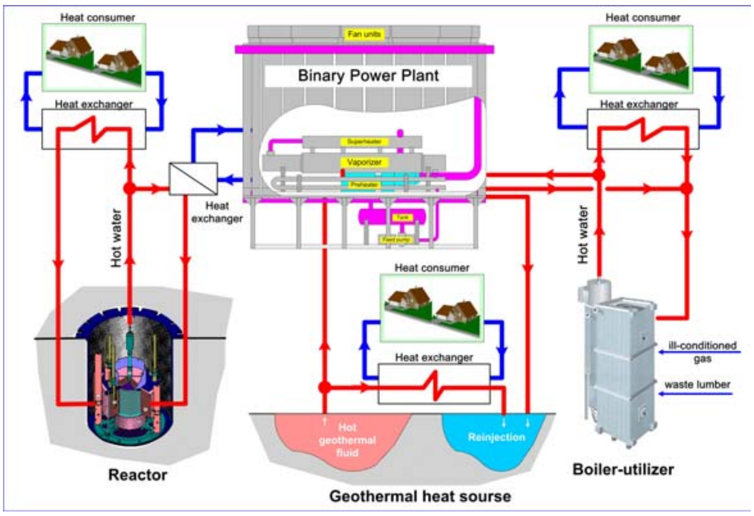

Fig. 6. BPP for power generation in various heating systems

a) in the heating system with a nuclear boiler

b) in the geothermal heating system

c) in heating systems with water-heating boilers

CONCLUSION

Russia possesses unique geothermal resources located almost through out the whole territory of the country. In the nearest future these resources will be utilized for creating local heating systems.

During next decade geothermal power will increase its portion in the total balance of power supply in our country and help improving power supply of remote northern regions.

Recently in Russia new geothermal technology and industry have been developed, providing an effective utilization of the earth heat at GeoPPs, GeoHPPs and GeoHPs, to generate electricity and heat and to develop local heat supply systems.

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