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GEOTHERMAL POWER ENGINEERING IN RUSSIA – TODAY

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ABSTRACT

Russia has large resources of geothermal energy for production of electric power, provision of district heating systems for industrial and agricultural needs. Exploitation of geothermal resources, implementation of drilling operations for geothermal heat production has been carried out in Russia for more than 50 years. Today almost all the territory of this country is well investigated. It was found that numerous regions have reserves of hot water with the temperature from 50 to 200°C at depth from 200 to 3000 m. These areas are located in the European part of Russia: Central region; Northern Caucasus; Daghestan; in Siberia: lake Baikal, Krasnoyarsk region, Chukotka area, Sakhalin Island.

Kamchatka Peninsula and Kuril Islands have the richest resources of geothermal power available for the production of up to 2000 MWe electricity and for more than 3000 MWt for district heating system.

Pauzhetskaya Geothermal Power Plant (GeoPP) (Kamchatka) has been under interrupted operation for more than 30 years. Paratunskaya GeoPP (Kamchatka) is the first GeoPP in the world using a binary cycle. However, until 1990 geothermal power engineering was poorly developed in Russia, since the prices for oil and diesel fuel were low in this country.

1. INTRODUCTION

Vast territory of Russia possesses rich resources of geothermal heat, that can be used for heat supply of towns and settlements, electric power generation at GeoPP with conventional, binary and combined cycles.

Figure 1 illustrates the main territories of Russia possessing geothermal power resources for industrial utilization.

The heat of hot geothermal water with temperature from 40 to 190°C has already been actively studied and used for about 50 years in the European part of Russia.

Daghestan Republic at the Northern Caucasus is the largest region for the development of geothermal energy. Total amount of resources at the depth of 0.5-5.5 km allows to obtain approximately 4 million m^3/day. At present, more than 7.5 million m^3/year of hot 50-110°C water is used in Daghestan. Among them, 17% as hot water; 43% for heating of houses; 20% - for greenhouses and 3% for balneotherapy and mineral water production.

Totally in Dagestan about 180 wells have been drilled at a depth from 200 to 5500 m. The regions of such towns (settlements) as Kizlyar, Tarumovka and Jushnosukhokumsk, possess unique reserves of hot water. For instance, Tarumovskoye deposit has the reserves of geothermal water of high salinity (200 g/l) with temperature up to 195°C. Six wells have been drilled to depths of about 5500 m, the deepest geothermal wells in Russia. Tests indicate high reservoir permeability with wells producing between 7,500 and 11,000 m^3/day at 14-15 MPa wellhead pressures. (Magamedov K.M. *et al*, 1999)

Broad use of geothermal heat is possible in the center of the European part of Russia and in S. Petersburg area.

Siberia also possesses geothermal heat reserves, which can be used for heat supply and agriculture. (Fig.1)

However, the richest geothermal heat reserves are in the East of Russia. Kamchatka and Kuril Islands have the reserves of hot water and steam m with temperature up to 280°C at a depth of 700-2500 (Fig.1).

In particular, Kamchatka and the Kurils Islands have the richest resources, with a generating power capacity of up to 2000 MW and of heat capacity no less than 3000 MW utilizing a steam water mixture and hot water.

Since the middle of 50's systematic geophysical surveys and drilling have been carried out in Kamchatka geothermal field. To date 385 wells have been drilled to depths of 170 m to 1800 m including 44 wells producing a two-phase fluid at an emergence temperature of more than 160°C. In 1966 Pauzhetskaya geothermal power plant was commissioned south of Kamchatka; at present it is under successful operation generating the cheapest power. The estimated potential of this geothermal field is 50-60 MW (up to 30 years).

Practically all territory of Kamchatka region has geothermal heat available in the form of hot water, two-phase fluid and steam. In the south of Kamchatka (zone No. 1) near the Pauzhetskaya GeoPP, exploration of the Koshelevskaya geothermal system has discovered resources sufficient for GeoPP, with a capacity of about 350 MW.

North of Mutnovskaya geothermal system there are resources available for the generation of 180-200 MW.

The eastern part of Kamchatka (zone No.2) is estimated rich of high temperature geothermal water resources, for a power capacity of about 250 MW.

In the center (zone No.3) and northern part (zone No.4) of Kamchatka the estimated power capacity of the geothermal resources with temperatures above 150°C is 550 MW, and the estimated heat capacity of the geothermal resources with temperatures below 150°C is up to 600 MW.(Fig.2)

2. GEOTHERMAL POWER AND HEAT PLANTS

The first geothermal power plant has been built south of Kamchatka, Russia, in 1965-69. Pauzhetskaya GeoPP (Fig.3) is the geothermal power plant which successfully works today producing the cheapest power in Kamchatka.

An experience of Pauzhetskaya GeoPP operation confirmed the possibility of prolonged exploitation of low steam parameters in direct cycle. Thus, for example, the pressure before turbine is maintained already more than 30 years at 2 bars level (appr. 120°C. Therewith the problems with salts sediment were absent.

However, in the 1970s-80s in Russia the construction of geothermal power plants was suspended for economic reasons, i.e. oil prices in the country were cheap, and electricity generation in Kamchatka was based on imported fuels.

At present fuel prices (oil and diesel) and fuel delivery have reached world market levels, and sometimes exceed it. For instance, the oil cost in Kamchatka is US$220 per ton, diesel fuel cost is US$ 340 per ton, and the geothermal cost of 1 kWh is US$ 0.20-0.30. In this connection interest in utilization of geothermal resources has greatly increased in Russia.

Latterly, the power and heat geothermal plants are under active construction. (Fig. 2) In 1993 module geothermal power plant (N=0.7 MW) has been put into operation in Kunashir Island, and in 1997, in the same place the heat geothermal power plant (Okeanskaya) has been commissioned too. The heat geothermal power plant is also installed in Paramushir Islands. The capacity of such plants varies from 3 to 20 MWt.

In Iturup Island about 30 wells have been drilled and nowadays 8 (4X2) MWe GeoPP are already delivered there.

These power plants have back pressure turbines, as well they are inexpensive and convenient in exploitation.
At present the program of construction of GeoPP series with direct, binary, and combined cycles is developed in Russia. As this takes place, the special consideration is given to ecology and efficiency of GeoPP.

By now several stock energy companies have been created in Russia. These SC are engaged in making, construction and exploitation of geothermal power and heat plants.

SC Geoterm is constructing the series of geothermal power plants in the Mutnovsky steam field. It is located in the center of Kamchatka 90 km from the Petropavlovsk-Kamchatski station. The field is well explored. More than 90 wells have been drilled, and two-phase fluids with an well-head temperature of 160-180°C have been discovered. The available geothermal heat resources are sufficient for the generation of 300 MW, based on the GeoPP of condensed and combined cycle.

Currently SC Geoterm is commissioning Verchne-Mutnovskaya GeoPP, with a capacity of 12 (3X4) MW. This geothermal power plant is of the block type and consists of 14 containers equipped with facilities that have been completely factory-tested (Fig.4) The severe climatic conditions entail specific scientific and technical decisions, and, first of all, the utilization of the blocks of the GeoPP, the construction and installation of which should take no more than two years.

Verchne-Mutnovskaya GeoPP is a power plant of the next generation. The air condensers make it environmentally friendly. After leaving the turbines the steam enters the condensers through pipes. All condensate and gases after the condensers are reinjected, so this geothermal power plant functions with no emissions into atmosphere.

By 2001 the IV block of geothermal combined cycle with a capacity of 9 (3+6) MW will be constructed.

SC Geoterm has also started construction of the first stage of the Mutnovskaya GeoPP, with a capacity of 50 MW. The European Bank for Reconstruction and Development provided SC Geoterm with a loan of US$ 99.9 million, and the preliminary civil works and construction of the infrastructure are now under realization . In the summer of 2001 the first stage of the Mutnovskaya geothermal power plant is scheduled to be commissioned. At the same time it is planned to commission the Control Center for the management of all the geothermal power plants (about 20) that will be constructed in Mutnovsky geothermal field. Currently the required infrastructure and remote control of 15-20 GeoPP are under construction. The Center will be located in the Termalny settlement.

Construction of small GeoPP with binary cycle is considered to be highly prospective for remote regions of Kamchatka, Kuril islands, Siberia and Northern Caucasus where central power supply is absent.

There are great resources of hot water at temperatures of 90-120 ^{0}C in Kamchatka, which led plans to construct a series of state-of-the-art binary cycle geothermal power plants with the objective of generating power in remote settlements.

In 1967 Paratunskaya geothermal power plant was constructed – this is the first binary cycle geothermal power plant in the world. Experience in constructing and operating this plant has confirmed [7]:

- Real opportunity of power production from hot water (water temperature >80 ^{0}C);
- Great perspectives of the utilization of double circuit binary cycle power plant. At present this method is well spread all over the world.

Construction of GeoPP with a combined cycle is highly prospective for severe climate conditions of Russia. It is possible to reach very low temperature of working medium concentration (10÷15 ^{0}C) and have system, which does not freeze even at the temperature of minus 50 ^{0}C.

By 2001 the IV unit of geothermal combined cycle with a capacity of 9(3+6) MW will be constructed by Geoterm SC.

The second stage of two units of Mutnovskaya GeoPP with a combined cycle with total capacity of about 60 MW – this will the most economic-effective GeoPP with steam rate of not higher than 5.4 kg/kW.

3. HEAT PUMPS

Long winters with low air temperatures in some regions of Russia require developed heat supply system (practically all the year round). Therefore recently construction of heat supply plants with heat pumps is developed in Russia.

Efficiency of heat pumps application sharply increases under utilization of geothermal fluid with temperature within the range from 20 to 50 ^{0}C.

Nowadays plant with heating pumps are successfully operating in Siberia and Kamchatka. Their total amount exceeds 100, and unit heating pump capacity makes 10÷5000 kW.

4. PERSPECTIVES OF GEOTHERMAL ENERGY DEVELOPMENT

During last years there have been significant changes.
There was a sharp rise in oil and diesel fuel prices.

1. Decentralizing of power systems took place, and now regions have to solve problems of their power demands themselves.
2. The conditions for attraction of investors and creditors from different countries were created.

Geothermal power engineering in Russia is successfully developing today: Verchnye-Mutnovskaya GeoPP has been put into operation. Mutnovskaya GeoPP is under construction in Kamchatka (up to 300 MWe). Wide implementation of heat pumps is planned to be held in the European part of this country and in Siberia.

The program of geothermal power engineering development in Russia provides electricity and district heating systems to a number of important regions of Russia.

Nowadays construction and operation of the power and heating geothermal plants can be extremely profitable for banks and investors. In Kamchatka the atmosphere and conditions are favorable for investments; there is also an opportunity for the construction of the series of geothermal power plants based on the BOO and BOT scheme.

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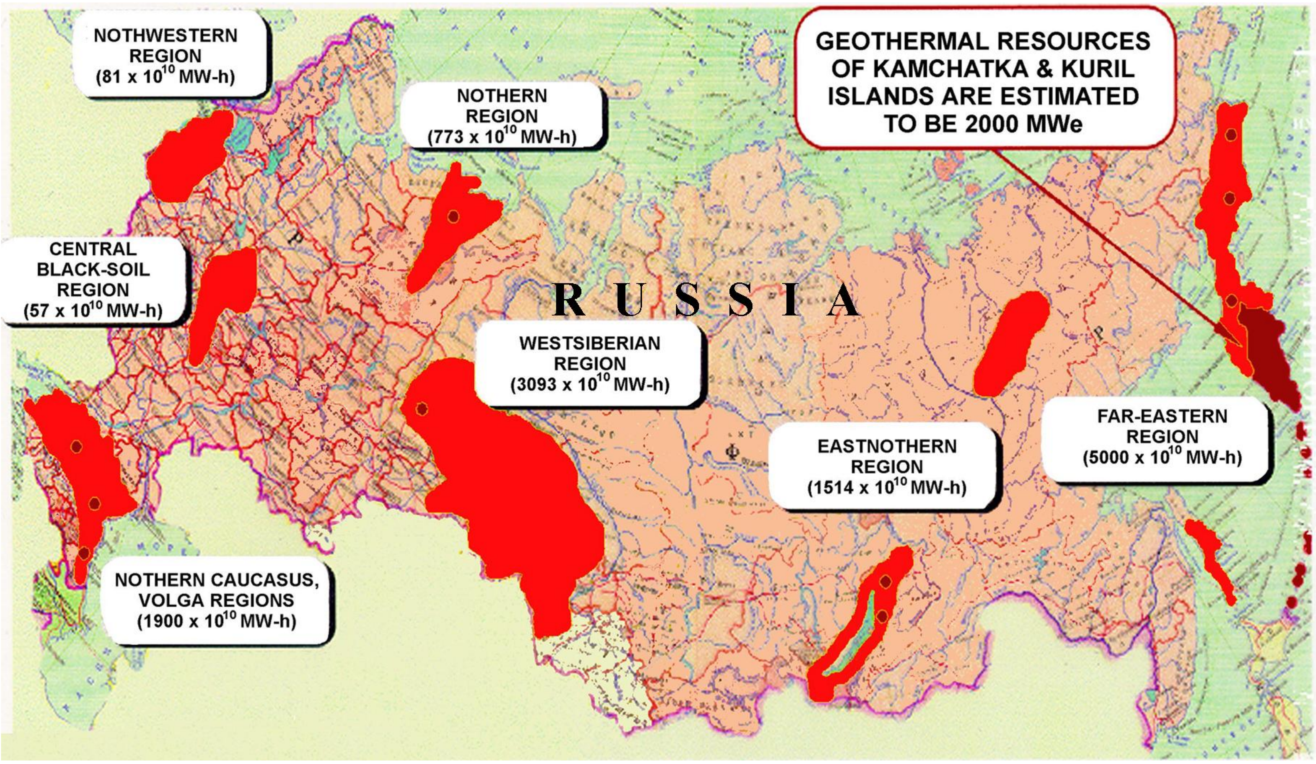

Figure 1. Basic resources of geothermal heat in Russia
(- hot water (t=60÷160 ^{0}C) for heat supply and binary GeoPP; - Steam-water (t=120÷180 ^{0}C) for GeoPP)

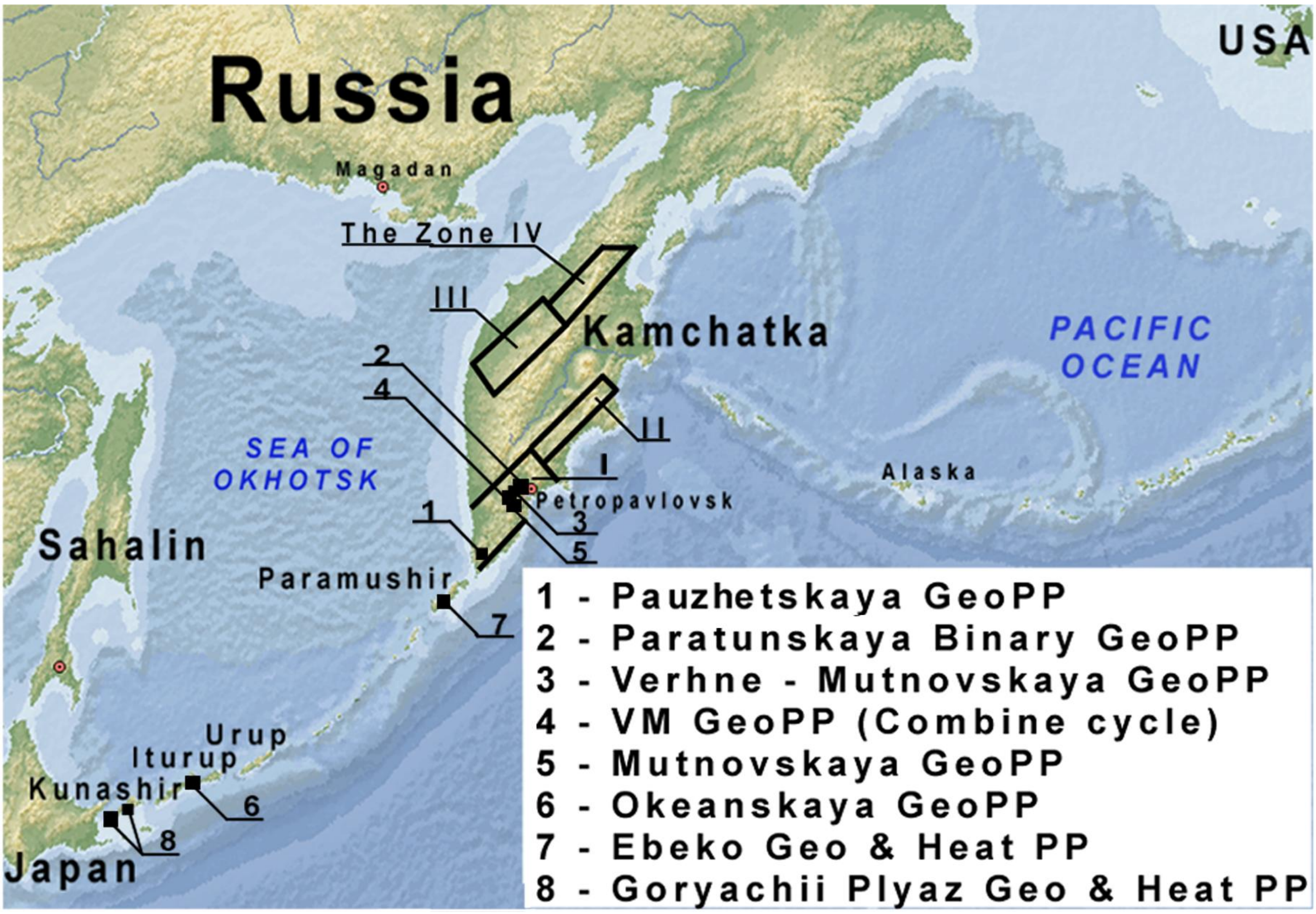

Figure 2. Geothermal power and heat plants in Kamchatka and Kuril Islands.

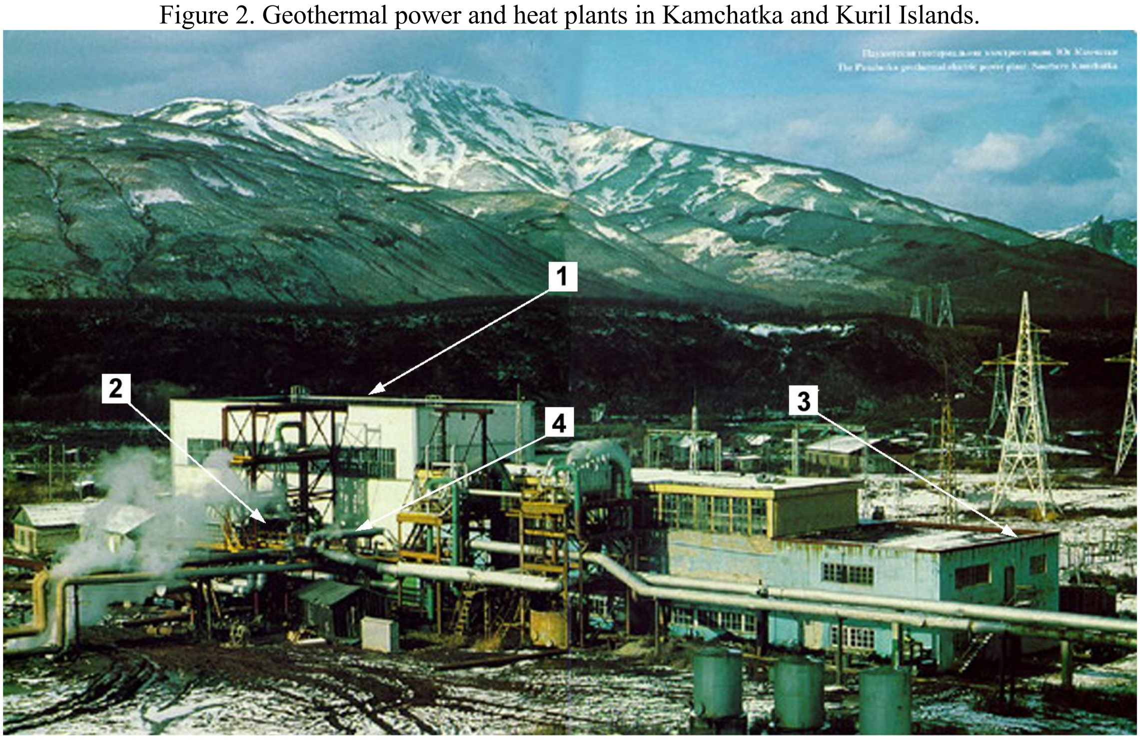

Figure 3. Pauzhetskaya GeoPP (1965) 1—power unit; 2— wet steam supply ($p_0 \approx 4$ bar); 3— administrative building and laboratory; 4— geothermal heat input.

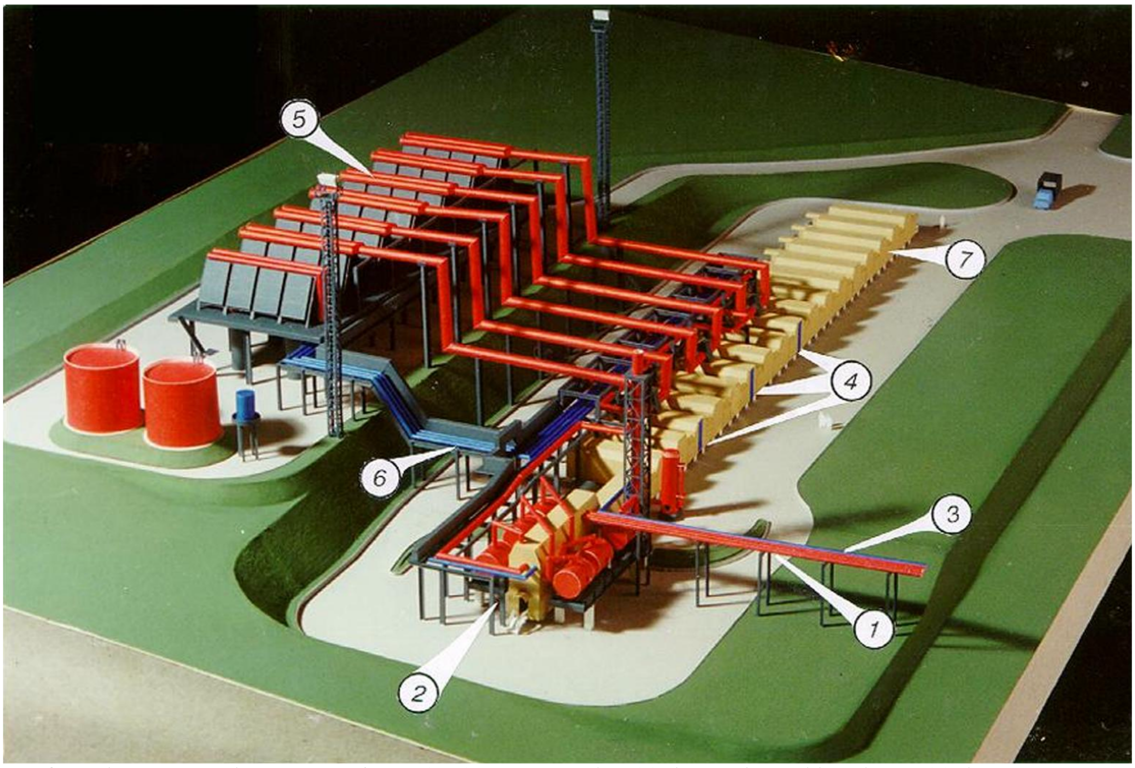

Figure 4. Verhne-Mutnovskaya GeoPP for 12 (3x4) MWe capacity: (*1*) the geothermal heat input; (*2*) the steam-preparation installation; (*3*) removal of the separate; (*4*) turbine-unit modules; (*5*) the air condensers; (*6*) condensate removal; (*7*) complex of headquarters and domestic amenities.

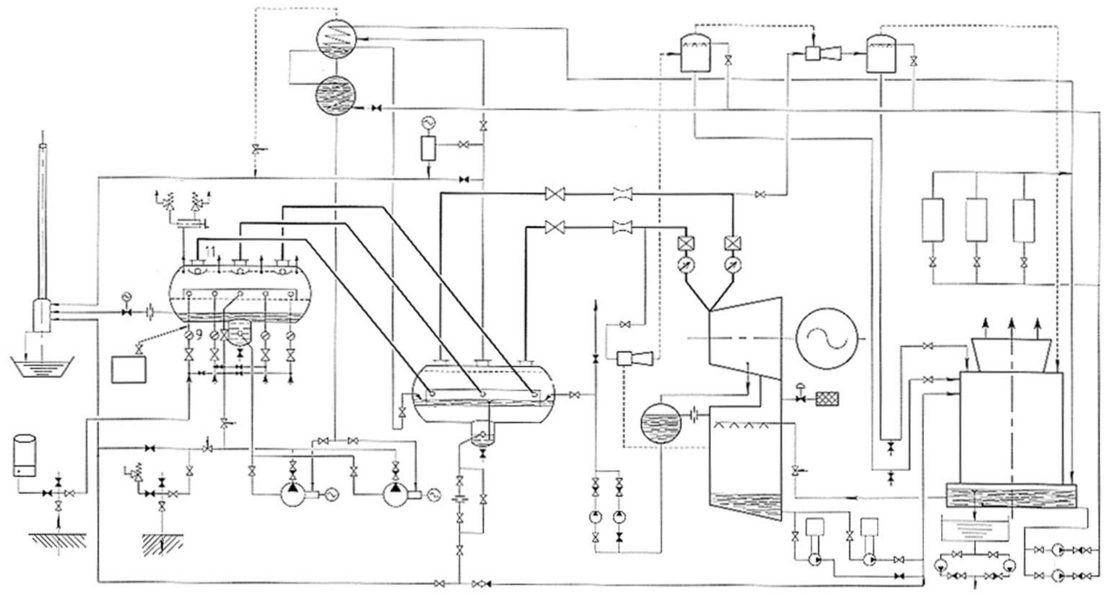

Figure 5. Scheme of the first stage of Mutnovsky GeoPP 50 (2x25) MW 1-Separator (I Stage); 2-Separator (II Stage); 3-Turbine; 4-Water Cooler Tower

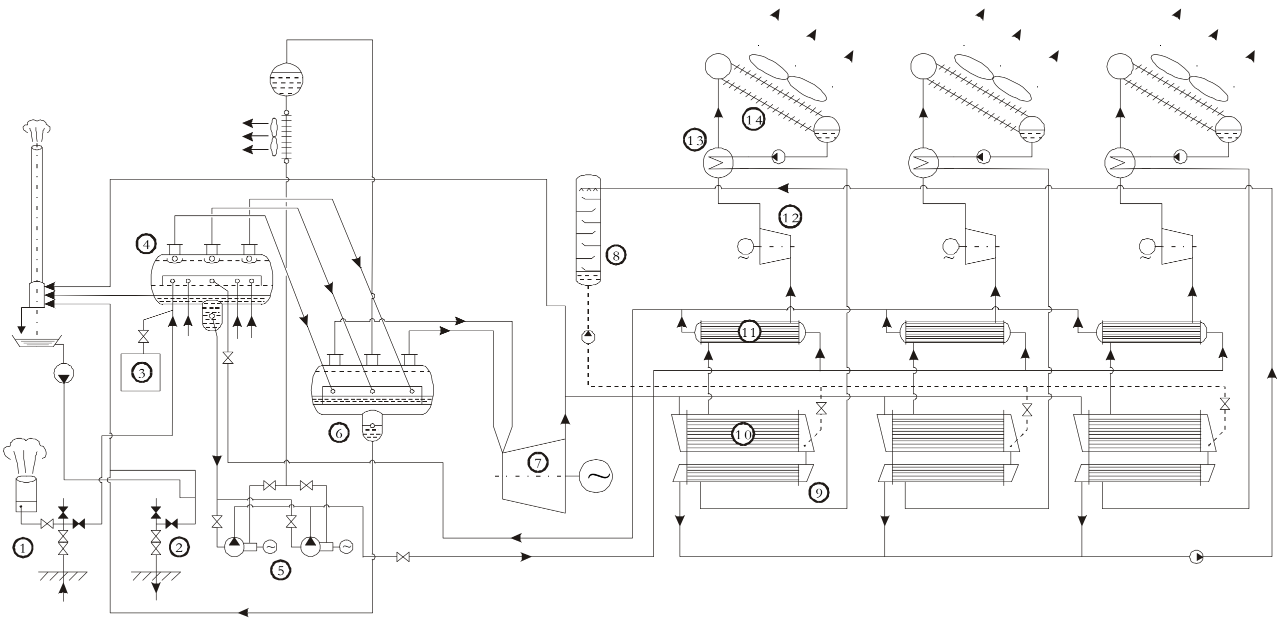

Figure 6. Scheme of the second stage of Mutnovsky GeoPP with a combined cycle (N≈60 MW)
1 – production well; *2* – reinjection well; *3* – corrosion protection system; *4* – primary separator; *5* – reinjection pumps; *6* – secondary separator; *7* – steam turbine; *8* – NCG absorber; *9* – preheater; *10* – condenser-vaporizer; *11* – superheater; *12* – working fluid turbine; *13* – recuperator; *14* – air cooled condencer.