Geothermal Energy Development in Kamchatka and Kurils Islands

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ABSTRACT

The construction of several geothermal and heat power plants is being implemented at Kamchatka Province and Kurils Islands. Within the next 5-10 years it is planned to provide these regions completely with electricity and heat from geothermal heat sources.

Today these regions of Russia are the show case of international geothermal projects having the high economic efficiency.

Introduction

Such regions of Russia as Kamchatka, Kurils Islands, Sakhalin Island, Magadanskaya oblast, Dalny Vostok and some other northern Russian regions, remotely located from centre, nowadays have initiated the global reconstruction of their energy systems to use their own power resources.

This is due to the recent changes in Russia, which have fundamentally affected (have increased) organic oil prices (oil, fuel oil and coal) and the price of its delivery to the distant regions of Russia.

As an example, at present 1 kW/hour of power cost in Kamchatka and Kurils Islands is variable from 10 to 30 cent, because these regions do not have their own oil, coal and gas resources. Oil supplied from Siberia or different countries of the world completely provides for local energy use.

As is well known, the above regions are quite rich in minerals and sea products. However, industry and human life here can not be adequately supported due to the excessively high price of heat and electric power. Therefore, a program of reconstruction of building efficiency in the regions is in progress.

Nowadays, about 450 thousands of people live in Kamchatka and the electric capacity, produced at thermal and diesel power plants, amounts to 420 MW. Simultaneously there are considerable resources of geothermal earth heat in these regions, poorly used at present.

Geothermal power resources exceed several times the demand for them and so an extensive program of the construction of electric and heat power plants, with geothermal fluid as a working body, is expanding here today.

Geothermal Resources

As is well known, the geothermal heat at Dalny Voctok comes up relative closely to the Earth's surface in such areas as Alaska, further, central and southern Kamchatka regions, Kurils Islands, particularly, Sakhalin Island and Japan (see Figure 1) (Kononov V.I. and Dvorov I.M., 1990).

Kamchatka and Kurils Islands are situated in the early volcanism zone and are predisposed to the geothermal systems formation near the Earth's surface, permitting the development of industrial use of them for energy and heat supply.

Two-phase geothermal fluid resources of Kamchatka and Kurils Islands make possible to construct Geothermal Power

Figure 1. Geothermal energy development in Kamchatka and Kurils island.

Plant (GeoPP) with total capacity up to 2000 MW_e and GeoPP up to 3000 MW_t.

Geothermal heat is available on the whole territory of Kamchatka (hot water, two-phase flow and steam).

Since the middle of 1950's the seismic, geophysical and drilling works are under the implementation on the steamfields in Kamchatka. In this time interval 385 wells have been drilled with 170-2000 m depth. Paugetskaya and Koshelevskaya geothermal systems in the South of Kamchatka with thermal reserves for GeoPP with a capacity about 450 MW_e have been already explored (see Figure 1).

In the North of the Mutnovsky Geothermal System the thermal reserves for 180-200 MW_e are also available.

Kamchatka's East region (Zone II) has rich high-temperature geothermal water resources with their energetic power being evaluated as 250 MW_e.

In the center of Kamchatka (zone III) and in its North (zone IV) the geothermal resources with temperature over 150°C are estimated as 550 MW_e and with lower temperature 150°C – as up to 600 MW_t (Povarov O.A. *et al.*, 1994).

Electrical and Heat Geothermal Power Plants on Kurils Islands

Kurils Islands have a critical need in use the own power resources of geothermal heat. The lack of the own organic fuel and the distance of Kurils Islands from the continent would require the creating of modular (unit) geothermal power plants providing full industrial readiness of them, i.e. delivered assembled.

The first unit type GeoPP for Kunashir Island (nearby Japan) (see Figure 1) was constructed at "Kaluga Turbine Works" SC according to order of "Energy" SC and has been commissioned in 1992.

The above-mentioned GeoPP has confirmed the construction and use of small uncondensing unit (container) type GeoPP with a capacity from 0,5 to 3 MW_e. These GeoPP are inexpensive, rapidly constructed (erected) and are easy to operate and maintain. The combination of such GeoPP with Geothermal Heat Plants (GeoHP) allows to use the earth energy and to provide small settlements with power and heat.

In 1997 on Kunashir Island 20 MW GeoHP was put into operation. Now the drilling and construction works to develop the geothermal power plant are in progress there.

The considerable industrial reserves (up to 300 MW) of geothermal fluid (steam-water) have long been discovered at Iturup Island and so the construction of 12 MW_e Ocean GeoPP is under the execution now.

Ocean GeoPP is located on Baransky volcano slope near the Sernaya river source at a distance of 17 km from Kurilsk. More than 10 wells have been drilled at the Ocean Deposit. As to PGO "Sakhalingeology" data the Ocean Deposit disposes of two-phase geothermal fluid resources up to 60 MW.

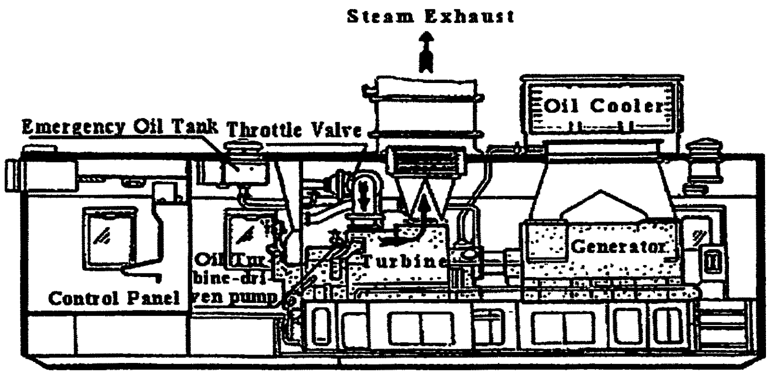

Figure 2. Turbine - generator unit for GeoPP.

The first three unit GeoPP, with a capacity of 2 MW each, have been already supplied to Iturup Island.

The unit "turbine-generator" and other equipment for GeoPP, assembling at the factory in one carriage, are shown in Figure 2. The dimensions of carriage (container) are: 10.5×4.7×3.6 m, its weight is over 45 ton. Turbogenerator (back pressure unit) allows working in a wide range of initial steam pressure values p_0 = 4-10 atm. Being tested, this unit has a turbo-oil pump, that also works with geothermal steam. Such design allows the GeoPP exploitation without any external electricity source. In this case any GeoPP can be put into operation independently, without diesel engines and other external power sources.

The turbogenerator is completely mounted and tested with 100% load at the factory. Further, it is assembled ready to use when received at the steam field.

In 1994 two GeoPP of the same type were created and manufactured in Russia for GeoPP "San-Jasinto". These GeoPP have successfully pass through tests at "Kaluga Turbine Works" factory and will be shipped to Nicaragua (Povarov O.A. and Tsimmerman S.D., 1998).

Experience shows that the opening up of new geothermal fields, located a distant from industrial regions, it is expedient to construct upon the following principle: geothermal fields investigation – first steam production – construction and commissioning of unit GeoPP without condenser – opening up of the geothermal field – construction and exploitation of large GeoPP.

Until now geothermal steam reserves have not discovered at Paramushir Island. There is a great need in heat in this area. At present the drilling works for hot water (70-90°C) extraction and advanced works on 20 MW_e GeoHP construction for the heat supply of Severo-Kurilsk are under the implementation there.

Today "Kaluga Turbine Works" SC has already manufactured several unit type geothermal heat plants with titanium heat-exchangers for Kurils Islands. These GeoHP are completely automated.

Power Plants in Kamchatka

Kamchatka is the unique place, possessing exclusive reserves of the Earth's heat, which comes close to the Earth's surface.

Geothermal steam and water resources in Kamchatka would allow to obtain up to 5000 MW of electrical and heat power, to satisfy all the demands of this area in power, heat supply, and to transform it into the highly developed region of Russia (Povarov O.A., 1999).

Since the middle of 1950's systematic geophysical and drilling works have been carried out on Kamchatka steam fields. In this period there have been drilled 385 wells with depth from 170 to 1800 m , including 44 production wells with the temperature of two-phase fluid at the Earth's surface over 150°C.

In 1966 the Paugetskaya GeoPP in the South of Kamchatka has been put into operation, which at present is under the exploitation, producing the cheapest electric power. Today the geothermal field potential is estimated as 50-60 MW_e (within 30 years).

At the South of Kamchatka (zone I) not far from Paugetskaya GeoPP, the Koshelevskaya geothermal system, with heat reserves for the GeoPP of approximately 350 MW_e (see Figure1), has been already proved. Almost on the whole territory of Kamchatka geothermal heat is available (hot water, two-phase flow, etc.).

The east side of Kamchatka (zone II) is rich in high temperature resources of geothermal waters and their power capacity is evaluated as 250 MW_e.

At the center of Kamchatka (zone III) and in the North the geothermal reserves sources with temperature over 150°C – to 600°C are located.

Nowadays the opening up of Mutnovsky geothermal deposit situated 90 km to the south of Petropavlovsk-Kamchatsky (zone I in Figure 1) is aroused maximum interest. This geothermal field has been thoroughly investigated and over 90 wells have been drilled there. It is possible to obtain around 300 MW_e at the above field.

Geothermal fluid is the two-phase mixture with 0.7-1.0 MPa pressure, therewith water is 60-70% of the total mass fluid consumption. Canyons, ravines and small streams in the center of the Mutnovsky steamfield don't permit construction of GeoPP in one energy unit (50 or 100 MW), as the steam collecting is almost impossible on large sites. Therefore the major conception of the Mutnovsky Steamfield GeoPP construction lies in unit (module) GeoPP with small capacity (from 4 to 30 MW). All these plants will transport the energy to the closed type (in building) general electric dispensing system, located at the site of the Mutnovsky GeoPP first stage (Povarov O.A. and Tomarov G.V., 1995).

The specific climate conditions of the Mutnovsky reservoir are the following: the average annual temperature –1.9°C (in August up to +25°C, in winter it may be increased up to - 37°C), the snow cover height achieves 10 m. On account of these circumstances the construction period lasts only 4-5 months.

Severe climate conditions require special science-technical solutions and, first of all, concerning the use of such unit GeoPP, the construction and erection of which should not exceed two years. During last years the following companies were founded in order to solve power problems with use of geothermal resources of the Mutnovsky deposit in Kamchatka: "Geoterm" SC with the participation of RAO "UES of Russia", Administration of Kamchatka, "Kamchatskenergo" SC and "Nauka" SC.

The equipment design, creation, production and the construction of the first multi-modular geothermal power plant – the Verkhne Mutnovsky GeoPP (VM GeoPP) of capacity 12 (3×4)MW was organized by means of Ministry of Science support. Verkhne Mutnovsky GeoPP is the pilot geothermal power plant in series of GeoPP, constructing in Kamchatka. Its equipment has been manufactured at "Kaluga Turbine Works" SC ("KTW" SC), "Podolsky Mashinostroitelny Plant" SC and others (Britvin O.A. *et al.*, 1999).

Figure 3 shows the Verkhne Mutnovsky GeoPP.

New principles were determined in the foundation of the Verkhne Mutnovsky GeoPP creation:

1. Unit steam preparation system with complete industrial readiness, located in direct proximity to GeoPP, has been applied;
2. GeoPP of modular type (Figure 2) with 100% industrial readiness of general unit-modules (turbogenerators, electrical engineering equipment, general control board and i.e.);
3. Environmental friendly diagram to use the geothermal fluid with air condensers (AC), that allows selecting the steam energy in turbines, and directing the condensate to the injection wells (Figure 3). In this case fluid doesn't enter the atmosphere.

Two-phase flow from three production wells is transported towards collector by the pipelines (Figure 3) and further, after the two-stage phase separation system the steam arrives at three power units of capacity 4 MW each.

In Russia new horizontal type separators for GeoPP were created, that incorporates three phase separation effects as: centrifugal, of jalousie and gravitational. The horizontal type separators use on Verkhne Mutnovsky GeoPP has confirmed high efficiency of water disposal from steam (up to $y \angle 0{,}05\%$).

Figure 4 shows the horizontal separators unit, steam-expanders and silencers before shipping from Moscow to Kamchatka (appr. 9000 km) by direct flight (weight around 120 t) in the most powerful aircraft in the world AN-124.

Horizontal type of separators provides not only the maximum phase separation effect, but allows creating a space-saving device for any well production as well.

In this situation the steam entering the turbines with up to 0.8 MPa pressure is practically fully drained and therefore it is clean enough. The steam quantity entering the turbines stands at the level of Thermal Power Plant average values.

Verkhne Mutnovsky GeoPP is the power plant of new generation. This is an environmental friendly power plant, as the air condensers are used in it. The steam exiting the turbines is transported towards the condensers inside of pipes and condensed there. All condensate and gases exiting the condensers are injected again into the ground.

At the Mutnovsky geothermal deposit not far from the Verkhne Mutnovsky GeoPP at Dachny site the construction of the Mutnovsky GeoPP 1st stage of capacity 50 (2×25) MW_e is now underway by "Geoterm" SC.

This GeoPP combines the best power equipment and the experience from different countries (Russia, Germany, USA, Iceland and others), so it is creating by means of EBRD support

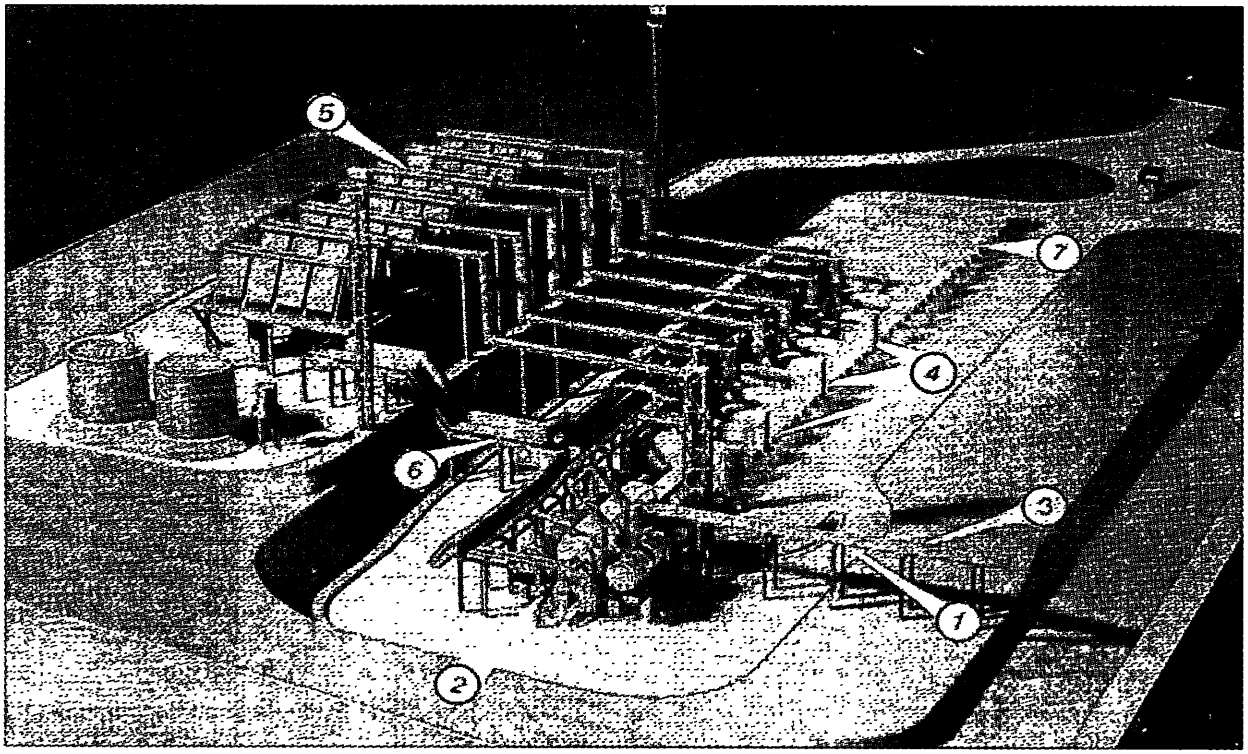

Figure 3. The VM GeoPP for 12 (3×4) MWe capacity: (*1*) the geothermal heat input; (*2*) the steam-preparation installation; (*3*) removal of the separate; (*4*) turbine-unit modules; (*5*) the air condensers; (*6*) condensate removal; (*7*) complex of headquarters and domestic amenities.

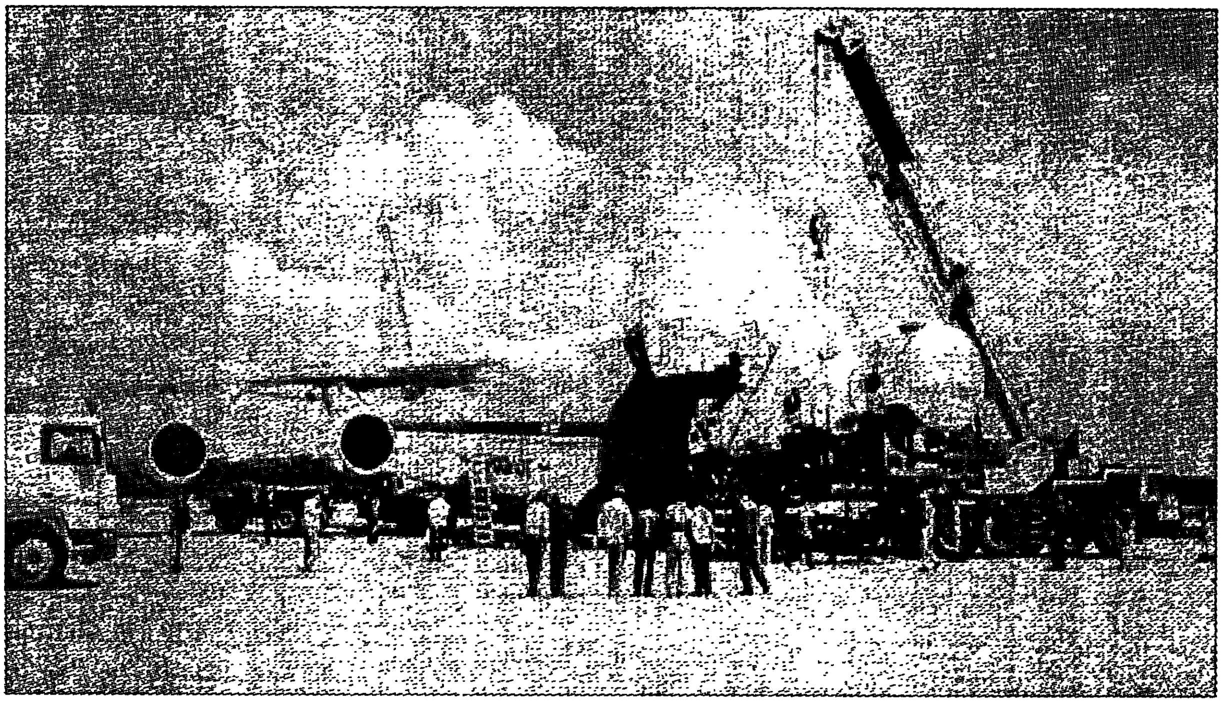

Figure 4. Block of moisture separators in the airport in Moscow.

(99.9 million USD loan) and is constructed in terms of the open international tender.

"Geoterm" SC will sale the power at the steam field of the general power company of Kamchatka– "Kamchatskenergo" SC. The transmission line with a distance of 90 km (220kV), the road (60 km) and also the major power plant in Elizovo (30 km of Petropavlovsk-Kamchatsky), capable of taking over up to 120 MW_e, belong to "Kamchatskenergo" SC.

"Geoterm" SC has the use of concession for all Mutnovsky Geothermal field and also has the effective long-terms Power Purchase Agreement.

The preliminary works have been already accomplished at the Mutnovsky GeoPP construction site. Figure 5 shows the layout of power unit (1), closed dispensing power plant (2), cooling tower (3) and other buildings (4-10).

The whole power plant occupies a space of 250×250 m^2. It is planned that Mutnovsky GeoPP should be put into operation in 2001.

The preliminary works on the Mutnovsky GeoPP 2nd stage construction are under the execution now. The GeoPP should be located on the site beyond the canyon (appr. 500-700 m). Several wells have already been drilled, the steam resources approved, and the construction of the IV binary and combined GeoPP planned.

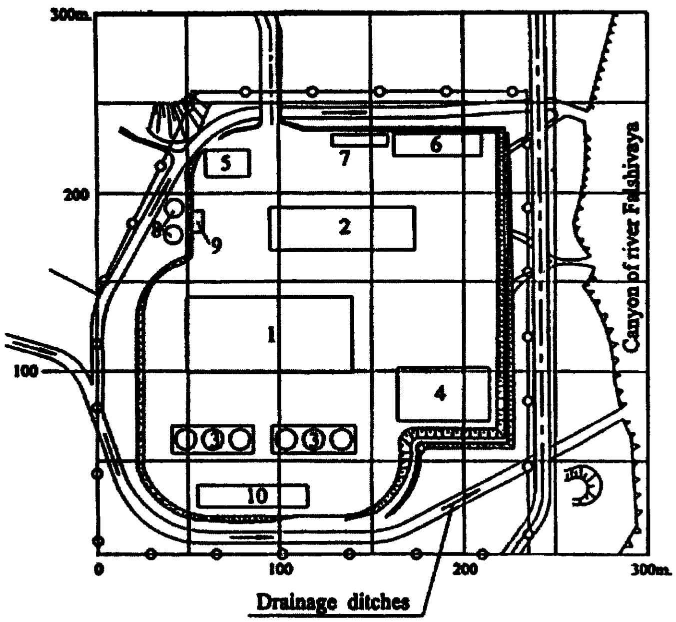

Figure 5. Layout of buildings Mutnovsky Single Flash Power Plant: (1) Power house; (2) Indoor Switchgear; (3) Mechanical draught cooling towers; (4) Emergency holding pond for separated brine; (5) Working Hostel; (6) Garage, Workshops, Storage; (7) Open parking place; (8) Firefighting water storage tanks; (9) Water supply pumping station; (10) Water treatment facility: storm water; sewage water.

Large water reserves of temperature up to 180°C are available in Kamchatka so it is planned to construct up-to-date GeoPP series there with binary cycle to produce the power for settlements, by a distance of centre. In 1967 the 1st in the world binary geothermal power plant was constructed at Paratunsky deposit (appr. 30 km of Petropavlovsk-Kamchatsky) (Moskvicheva V.N. and Popov A.E., 1970). This stated a new direction of power production using low-enthalpy heat (hot water of temperature from 90°C to 180°C), which has received wide development in the world and, at present, around 300 binary cycle power units, manufactured in general by ORMAT company, are already operating.

There is great potential for use of binary cycle in such cold regions of Russia as Northern site and Dalny Vostok.

Today it appears quite perspective to use turbo-installations with organic working body in combined diagram applying turbines using geothermal steam, as well as the binary installations use with turbines using organic fluid in order to increase the efficiency of use of exhaust gases power at the gas pumping over stations, iron and steel works and others.

At the Mutnovsky deposit in parallel with common GeoPP it is intended to construct no less than 30 GeoPP using organic working body for the purpose of making more effective use of geothermal fluid heat. As already noted above, the content of hot water (separate) of the two-phase geothermal fluid is from 30 to 70%.

The use of binary and combined GeoPP at the Mutnovsky deposit would increase the whole geothermal system efficiency by 20-40%.

"Geoterm" SC has already proceeded to Verkhne-Mutnovsky GeoPP IV power unit creation. The above unit is produced based on combined cycle (see Figure 6).

The part of steam after Verkhne-Mutnovsky GeoPP separators will be transported to the steam turbine of capacity 2.5 MW. This is the counter-pressure turbine (appr. 1.0 bar), after which the steam is transported to the heat-exchanger A, when the first stage of the organic fluid is heated. The organic fluid is transported after the pre-heater A to the heat-exchanger B (evaporator). This heat-exchanger is heated up by hot water (separate) of the whole Verkhne-Mutnovsky GeoPP with temperature approximately 100°C and provides for organic fluid steam production, which is directed to the turbine.

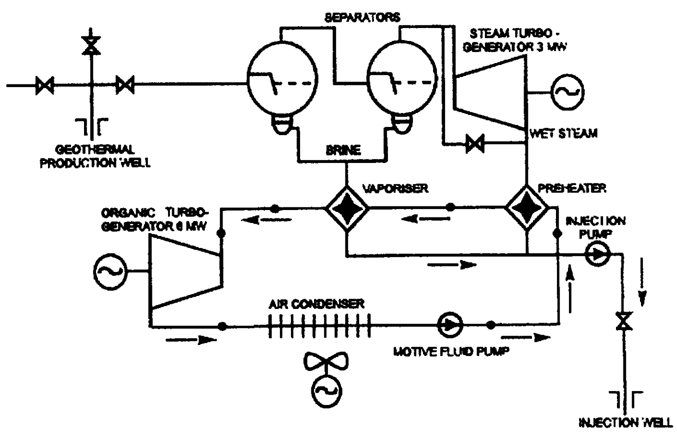

Figure 6. Geothermal combine cycle of power plant 9 (3+6) MW$_e$.

The organic fluid turbine, constructed for Verkhne-Mutnovsky GeoPP, will be a full-size turbogenerator for binary installation with air condensers.

The high efficiency and reliability of slope-vertical type air condensers (see Figure 2) has already been confirmed by the first Verkhne-Mutnovsky GeoPP experience.

Perspectives of International Cooperation in Russian Geothermal Energetics

Kamchatka is an important region for international cooperation in the discovery of geothermal resources of this area.

Today the construction and exploitation of geothermal electric and heat plants may be very profitable for banks and investors. The favourable climate and the possibility of construction of GeoPP series, according to BOO and BOT processes, has been created in Kamchatka.

A long-standing analysis of situation in Russia, Iceland, Japan, Italy, New Zealand and other countries with participation and support of EBRD has shown that the geothermal energy development is the environmentally expedient way for existing resources to be utilized, at least, up to 500 MW_e and 1500 MW_t level.

There is permanent power and heat consumer in Kamchatka as industry, including defense, population and new production development. High qualified personnel of power engineering specialists and builders are available in this region.

The government of Kamchatka creates all the necessary conditions for non-traditional energy development, supporting the cooperation with energy system with neighboring countries.

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