

## GEOTHERMAL POWER AND HEAT PLANT DEVELOPMENT IN RUSSIA (KAMCHATKA)

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### ABSTRACT

*Russia possesses the unique reserves of geothermal resources. Geothermal power plants are being built in Kamchatka, Kuril Islands and in the North Caucasus. These regions are potentially rich in geothermal steam.*

*Steamfield exploration and geothermal power plants development have been underway in Russia (USSR) for over 60 years. The first geothermal power plant with an installed capacity of 11 MW was built in Kamchatka. The Pauzhetskaya Geothermal Power Plant is still successfully operating and generating power in south of Kamchatka.*

*In 1967 Soviet scientists created the first binary cycle geothermal power plant in the world. At present, 15 geothermal power and heating plants are under operating and construction in Russia and Latin America. These Plants are constructed with the equipment manufactured in Russia and other countries.*

*Mutnovsky GeoPP of 50 (2x25) MW shall be commissioned in early 2002. The second Phase of the Mutnovsky GeoPP is to be of 100MW. A series of Geothermal Power Plants of 300MW is to be built at the Mutnovsky steamfield.*

*Russian plants and companies take part in business activity in Latin America. In Nicaragua Russian investors and Russian Plants have opened "San-Jasinto Tizate GeoPP" steamfield. Russian Plants have already manufactured the equipment for 5(2x2,5) MW and 46 (2x23) MW Power Plants. The equipment is intended for tropical conditions and for 60Hz current.*

### 1.0 INTRODUCTION

The economical and political changes that have taken place in Russia greatly influence the way the power industry is developing. This, first of all, concerns changes in the prices on fuel and in the costs to transport it to remote regions in Russia.

Under these circumstances, it is natural that the regions should strive to use their own energy resources and develop renewable sources of energy. In the Far Eastern regions, Sakhalin oblast, the Kuril Islands, and, particularly, in Kamchatka, utilization of the Earth's thermal energy is coming to be a subject of great importance.

Recently, several, new joint-stock companies have emerged in Russia whose main activities are developing, constructing, and operating geothermal power stations.

The development of geothermal power engineering in the Russian Federation is based on the scientific and technical achievements of MEI, SC Nauka, and VNIAM, and also on the experience of the Kaluga Turbine Works (KTZ), the Podolsk Machine-building Works (PMBW), the Chekhov Power Machine-building Works (ChPMBW), and also of other manufacturers in creating and operating equipment for the power, nuclear and shipbuilding industries.

Russian plants and institutes in cooperation with German, Ukrainian, and USA companies are actively operating at a creation of new fully automated GeoPP. Only in Kamchatka and Kuril Islands it is intended to construct GeoPP and GeoHP of up to 500MW, total capacity. Figure 1 shows the location of geothermal plants in this region.



Figure 1 - Geothermal power and heat plants in Kamchatka and Kuril islands (I-IV – zones of explored geothermal resources of up to 2000MW<sub>e</sub> total capacity).

## 2.0 GEOTHERMAL POWER PLANTS OF CONTAINER TYPE

The development of new geothermal fields and the utilization of small geothermal deposits are accomplished by means of modular geothermal turbine installations of a small capacity ranging from 0.2 to 12MW. In Russia, such turbines are manufactured by KTZ, which makes use of many years of experience that was acquired in manufacturing and operating compact turbo generators for ships and industry (Fig. 1). The 1<sup>st</sup> KTZ turbine was installed at the Pauzhetsky GeoPP (Kamchatka) in 1967, and nowadays it is successfully functioning.

Table 1 lists the main characteristics of several turbine installations manufactured by KTZ for geothermal power stations:

Table 1 - Main characteristics of KTZ turbine installations

Capacity, MW <sub>e</sub>	$p_0, MPa$	$p_c, MPa$
0.5	$0.8 \pm 0.2$	0.1
2.0	$0.7 \pm 0.2$	0.1
2.5	$0.7 \pm 0.2$	0.1
4.0	$0.6 \pm 0.2$	0.01

These installations can be manufactured with electric generators for 50 and 60 Hz. A specific feature of these turbines is that there is no gearbox between the turbine and the generator. Naturally, due to their low speed, these turbines have a greater number of stages; nevertheless, the turbo generator is quite compact. It is installed on a common frame, which is also an oil tank (Fig. 2) (Povarov and Lukashenko, 1997).

Two such 60 Hz turbo generators with a tropical design, each having a capacity of 2.5MW, were manufactured for the San Jasinto geothermal power plant in Nicaragua. These units are to cover the needs of the power plant auxiliaries during the construction period, to function as a stand-by power-generating unit for the entire station in the operating period (starting up the station from “zero”), and to generate additional power (Povarov et al., 1999). The turbo generator has its own turbo oil pump, working on geothermal steam.

The layout of GeoPP consisting of components with total capacity of 5 (2x2.5) MW is shown in Figure 3. The geothermal power plant includes all required components of steam preparation, two turbine generators, and electrical technical modules with transformers providing the required electrical voltage.

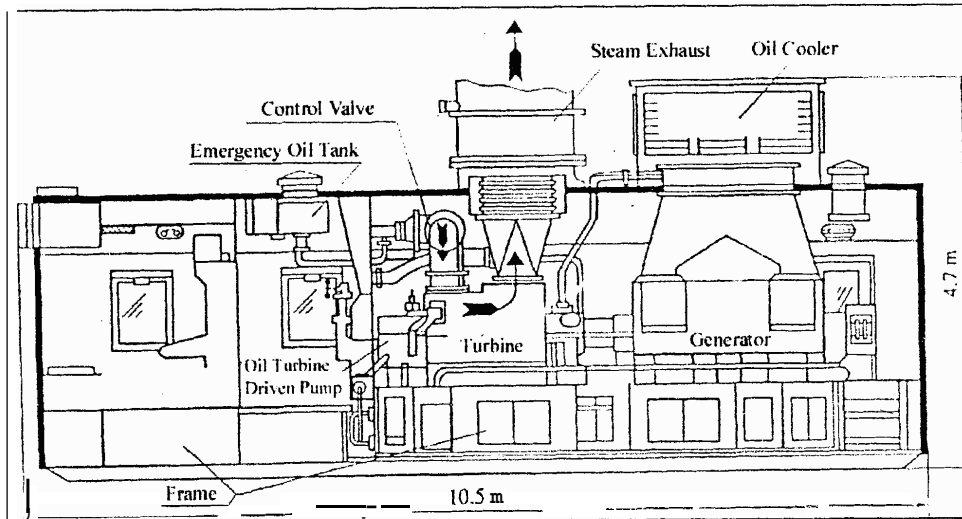


Figure 2. The 2.5MW Turbo generator for Geothermal Power Plant.

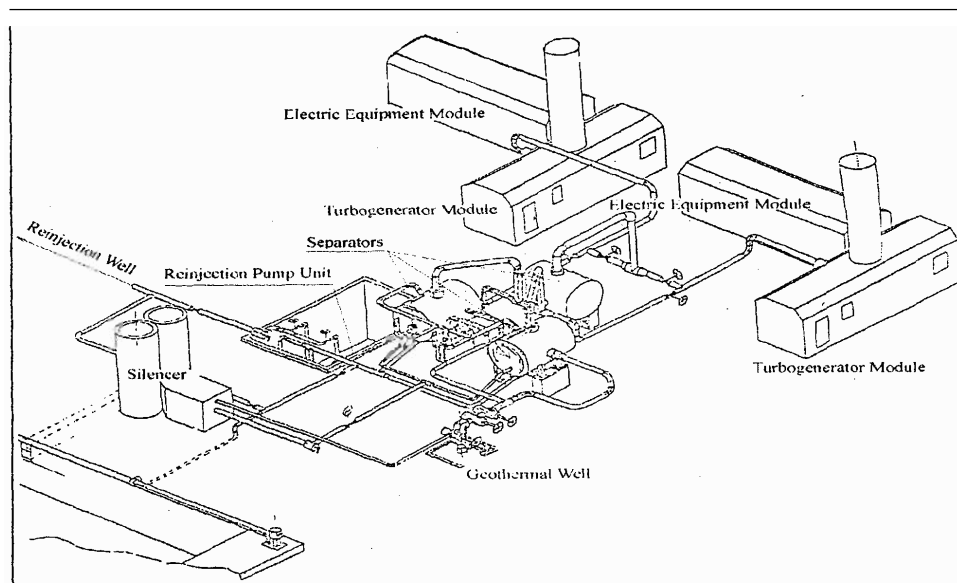


Figure 3. Modular geothermal power plant of 5 (2x2.5)MW<sub>e</sub>.

**Basic Technical Parameters**

Nominal Power : 5.0(2,5 x 2) MW  
 inlet turbine steam pressure : 7.0 ± 2.0 bara  
 Outlet turbine steam pressure : ~ 1.0 bara  
 Frequency of rotor rotation : 60 Hz  
 Steam flow rate : 40.3t/h

Inlet turbine steam moisture : <0.1%(by weight)

Voltage, kV:

- generator output : 6.3
- auxiliary power : 0.4
- output to network : 10.5; 13.8

This turbo generator can be started by itself without any other external power source, because a turbine-driven oil pump is also installed in it. The starting turbine (the turbine-driven pump) operates on geothermal steam and provides the main turbine and its control system with oil at the pressure required for starting up the main turbine.

Geothermal plants made in Russia without condensers based on turbines that exhaust into the atmosphere are less economically efficient because the available heat drop in the steam for expansion in the turbine is 20-30% smaller.

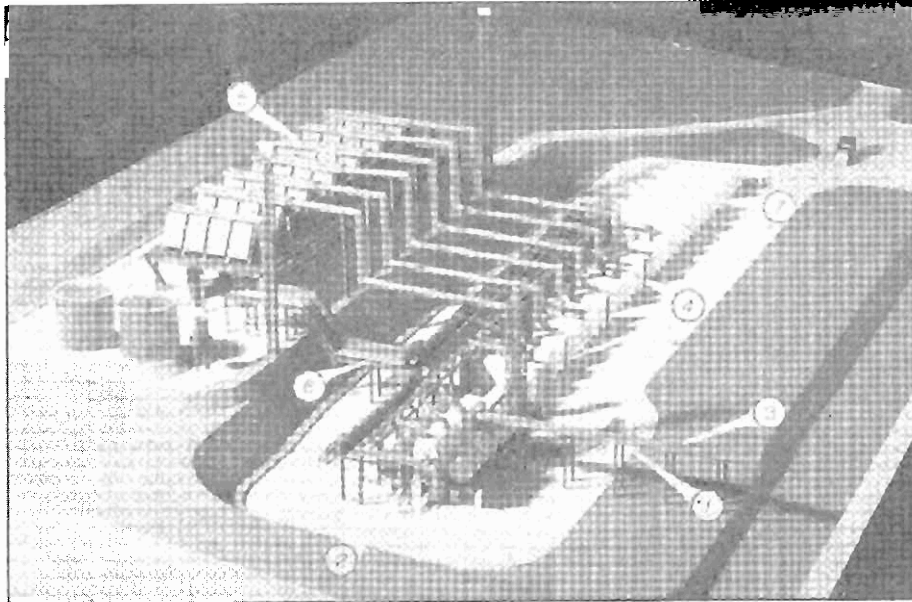


Figure4. Verchne-Mutnovsky Geothermal Power Plant

Nonetheless, modular geothermal power stations have the following advantages:

- they cost less (by 3040%);
- they are compact and are completely assembled at the manufacturer, including the electrical side with the transformer;
- construction and installation work at the geothermal power plant takes two to three months less time;
- one such plant can be installed right on one well, without any need for laying long pipelines;
- transportation is simple;
- for raising the output of the geothermal power plant, if needed commercially, the cycle of the station can be extended; as the result of this modification, the wet steam from the turbine (at  $t \approx 105^{\circ}\text{C}$ ) may be used for heating and combined cycle);
- the station can be quickly relocated from one geothermal field to another.

in 1999 in Kamchatka 12 MW, Verkhne-Mutnovsky GeoPP (VM GeoPP) was put into operation at the Mutnovsky geothermal field Briin et al., 1999). This is a pilot power plant, which differs from the conventional GeoPP conceptions (Fig. 4):

- The technical GeoPP scheme provides an ecologically clean system using a geothermal fluid, eliminating its direct contact with the environment at the expense

of application of air condensers, and 100% reinjection of geothermal fluid;

- Non-condensable gases, contained in the steam, are removed with ejectors then dissolved in the condensate and reinjected into the ground;
- A unit-module GeoPP construction conception was used. Units (modules) of turbo-generators, electro technical equipment, control panel, and others are assembled by the manufacturer, tested at 100% load, and delivered completely assembled to the construction site.
- A system for protection of equipment GeoPP against corrosion uses film-forming amines.

The high quality of steam preparation and VM GeoPP equipment manufacturing provides for effective operations at this power plant. An average daily load of VM GeoPP turbo generators in winter 2001 (December-January-February) occasionally exceeds 100% (of rated power). VM GeoPP stable operation in the mountains and other complicated climatic conditions represents a reliable energy system: VM GeoPP itself, cable transmission line, electric substation at the Mutnovsky steam field, main transmission line (90km), and electric substations in Elizovo. Experience in VM GeoPP creation and exploitation confirmed the reality of the GeoPP series development at the Mutnovsky reservoir, which possesses huge reserves of geothermal heat.

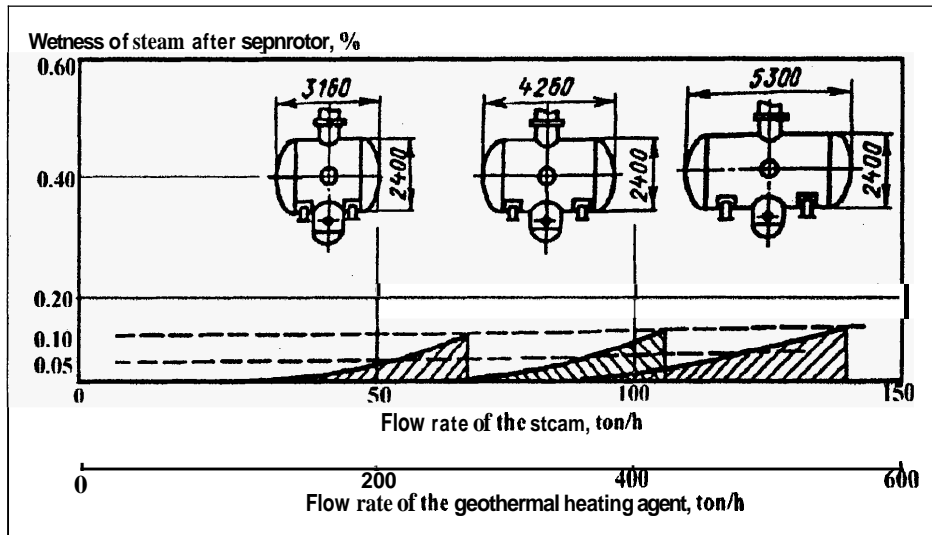


Figure 5. The effectiveness of horizontal separators for geothermal power plants

### 3.0 STEAM SEPARATORS FOR GEOPP FIELD

In Russia, a horizontal type of steam separator for geothermal power plants was developed; this separator differs from vertical type separators that are known in other countries. The change in length of horizontal separators results in low velocities of the steam flowing through them and can ensure a high efficiency of separation of the moisture virtually at any flow rate of the geothermal agent (Povarov and Lukashenko, 1997).

The horizontal separators made in Russia are more compact and have a smaller mass than separators manufactured in other countries, because, first, separators of this type provide several mechanisms of moisture separation, namely, centrifugal, bubbling, and gravitational; and second, these separators are combined units that consist of the separator itself, a collector of the condensate, and a cut-off valve – all located in a single housing. The efficiency of separators of this type is very high because the dryness at the outlet from the separator is  $x > 0.999$ ; that is, a wetness of the steam of  $y < 0.1\%$  as shown in Figure 5 (Povarov and Lukashenko, 1997).

In separators made in Russia, a rise in the flow rate of the geothermal heating agent by weight is accompanied by an increase in the wetness of the steam from 0.01 to 0.1%. Therefore, when the flow rate of the steam is increased, the

length and the volume of the separator can also be increased, thereby optimizing the velocity of the up-flowing dried steam. Separators of this type can be used in creating steam collectors and steam expanders for the entire geothermal power plant.

### 4.0 TURBO GENERATORS FOR LARGE GEOPP

The present-day direction of developing of big geothermal fields in Russia proposes the construction of GeoPP series of not more than 50MW<sub>e</sub> capacity, located at the distance from 2 to 10km. At present, the most promising direction for developing geothermal plants is the creation of compact (modular) turbine installations that can be transported to the construction site in their assembled state. The capacity of such condensing turbines may vary and even be as high as 25MW. This concept for creating and constructing a series of geothermal power plants was chosen by the Intergeotherm Joint-stock Company established by Russia and Nicaragua, and at present it keeps on developing together with German, Canadian, and Icelandic companies.

Today, in Nicaragua, at the San Jasinto-Tizate geothermal field, geophysical investigations have been completed, and several wells have been drilled at a depth of up to 2500m; these results were essential for starting work on the next stage of the project, that is, on constructing

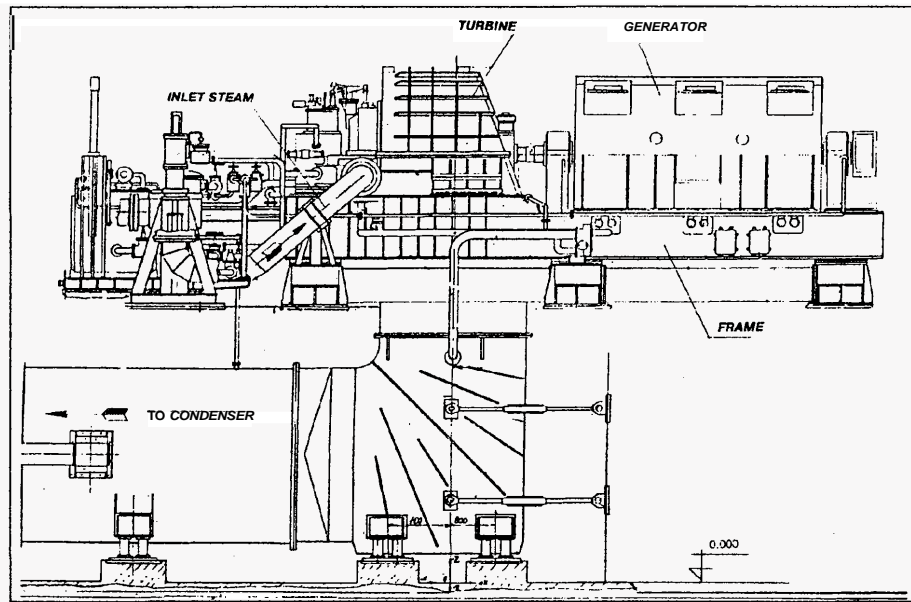


Figure 6. Turbine with generator of 25MW<sub>e</sub> capacity for 60 Hz

the first stage of the geothermal power plant. This stage consists of two sets of two-flow turbo machines having a capacity of 2x2.5 and 2x23MW, respectively. The work was done by means of drilling and power-generating equipment made in Russia. The total capacity of the geothermal power plant may achieve 150-180MW<sub>e</sub> (Ostanpenko et al, 1998).

The turbine and the generator are mounted on a common frame. The generator operates at 60 Hz. The experience gained with a single flow turbine, and the results of the latest research and development work done in Russia, helped create a compact, tight, and highly reliable turbo generator. The turbine installations, and all of its components, were manufactured by KTZ (Fig. 6).

The prototype for these turbines were units manufactured by KTZ that have been used for a long time for driving feed pumps at the nuclear power plants (Kiryukhin et al, 1987). These turbines have an exceptionally efficient flow path ( $\eta_{0i}=88\%$ , according to tests at power stations) and are very reliable. During the last 20 years of operation, no blades or rotors have failed and there were no other accidents.

For improving the economic efficiency and reliability of the turbine, a special moisture-separating turbine stage is provided. It is installed in the place normally occupied by the fourth stage.

Another direction of compact turbo generators creation is the development of two-flow turbines, which allow obtaining up to 50MW<sub>e</sub> in one installation. Construction of the 1<sup>st</sup> stage of the Mutnovsky GeoPP of 50 (2x25) MW<sub>e</sub> capacity is actively underway today (Britvin et al., 2001). The power unit will be put into operation in April-July 2002 (Britvin et al., 2001).

The GeoPP heat scheme is conventional, for single-circuit GeoPP, using mixed types of condensers and mechanical-draft cooling towers.

The main GeoPP parameters are:

- Rated capacity – 50 MW<sub>e</sub>.
- Steam consumption – 320 t/hour.
- Pressure of steam before turbines – 6 bara.
- Steam pressure in condenser – 0.05 bara.
- Percentage of non-condensing gases in steam 0.15%.

Figure 7 shows the 1<sup>st</sup> MGeoPP general view. This GeoPP has been constructed taking into consideration severe climatic conditions; therefore all equipment is housed in the buildings with reliable geothermal heating. The electro technical equipment is placed in the building on the left on Figure 8. This facility is connected by closed passage to the main building.

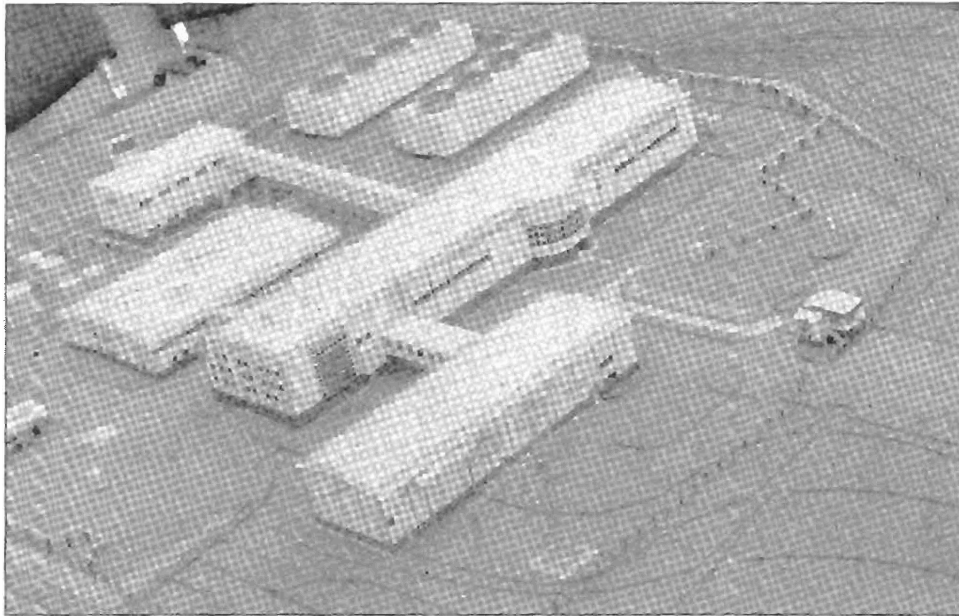


Figure 7. Mutnovsky GeoPP of 50MW capacity

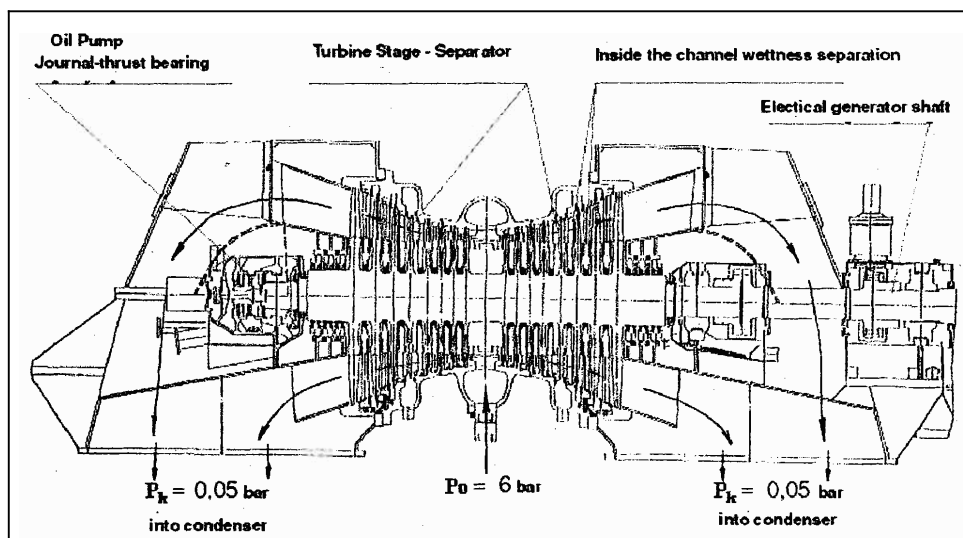


Figure 8. Two-flow turbine 25 MW capacity for Mutnovsky GeoPP

In the main MGeoPP building, 2 turbo generators of 25 MW capacity each, and 2 steam collectors, where steam from separators enters, are placed. Figure 8 shows two-flow turbine 25 MW capacity for Mutnovsky GeoPP.

## 5.0 RUSSIAN MUTNOVSKY GEOPP 2<sup>ND</sup> PHASE

SC Geotherm has already commenced organising a new geothermal project "2<sup>nd</sup> Phase

Mutnovsky GeoPP of 100 MW<sub>e</sub> capacity (MGeoPP-100)". As already mentioned above, the Mutnovsky geothermal field potential is assessed at 300 MW<sub>e</sub>. Long-standing geophysical investigations and drilling work, which has already been done, has allowed us to define new sites for MGeoPP-100 construction on this field (Povarov et al., 2001).

Now three different options for the MGeoPP-100 construction are under consideration:

1. Use of the 1<sup>st</sup> MGeoPP actual iteration of two power units of 25 MW<sub>e</sub> capacity each.
2. Use of a GeoPP combined cycle for the 60 MW<sub>e</sub> power unit (Fig. 8). This cycle has an important advantage under the conditions in Kamchatka. The whole system is non-freezing, as the freezing point of binary cycle working body is lower than 45°C while the lowest temperature at the Mutnovsky geothermal field is above 32°C.
3. Construction of two or three direct cycle power units, 50 and 35 MW<sub>e</sub> turbo-generators, respectively. SC Geotherm plans to announce an international tender for MGeoPP-100 construction in 2001. The completion for the above plant project is due at the end of 2003.

The first and all subsequent Mutnovsky GeoPPs are created on the principle of "man-less operation technology". This is because the severe climatic winter conditions, and the GeoPP remoteness from the centre of Kamchatka, require maximum reliability of all equipment and minimum involvement of people to operate it.

The 1<sup>st</sup> Mutnovsky GeoPP is now a fully automated power plant. Its automated system control enables us to start, stop, and operate GeoPP during operation both directly from the control room, and at a distance through the transmission of a signal on the transmission line 'wires, fiberoptics and space communication system.

- Electricity transmission from the Mutnovsky GeoPP is implemented through the transmission line, which runs towards the *Avacha* substation in Elizovo, located 30 km from Petropavlovsk-Kamchatski. An existing transmission line enables transmissions of 160 MW<sub>e</sub> to Elizovo, i.e. there are complete provisions for electricity transmissions from Verkhne-Mutnovsky, the 1<sup>st</sup> and the 2<sup>nd</sup> Phase Mutnovsky GeoPP.

To construct and operate new geothermal power plants at the Mutnovsky Geothermal Field, the construction of new transmission line for 150 MW<sub>e</sub> is required. At the present time, the preliminary work on the construction of this transmission line is underway. The 1<sup>st</sup> and 2<sup>nd</sup> transmission lines should provide electricity transmissions from the Mutnovsky reservoir to

the centre of Kamchatka (total capacity not less than 300 MW<sub>e</sub>).

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