# GEOTHERMAL POWER PLANTS FOR ELECTRICITY GENERATION AND HEATING PURPOSES FROM RUSSIA

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## ABSTRACT

Russia lias large resources of geothermal heat located at Kamchatka, Kurile Islands, Sakhalin, Stavropol Region, Dagestan, and Kabardino-Balkaria.

Over the last five years a commercial production of equipment for electric and heat geothermal power **plants** have begun in Russia. In the beginning of 1993 the 500 kW pilot power-generating module was put into operation at Kunashir Island.

Now Russian enterprises manufacturee steam production equipment (separators, well valves, compensators etc.), turbine-generators for 0.5. 1.7, 2.5, 4.0, 12.0. and 23.0 MW electric geothermal modules (witli electric part) and up to 20 MW heat modular geotheriiial power plants. The San Jacinto Geothermal Electric Power Plant (115 MW total capacilty), which is under construction, will be equipped witli 23 MW power-generating units from Russia.

## 1. USE OF GEOTHERMAL ENERGY IN RUSSIA

Russia has large resources of geothermal heat; most of them (up to 70%) are located in Far East and Western Siberia.

The first Russian experience with electricity production from tlie geotheriiial lieat was implemented in 1967 at the Pauzlietka field (Kamchatka). Here tlie first 500 kw geothermal binary two-circuit test power plant **in** the world was put into operation. Geothernial water at temperature 75 °C was used for heating an operating medium (freone) for the turbounit.

Industrial electricity production at the first Russian geothermal electric power plant also started in 1967 at the Pauzhetka field. ***An*** installed capacity of the first stage of the Pauzhetskaya Geothermal Power Plant was 5 MW, and in 1952 it was increased to 11 MW.

At the Pauzlietskaya Geothermal Power Plant an exhaust steam froin the turbine is discharged into a direct contact condenser with barometric tube. Nori-condensing gases are removed with water-jet ejectors. Concurrent cooling system of this power plant uses water froin Pauzlietka river.

Use of the geotheriiial heat for heating purposes in Russia was widely developed in 1950s, especially in Dagestaii. By 1969 there were more than 100 consumers of geotheriiial heat in Russia, including 50,000 inhabitants **in** seven towns and greenhouse enterprises of 15 hectares in 'total (at present more than **22** hectares). Now the geotlierinal lieat is used directly in Kamchatka, Kurile Islands, Dagestan, Kabardino-Balkaria, Krasnodar Region, and otlier regions of Russia.

Geothermal water is used for process purposes in chemical, petroleum, textile, furniture, and food industry as well as at more than 150 balneological **resorts.**

## 2. PILOT 500 KW GEOTHERMAL POWER-GENERATING MODULE

In recent years, due to conversion aiid privatization, additional opportunities for further development of geothermal power industry **in** Russia appeared. This was favoured by a large number of drilled wells on Mutnovkn and Pauzhetka fields in Kamchatka, and on Kurile Islands (Kunashir, Iturup, aiid Paramushir).

Construction of the pilot 500 kW power-generating module at Kaluga Turbine Plant (KTZ Stock Conipany) was the first result of efforts of Russian specialists. In the beginning of 1993 the module was put into operation on Kunashire Island. Technical parameters of the module are:

| | |
|---|---|
| capacity | 500 kW |
| initial steani pressure | 0.7 MPa |
| steaming rate | 10 t/h |
| weight | 20 t |
| dimensions | 5.3 x 3.03 × 3.49 m. |

An external view of the turbine-generator of the500 kW module is shown in Fig. 1. It is **in** the form of a compact closed container. The module has operated for more than 10,000 hours at the time of this report.

The use of modular sniall-capacity geothermal electric power plants to produce electricity for small remote settlements is worthwhile. Besides, the formation of power system by integratioii with power transmission lines of separate module units iito power centers in some cases could be more profitable than construction of large geothermal electric power plants.

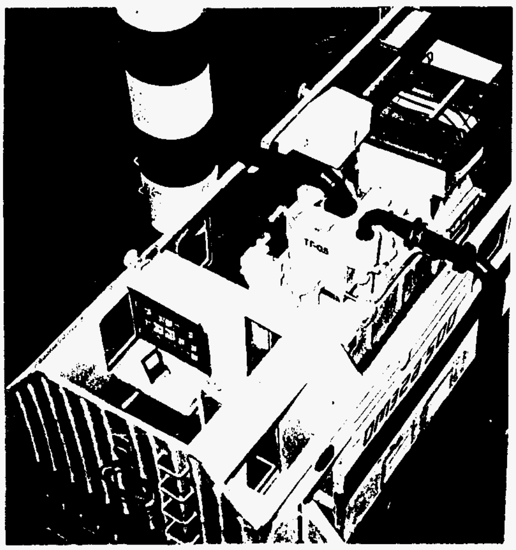

Figure 1. External view of 500 kW turbounit.

## 3. EQUIPMENT OF STEAM PRODUCTION SYSTEM.

Tlie efficiency and reliability of geothermal electric power plant largely depends on operation of tlie steani production systeni. The equipment of the steani production system has been developed in Russia for the past two-three years.

A diagram of the steani production system of *23* MW geothermal power-generating unit is shown **in** Fig. 2. The design is based on the scientific-and-technical celaborations of Scientific and Training Centre of Geothermal Energy of Moscow Power Institute (STC Geo MEI), KTZ Stock Company, and other institutions. The problems of ecology, efficiency of operation, corrosion resistance, and reduction of salt content in the production system received the bulk of attention during developnient of the steam preparation equipment.

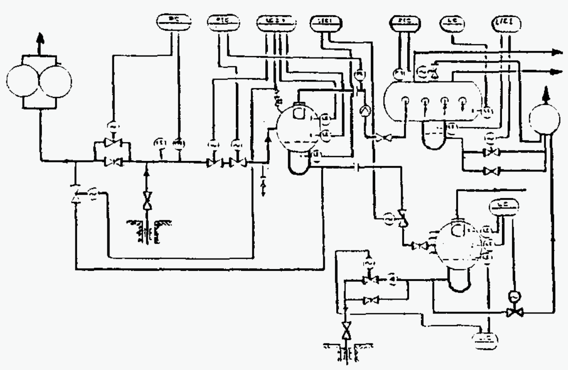

Figure 2. Diagram of steam preparation systeni of geo thermal power-generating unit.

### 3.1. SEPARATORS.

Gravity separators developed by STC Geo MEI, VNIIAM, and Nauka Stock Company have high moisture removal efficiency and, at the **same** time, **are** at the level of traditional designs in weight and dimensions. Up to now, a number of standard sizes of separators have been developed. The separators provide preliminary moisture renioval from wells (well separator). Secondary separation **is** provided by separators located **in** the **main** header (plant separators/steam collectors).

It is known that gravity principle of separation allows for better steam drying compared with tlie centrifugal design and provides minimum **pressure** loss of the energy supply. The small sensitivity of the gravity separation to change of steam content **of** mixture is an advantage.

Design of the gravity separator is shown in **Fig.** *3.*

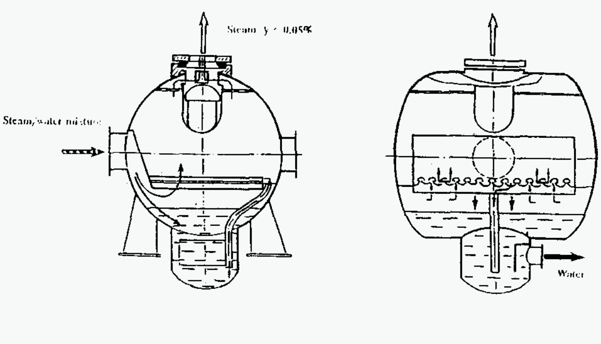

Figure 3. Gravity separator

The well and plant gravity separators include a duct for mixture delivery, distribution shields, and steain reception shields. Tlie plant separator is equipped with steani washing systeni. Tlie well separator can be successfully **used** as an expander.

Figure **4** shows comparison dependence between moisture content and mixture with stearn flowrate for different standard sizes of tlie gravity separators (steaming rate of *55,* 85, ana 115 t/h). The stearn moisture content at the separator outlet doesn't exceed 0.05% at nominal load.

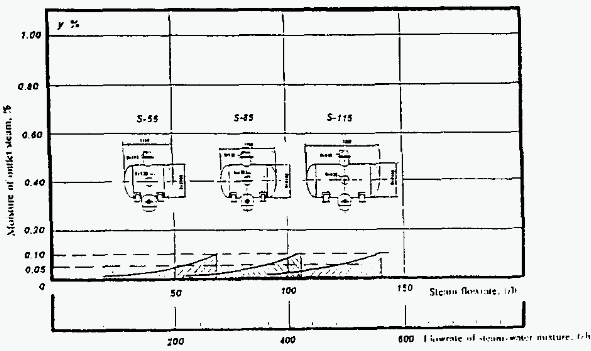


Figure **4.** Dependence between moisture content at the outlet of separators and wet steani flowrate.

### *3.2.* WELL HEAD.

A batch of special well valves and compensators for well head installation wss designed by specialists of STC Geo MEI and manufactured at Chekhov Valve Plant. An assembly of the head compensator and the well head is shown in Fig. *5.* **All** equipnient is manufactured from corrosion-resistant metals.

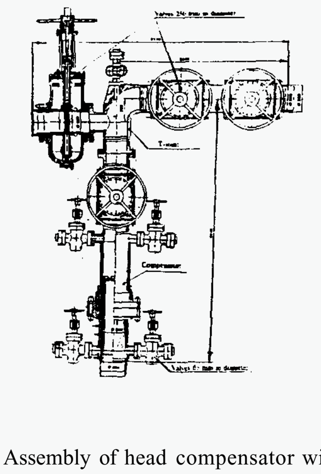

Figure *5.* Assembly of head compensator with vales.

### *3.3.* SILENCER

The dynamic-type silencers were designed in STC Geo MEI, They simultaneously reduce noise and daniage to tlie environment. **Tlie** silencer (Fig. *6)* employs the following new design. principle for noise suppression.

Discharged water-steam mixture is divided into two flowstreams which enter tlie silencer tangentially at different levels **in** tlie intracase space. The rotation of counter vortex flows in parallel planes leads to dissipation of sound energy. Separated moisture is collected **in** the bottom of the silencer and discharged, while at the same **time,** the silencer's separation capabilities are drying tlie steam exhaust.

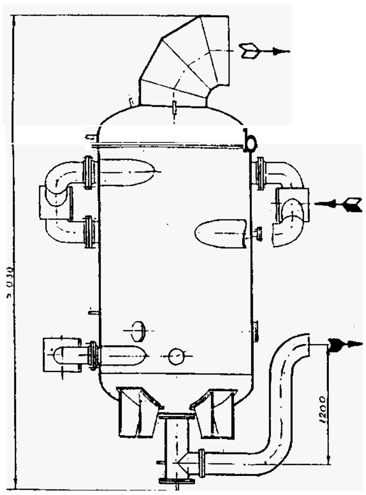

Figure 6. Dynamic-type silencers for geothermal power plants.

3.4. PUMPS.

Special corrosion-resistant pump installations **are** provided for injection of the separated moisture into an injection well.

## 4. GEOTHERMAL ELECTRIC POWER PLANTS

KTZ Stock Company, Russia, installed and started production of geothermal electric power plants that have different capacity.

### 4.1. MODULAR GEOTHERMAL POWER PLANTS OF SMALL CAPACITY.

KTZ Stock Company is developing a set of modular geothermal power plants of 0.5 4.0 MW capacity for use **in** remote and small-populated regions of Far East Russia (Fig.7). These plants have the following advantages:

- preservation of local landscape due to minimum of assembly and construction works;
- container design significantly simplifies transportatiori of geotherinal power-generating units to operating area of even tlie most hard-to-reach regions (for example, Kurile Islands);

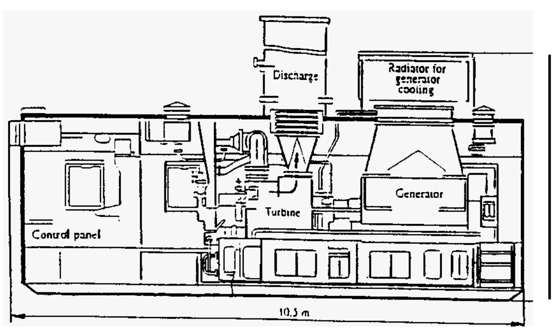


Figure 7. 2.5 MW module geothermal power-generating 'unit.

- delivery of completely assembled equipment tested at factory test facilities reduces costs acid makes assembly and commissioning simpler. This is especially important for regions with severe climate;
- automatic coiitrol system provides practically unmanned operation of modular geotlieriiial power plants;
- modular plants can be used nt exhausted wells unsuitable for further operation of large geothermal power plants due to drop of geotlieriiial fluid production;
- a possibility for quick transposition of modules from one well to antotlier exists.

At present modular geotlieriiial electric power plants of 0.5, 1.7, 2.5, and 4.0 MW have been designed. KTZ Stock Company has already manufactured four 1.7 MW geothermal electric power plants.

### 4.2. GEOTHERMAL ELECTRIC POWER PLANTS OF INTERMEDIATE CAPACITY.

KTZ Stock Conipany with participation of STC Geo MEI finished design of the intermediate-capacity geothermal power-generating units (6, **12,** and 23 MW). The 23 MW units are under manufacture.

The design of **the** turbine-generator of this size class is shown **in** Fig. 8. The turbine flowpath consists of seven stages and has an intra-channel moisture separation features and highly efficient moisture separation stage (no. **4).** It provides decrease in moisture content from 15 down to 10% at the turbine exhaust. Internal relative efficiency of the turbine flowpath at nominal load reaches 0.539.

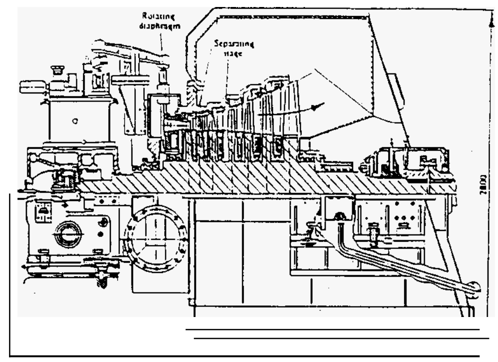

Figure 8. Design of turbounit for 23 MW geotliermal power-generating **unit.**

Turbine-generator speed and load is controlled by a grid control valve.

A direct contact condeiiser is installed at the turbine exhaust. **A** circulating water supply is used with a mechanical-draft tower. Some technical parameters of tlie turbine-generators of the intermediate-capacity geothermal power plant size are enlisted below:

| | | | |
|---|---|---|---|
| Capacity, kW | 6,000 | 12,000 | 23,000 |
| Inlet pressure, MPa | 0.2 | 0.6 | 0.7 |
| Steaming rate, t/h | 75 | 90 | 170 |
| Back pressure, MPa | 0.01 | 0.0085 | 0.012 |

### 4.3. TWO-CIRCUIT GEOTHERMAL ELECTRIC POWER PLANTS

Power Engineering Institute (ENIN) developed a concept of the two-circuit geothermal power plant for use on steam/water tliernial sources at Kurile Ridge. The cycle diagram of the two-circuit geotlieriiial power plant includes the following main elements: separator, steam generator, expanders, turbine, economizer, adsorber, ejector, condeiiser, cooling tower, injection pumps, and silencer. The steam/water mixture with pressure of 0.8 MPa is used in the first circuit. The gravity-type steani separation systern provides moisture content of no more than 0.05% at the turbine inlet.

Ecologically compatible two-circuit geotlierinal electric power plant has been constructed in Stavropol' Region at Kayasulinsk Field. The cycle diagram of the geotherinal power plant uses geothermal brine and freone **in** the first and the second circuits respectively.

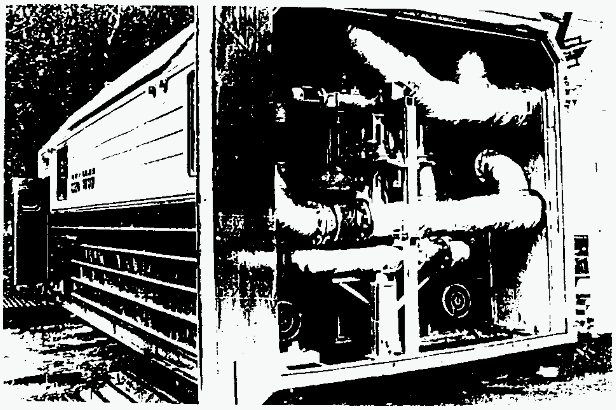

Figure 9. External view of container-type 20 MW geothermal heat plant.

## 5. GEOTHERMAL HEAT POWER PLANTS

**At** present KTZ Stock Company produces 20 MW froni geothermal energy using geothemial stearn or water with temperature of 140 "C. The exhaust steani of geothermal modules can be used as the heating one, and separated moisture downstream the separators as the heating medium.

The geothermal heat power plants (Fig. 9) includes wagon-container with heat exchangers, pumps for circulating hot water, a control room, and other equipment. Complete factory assembly and container design minimize costs and time of transportation and commissioning. The two 20 MW geotherinal heat power plants were manufactured and shipped for operation on Kurile Islands.

Technical specifications of t.. : geotlieriiial heat power plants produced at KTZ Stock Company are enlisted below.

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| Heat capacity, MW | 20 | 20 | 6 | 6 |
|---|---|---|---|---|
| Heating medium | water | steam | steam | water |
| Material of heat exchanger | titanium | brass cupronickel | brass cupronickel | titanium |
| Temperature of heating medium, °C | 110 | 104 | 104 | 110 |
| Flow of hot water, $m^3/h$ | 690 | 690 | 210 | 210 |
| Temperature of hot water, °C | 95 | 92 | 92 | 95 |
| Weight, t | 32.0 | 35.0 | 25.4 | 23.0 |