INTERNATIONAL PROJECT OF MUTNOVSKY 50 MW GEOTHERMAL POWER PLANT

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SUMMARY - In 2002 Geotherm SC is to commission the first phase (50 MW) of the Mutnovsky Geothermal Power Plant. The project is financed partly from a European Bank for Reconstruction and Development loan and is implemented using equipment and consultancy services from a number of countries. This paper provides a brief description of the project, its major equipment and the technical features that have been implemented. Looking ahead, further development of the Mutnovsky field and implementation of the second phase (100 MW) of Mutnovsky Geothermal Power Plant is being planned to make greater use of Kamchatka's renewable energy resources.

1. INTRODUCTION

Factors that greatly impact on the implementation of the Mutnovsky Independent Power Project are the present restructuring of the power industry in Russia, independent power producers entering the electrical power and heat market, considerable increases in prices of oil, coal, gas and fuel transportation difficulties. Electricity costs in Kamchatka exceed 10 USc/kWh, thus making projects utilising local energy resources very attractive (Britvin et al., 2000; Britvin et al., 2001). Kamchatka has abundant geothermal resources to supply electrical power and heat to the local population and industries for the next 100 years (Kiryukhin, 1996). The development of the Mutnovsky field is a major step towards this.

The Mutnovsky geothermal field is located 70 km south of Petropavlovsk-Kamchatsky, the administrative centre of' the Kamchatka region in the Far East of Russia (Figurel). This field is the best investigated resource in Kamchatka with proven fluid reserves estimated at no less than 300 MW_e. The resource is approximately 10 km long and 3 km wide with a general northeasterly trend. The field is hosted by a sequence of basaltic to rhyolitic lavas, pyroclastics and epiclastics that are intruded by a series of diorites at depth and is interpreted to lie within a graben. Permeability in the field is regarded as fracture controlled both through tectonic structures and at intrusion margins (Kiryukhin, 1996). The field is single phase at depth with an overlying two-phase zone with a more restricted vapour-dominated zone in the Dachny sector. The standing water level of wells is between 400 to 500 masl and feed zone temperatures range from 250 to 270°C. The maximum measured temperature is 310°C. Discharge enthalpies of the wells range from 1000 to 2700 kJ/kg. (Kiryukhin, 1996).

In 1999 Geotherm S.C. commissioned the 3 x 4 MWe Upper Mutnovsky pilot power plant and

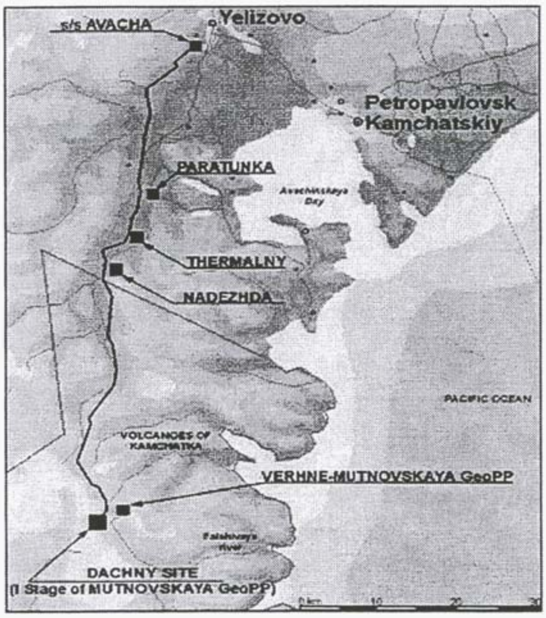

Figure 1. Project location, southern Kamchatka Peninsular, Russia

the 2 x 25 MWe 1st Phase Mutnovsky Geothermal Power Plant (MGeoPP) is scheduled for commissioning in 2002. Extensive research and investigation activities since the mid 70s have resulted in drilling over 90 exploratory and injection wells, construction of the access road and installation of a 220 kV transmission line enabling transmission of at least 160 MWe into the Kamchatskenergo power system. In addition an electrical substation capable of receiving up to 200 MWe was built at Avacha near Elizovo city.

3. PROJECT PARTICIPANTS

The Mutnovsky Geothermal Power Plant Project (MGeoPP) is implemented by the Russian company – Geotherm S.C. Grant funds received from the European Bank for Reconstruction and development (EBRD) in 1997 were used to appoint consulting companies WestJEC (Japan) and GENZL (New Zealand). In association with Nauka S.C. (Russia) they produced the Feasibility Study based on which the EBRD provided loan funds for the project implementation. The EBRD loan is to the government of the Russian Federation and on-lent to Geotherm S.C. Other financing is from State Budget funds and Russian co-investing companies: RAO UES, "Kamchatsenergo" S.C. and the State Property Committee for the Kamchatka region. The total project budget is US$ 154 million with shareholders and loan funds at 35% and 65% respectively.

4. PROJECT MANAGEMENT

A Project Management Unit (PMU) consisting of Geotherm's Moscow and Kamchatka based staff was set up by Geotherm S.C. The Moscow team is responsible for project funding and financial issues, preparation of procurement documentation, procurement activities for various project implementation contracts and for all work associated with consultancy contracts. Project site activities, including managing the three main construction contracts and plant operation and maintenance fall under the responsibility of the Kamchatka team.

5. PROCUREMENT

Procurement of all goods, works and services for the Project was undertaken using international competitive tender procedures in accordance with EBRD policies and rules and resulted in calling 14 tenders. Over 30 engineering companies participated in the first tender for Consultant's Services, awarded in 1998 to the Worley International-Kingston Morrison consortium (New Zealand) in association with Nauka S.C. (Russia). The consultant developed the conceptual designs and prepared tender documentation for the three main Engineering, Procurement, Construction (EPC) contracts, using FIDIC Orange Book contract conditions. Contracts were awarded to the following Russian companies:

Power Plant: GUP VO Technopromexport (TPE);
Fluid Collection and Disposal System: (FCDS): OSC Kamchatskagropromstroi (KAPS);

Well Drilling: Vostokgeologia GP Mutnovka Consortium.

Foreign sub-contractors also participate in the project, e.g. Siemens (Germany) supplies the Distributed Control System (DCS) and 220kV Gas Insulated Switch-gear, relay protection is supplied by Alstom (Germany), Psychrometric Systems Inc (USA) is the supplier of mechanical draft cooling towers and well head equipment is procured from Cameron (USA).

6. SITE CLIMATIC CONDITIONS

The geothermal field is located in the vicinity of Mutnovsky volcano on a plateau some 800m above sea level. A 130 km long road was built to connect Petropavlovsk–Karnchatsky and the site. The nearest village is 50 km from the construction area. Site climatic conditions are extremely severe and the winter period is long with snow lying for 8-9 months (fiom October through June). Average annual height of snow cover exceeds 4 m in open places and reaches 17 m in valley areas. The site is windy and wind speeds can reach 45 m/s, with some gusts up to *60* m/s. The annual average temperature is -1.9°C with -13°C the average temperature recorded in February, the coldest month of the year, and +12,4°C in July, the warmest month in Kamchatka.

7. SITE AND BUILDING LAYOUT

- The 1st phase of the MGeoPP comprises 2 x 25 MW power units installed at the Dachny site, a Fluid Collection and Disposal System, drilling of two new production wells and work-over of existing wells. Due to the severe climatic conditions all plant and equipment is located inside four main buildings as shown in Figure 2. Other site facilities include two induced draught cooling towers, water and fuel storage tanks, water treatment facilities and a brine emergency holding pond. To ensure safe plant operation and access in winter when snow cover can be up to 6 metres, enclosed

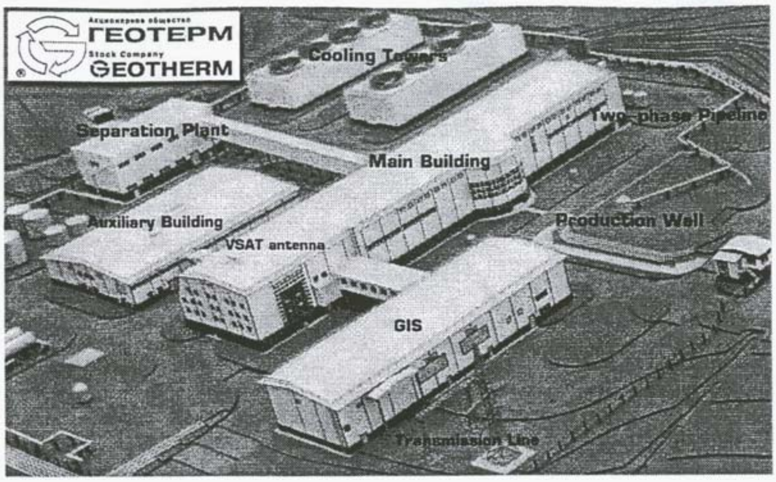

Figure 2. General Layout of the 1st phase of Mutnovsky Geothermal Power Plant -(2x25) MW.

air bridges interconnect all buildings. The Main building provides a **24** room hostel for plant operating staff and plant and equipment comprises:

- Secondary separators;
- Turbine generators and condensers;
- Cooling water circulation pumps;
- Cooling water chemical treatment plant;
- Plant control room and control system;
- 10kV and 400V switchgear/transformers;
- Non condensable gas removal system.

The GIS Building contains:

- Main 10kV/220kV transformers;
- Ice-melting transformer;
- 220k GIS switchgear;
- Protection relay panels.

The Combined Auxiliary Building houses equipment and provides facilities as follows:

- Black-start diesel generators;
- *Air* compressors;
- Store, Workshop and Garage.

The Separator Building contains the following plant and equipment:

- Primary separators (Figure **4);**
- Brine injection pumps;
- Silencers;
- Vent valves;
- **DCS** equipment;
- **400** V switchgear.

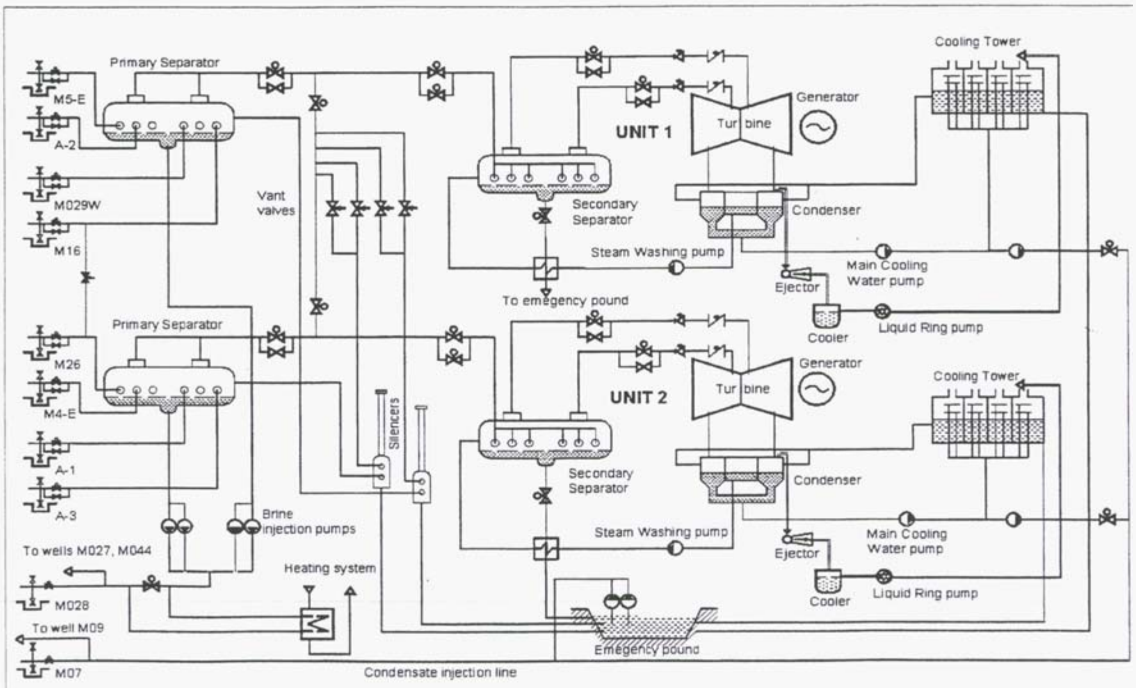

Figure **3.** The Mutnovsky Geothermal Power Plant **Flow** Diagram

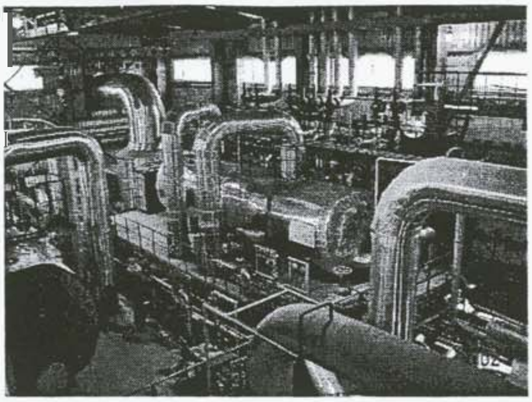

Figure 4. Primary separators inside the Separator Building

8. FLOW DIAGRAM AND MAIN PLANT FEATURES

A simplified flow diagram of the MGeoPP is shown in Figure 3. Separate pipelines deliver two-phase fluid with between 30%–100% steam content (by weight) from 7 production wells to primary separators installed in the Separator Building. Wells M5E, M016, M29W and A2 are connected to the separator of Unit No 1, whereas wells M026, M4E and A3 wells are connected to the separator of Unit No 2. The M016 and M026 pipelines are interconnected by means of a cross-over pipe to allow balancing the output fi-om Unit 1 and 2 separators.

The design features horizontal type separators (Figure 4), which also function as a header and collect the fluid (steam-water mixture) from different wells. Horizontal type separators are very efficient (Povarov, *et al.*, 1997) in terms of moisture removal and achieve near-dry steam at the outlet (not less than 99.98% by weight).

The separators are provided with overpressure and brine carry-over prevention systems. Brine re-injection pumps fitted with variable frequency drives control the brine level in the separators. Exceeding the high level point in the separator opens the emergency valve to discharge brine into the noise silencer. Steam blocking float valves prevent water discharge into the steam pipelines when separator fills with water in an operating emergency. Part of the brine is fiist used for power plant heating purposes before all brine is re-injected into wells M027, M028 and M044. The minimum allowable brine temperature is 145°C to avoid re-injection system silica scaling.

Steam from the primary separators is delivered into the main header from where two pipelines deliver steam to the turbines located in the Main Building. Rated steam pressure in the header is 6.5 bara and steam pressure is controlled by vent valves equipped with fast acting electrical drives. The pressure control system is designed to maintain pressure in the steam system even after one or both turbine generators have tripped. Steam washing and separation in the secondary separators located in the Main Building is carried out before delivery of steam to the turbines. Pure condensate extracted from moisture removal stages in the turbines is used for steam washing.

The steam turbines were manufactured at Kaluga Turbine Works (Russia) and are of the double flow type with 8 stages (Figure 5). The turbines are very efficient and designed to operate with a specific steam consumption of just 6.2 tonne/kWh. This is partly due to the very cold ambient conditions, which allows a very low condenser pressure of 0.05 bara.

Special turbine separator stages, developed by research and engineering staff of the Moscow Power and Engineering Institute together with Kaluga Turbine Works' personnel (Povarov *et al.*, 2001a) are used to achieve effective blade peripheral/internal moisture removal.

Application of moisture separation devices in the turbine flow path allows removal of almost all moisture, thus minimising erosion of turbine blades and resulting in a nearly 2.0% efficiency improvement of the turbine unit.

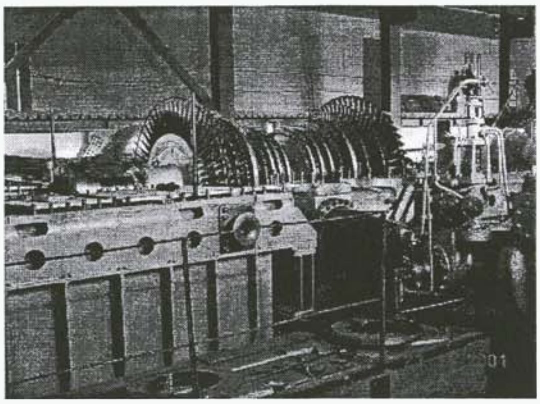

Figure 5. Installation of Turbine No1 at MGeoPP

Turbine Main Technical Characteristics

Turbine type	K-25-06-Geo
Output at generator terminals	25.0 MW
Steam flow rate	154.5 T/hr
Rated steam pressure	6.2 bara
Steam dryness at turbine inlet	0.9998
NCG content (by weight)	0.4%
Condenser pressure	0.05 bara

The direct contact condenser is located beneath the turbine exhaust and consists of three sections.

Steam is condensed once it comes into contact with cooling water jets located inside the condenser. Horizontal centrifugal type pumps located in the Main Building circulate the hot water to the cooling tower through fibre glass reinforced pipes. From the cooling tower basin cooled water flows by gravity and under vacuum back into the condenser

The NCG removal system consists of first stage steam-jet ejectors and second stage liquid ring vacuum pumps with gases vented into cooling tower fan stack diffusers.

Each generating unit features four cell counter flow type cooling towers with cell size of 12x12 m and a 10 m diameter fan. The cooling towers supplied by Psychrometric Systems, Inc. (USA) are manufactured entirely of fibre-glass reinforced plastic connected with stainless steel fittings. Cooling water system chemistry is controlled by alkali (NaOH) and biocide (CaHCl) dosing. Excess condensate is pumped into a 1.5 km long basalt fibre pipeline and re-injected into wells M09 and M07 drilled in the northem-sector of the field.

9. CONTROL SYSTEM

Mutnovsky GeoPP is designed for future unmanned and remotely controlled operation, due to the severe climatic winter conditions and the plant's remote location. Plant design also features maximum reliability of all equipment and minimal O&M staff based at the plant site.

The power plant and steam field are controlled by a Teleperm ME distributed control system (DCS) supplied by Siemens. All systems are fully automated and the DCS design enables starting, stopping, and operating the plant both from the control room, as well as remotely by transmission of plant control signal via the transmission line, fiber-optic cable or satellite communication system.

To provide permanent technical assistance and back up control of the power plant, SC "Nauka" (Moscow) is setting up a satellite communication system with direct communication between Moscow and the power plant (Figure 6). A satellite dish on the roof of the Main Building transmits a (128 kb/s information content) signal to a Russian satellite in heliocentric orbit, from where the signal is picked up 7,000 km away at the satellite dish of SC "Nauka" in Moscow, where the plant control centre has been set up. Control centre operators can contact equipment designers and manufacturers in Russia, Germany, and USA by email at any time and are able to provide quick expert feedback to plant operating staff in Kamchatka.

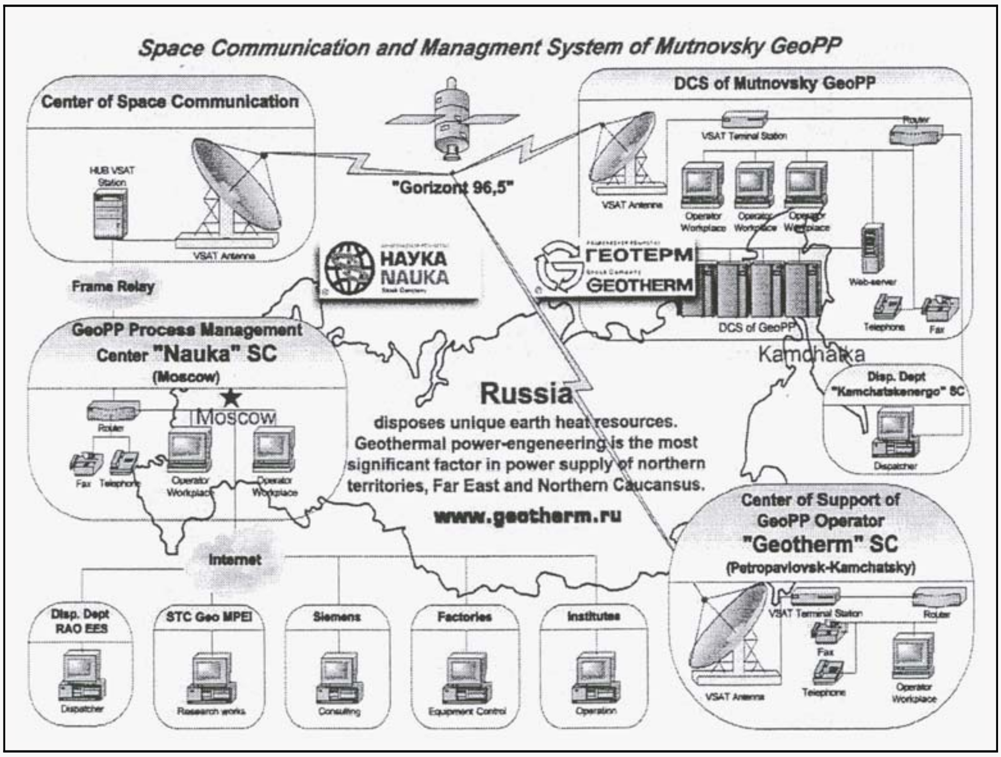

Figure 6. Satellite system for communication/control of the Mutnovsky Geothermal Power Plant

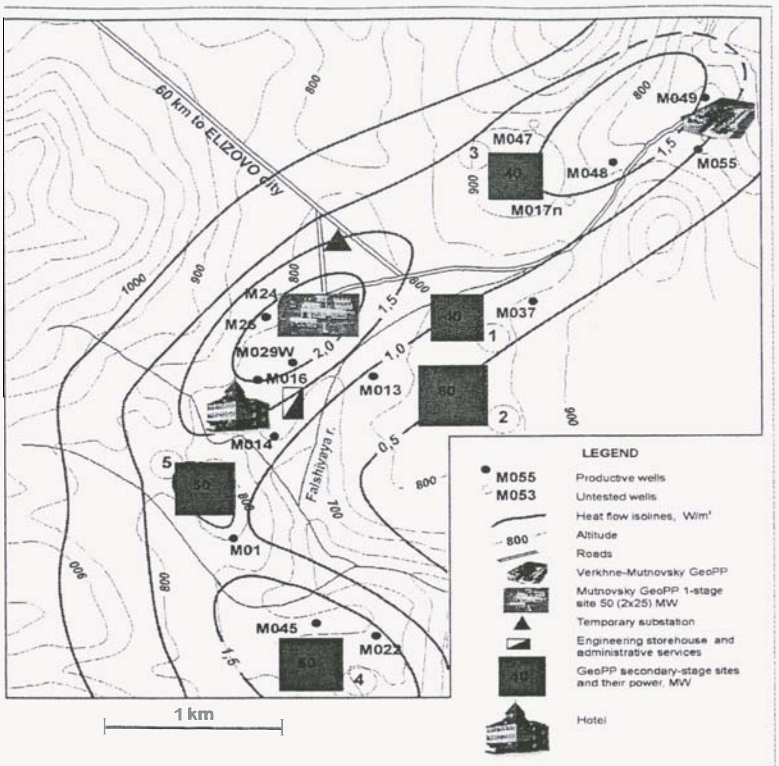

Figure 7. Location of Future Power Plants at Mutnovsky Geothermal Field

10. MUTNOVSKY DEVELOPMENT OPPORTUNITIES

The Mutnovsky geothermal field potential is estimated at up to 300 MWe and further field expansion can benefit from the developed construction infrastructure and the 220kV transmission line capable of transmitting 160 MW into Kamchatka's power system.

The Global Environmental Fund (GEF) grant provided to Geotherm S.C. in 2001 has been used to engage consultants from PB Power (UK), WIKM **J.V.** (New Zealand) and Nauka ***S.C.*** (Russia) for preparation of the Business Plan for the next phase of development and demonstrate that the project is technically and economically viable.

Currently Geotherm ***S.C.*** is making arrangements to implement the 2nd phase of Mutnovsky GeoPP, which will generate an additional 100MW$_e$. The sites for the future power units have been identified based on previously conducted geophysical investigations and exploratory drilling data (Figure 7). It is planned to construct the 100 MW MGeoPP on two sites located in the "Central Dachny" and "Yuzhny" field sectors (Povarov, ***et al.*** 2001b). A short transmission line will connect the future plants with the GIS building of MGeoPP-1, from where electrical power is fed into the power system. Similarly to MGeoPP-1 the future power plants will be designed to operate unattended and will be fully automated to allow future remote monitoring and unit control.

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