THE GEOTHERMAL POWER PLANT AT SAN JACINTO-TIZATE

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SUMMARY: The Nicaraguan-Russian publically held company INTERGEOTERM discovered geothermal heat reserves in the San Jacinto-Tizate geothermal field in Nicaragua. There are enough resources for the construction of 7 power units with a total capacity of 120 MW. The first stage of this geothermal power plant will have the capacity of 51 (2×2.5+2×23) MW, the equipment for this geothermal power plant was manufactured in Russia and other countries.

1. INTRODUCTION

The Nicaraguan-Russian company INTER-GEOTERM has been working on the development of San Jacinto-Tizate steam field for 6 years.

SC INTERGEOTERM carried out broad scale geophysical research and confirmed that the steam field in San Jacinto-Tizate possesses the geothermal steam resources for the construction of a power plant with a capacity of not less than 120 MW (Ostapenko et al., 1998).

The ,basic equipment such as turbines, generators, separators and fittings for the first stage of the 51 (2×2.5+2×23) MW geothermal power plant San Jacinto-Tizate were manufactured in Russia. The preliminary civil works on the steam field are completed.

The SC INTERGEOTERM program for the development of the San Jacinto-Tizate geothermal field stipulates the start with commissioning into operation of a 5 MW (two-turbine-generators 2.5 MW each) plant, followed by the construction and commissioning of the first stage of a 46 MW geothermal power plant, consisting of two power units of 23 MW each. This means that in 18-20 months Nicaragua can receive an additional 51 MW of power based on the development of its geothermal resources. This is to be followed by the installation of three 23 MW power units.

The development concept of Nicaraguan steam fields using modular geothermal power plants of 20-25 MW each as proposed by SC INTERGEOTERM has been proved to be worthwhile.

The idea of assembling the small power units near the production wells and picking up the power by a common power sub-plant with power transmission into the Nicaraguan electrical grid seems to be the most profitable and fastest way of developing the resources.

2. GEOTHERMAL POWER PLANTS OF CONTAINER TYPE

Two modular units have been designed and manufactured by the SC Kaluga Turbine Plant, Russia. The layout of GeoPP consisting of components with total capacity of 5 (2×2.5) MW is shown in Figure 1. 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.

Basic Technical Parameters

Nominal Power	2,500 x 2 kW
Inlet turbine steam pressure	7.0 ± 2.0 bg
Outlet turbine steam pressure	~ 1.0 ba
Frequency of rotor rotation	3,600rpm/60 Hz
Voltage, kV:	
♦ generator output	6.3
♦ auxiliary power	0.4
♦ output to network with transformer	10.5; 13.8
Steam flow rate	40.3 %
Inlet turbine steam moisture	< 0.1 %

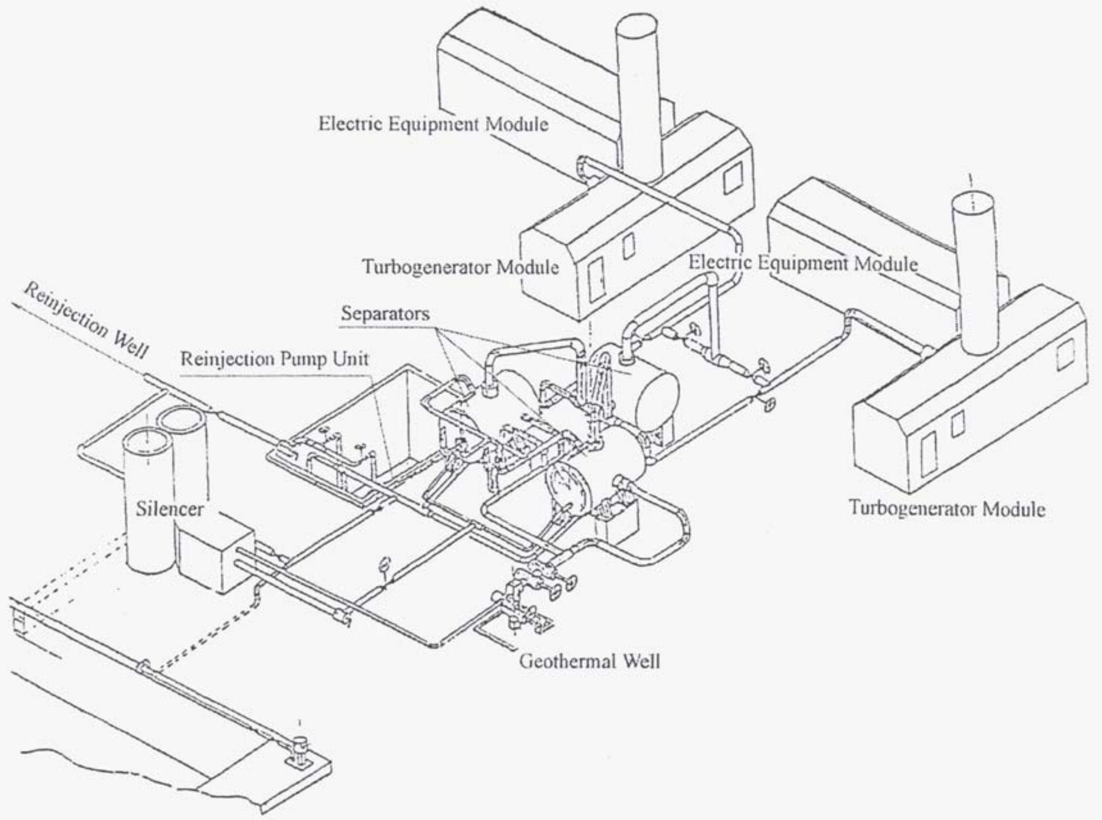

Figure 1. Modular geothermal power plant **of 5** (2x2.5) MW

The turbine generator unit is provided in a container with two turbines assembled inside: the main unit of capacity **2.5** MW, a turbine for an oil pump drive, and an electrical generator assembled on the frame common with the turbine and control desk is available (Fig. **2).**

This turbine generator container has been tested by the SC Kaluga Turbine Plant under **100%** load conditions. It will be delivered completely assembled transported by rail and sea **(Kiryukhin** et al., **1987** and Geothermal Modular Installations, **1993).**

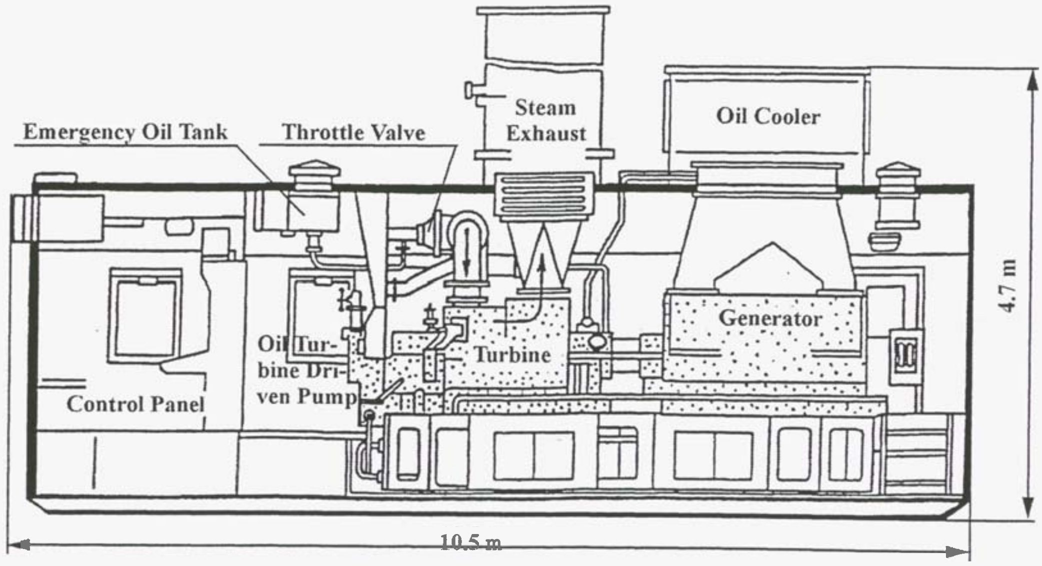

Figure **2.** Turbogenerator module of 2.5 MW geothermal power plant

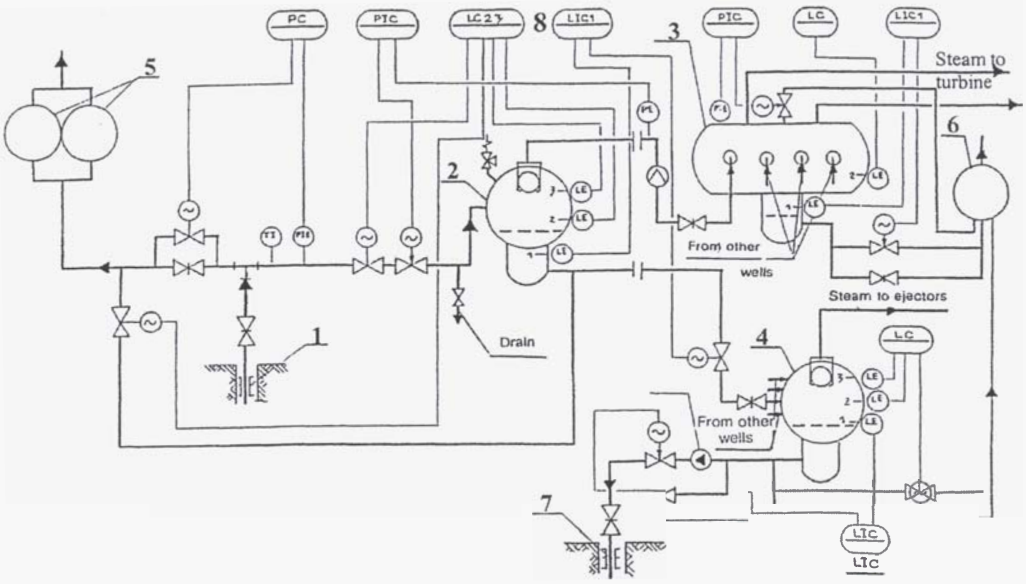

Figure **3.** System for preparing steam for a geothermal power plant

(1) Production well; (2) separator; (3) steam collector; **(4)** steam expander; (5) silencer of the production well; ***(6)*** silencer of the plant; (7) well for injecting hot water; **(8)** control and monitoring system.

The main requirements for installation and start-up of the container type GeoPP unit are:

- To provide the construction and drilling works during the period of steam field development with own power.
- To start-up the massive power units without the diesel units because the turbine generators are subject to automatic start-up without any external electrical source. Geothermal steam from the wells provides the turbine oil pump with the steam.
- To use these GeoPP for power sales in commercial purposes.
- To use the steam turbine generators in combined cycle together with the binary geothennal units oriented to increased efficiency.

3. PREPARATION OF THE STEAM AT THE GEOTHERMAL FIELD

The geothermal reservoir at San-Jacinto is located at a depth of 1,000 –2,500 m in the form of **hot** water at a temperature of **200-260°C. At** ground level, the well discharges a two-phase flow; its pressure ranges from 0.7 to 1.0 MPa, the wetness (y) of the steam is between 50 and 80% and the concentration of the admixtures of salts and non-condensing gases is up to 1%, which is a significant amount.

A system for preparing the steam is installed to ensure **normal** operation of the turbines. This system is made up of the following components, which are shown in Figure **3,** accessories, separators, steam expanders, silencers **and** pumps.

In Russia, a horizontal type of steam separator for geothermal power stations was developed; this separator differs from vertical type separators 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 at virtually any flow rate.

The horizontal separators are more compact and have a smaller **mass than** separators manufactured in other countries. The Russian made separators use several mechanisms of moisture separation, namely, centrifugal, bubbling, and gravitational. 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 these separators is very high because the dryness at the outlet **from** the separator is $x>0.999$; that is, a wetness of the steam of $y<0.1\%$ is guaranteed **for** the entire operating range, as is shown in Figure **4.**

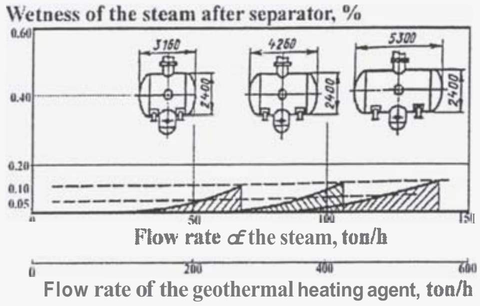

Figure 4. Effectiveness of the horizontal separators

In the Russian made separators, a rise in the flow rate of the geothermal heating agent is accompanied by an increase in the wetness of the steam fiom 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 station, as is shown in Figure 4

Steam expander 4 (Fig.3) is also installed in the field. This unit collects hot water at a temperature of 170°C downstream of separator 2, and produces steam as a result of reducing the pressure of 0.3 to 0.4 MPa and evaporating hot water. Evaporators can be used to substantially improve the economic efficiency of the geothermal power station because the additional steam flow rate of up to 10-15% obtained after the hot water is evaporated can be used in one of the intermediate stages of the turbine or in the ejector.

The system for removing the noncondensed gases and for maintaining a higher vacuum in the condenser of the turbine is either an ejector, if the concentration of these gases is less than 2%, or compressors, if the concentration **is** large.

4. POWER BLOCK CHARACTERISTICS

The first stage of GeoPP consists of two turbine generator units of 23 MW each. They are located in the common facility. (See Fig.5)

The turbogenerator is housed in the machinery department, the length is 24 m and height is **30** m. The height of crane rails is 18 m and the carrying capacity of the bridge crane is 32.5 tons. The condenser with the ejectors and coolers unit is located in the house on the 2 meters high mark. The electrical power equipment of power unit, main control room, servicing and auxiliary facilities are located opposite the machinery department. The opportunity to add other power units exists.

In the proposed design the condenser, with the barometric leg and pump station reservoir, **is** located outside the turbine generator.

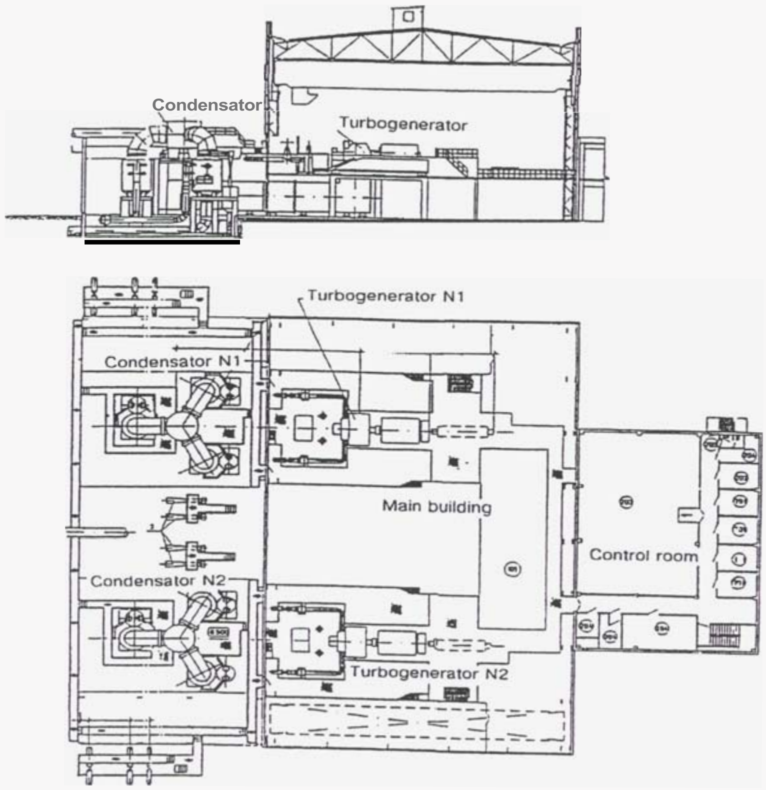

Figure 5. Power units arrangements

5. CONDENSING TURBINE INSTALLATIONS

Two-flow turbines having a down-take steam exhaust are installed on a high foundation. In these turbines, the length of the last-stage bucket measures fiom **584** to ***660*** mm and the pressure in the condenser is in the range of 9-12 MPa. Such turbine installations are delivered from the manufacturer to the geothermal field in a disassembled state; they are installed on site the same way as conventional thermal power stations.

At present, the most promising direction for geothermal station development 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 could be as high as 25 MW. This concept for creating and constructing a series of geothermal power stations was chosen by SC **INTERGEOTERM.**

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, light, and highly reliable turbogenerator. The turbine installation and all of its components, were manufactured by **KTZ** (Fig.6.) In creating the turbines, the latest technical advancements as well as the experience acquired from many years of operating KTZ turbines at the Pauzhetka geothermal power station, were taken into account. The prototype for these turbines were units manufactured by KTZ that were used for a long time for driving the feed pumps at nuclear power stations with VVER reactors of 1000 MW capacity. These turbines have an exceptionally efficient flow path (η_{oi} = 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.

The flow path of the turbine consists of seven stages; it ensures reliable operation of the turbine when the initial pressure is 0.8 ± 0.2 MPa and the final pressure is from ***0.006*** to 0.02 MPa.

To optimise the economic efficiency and reliability of the turbine, a special moisture-separating turbine stage is provided. It is installed in the space normally occupied by the fourth stage (Povarov, 1980). The separating turbine stage ensures an efficiency of moisture removal from the flow path fiom 20 to 80%, depending on the operating conditions.

The moisture–separating turbine stage also helps to obtain a "clean" condensate, which is used for "washing" the steam in the steam collector.

Italian and Japanese companies are also actively engaged in creating modular turbine installations for geothermal power stations having a capacity of up to 25 MW. Moreover, they manufacture large turbines consisting **of** a two-flow cylinder that is to be installed at ground level. These two types of modular turbine installations of 25 and 50 MW, after minor changes in the design, will be suited for use in a wide range of steam parameters and outputs from 12 to 70 MW.

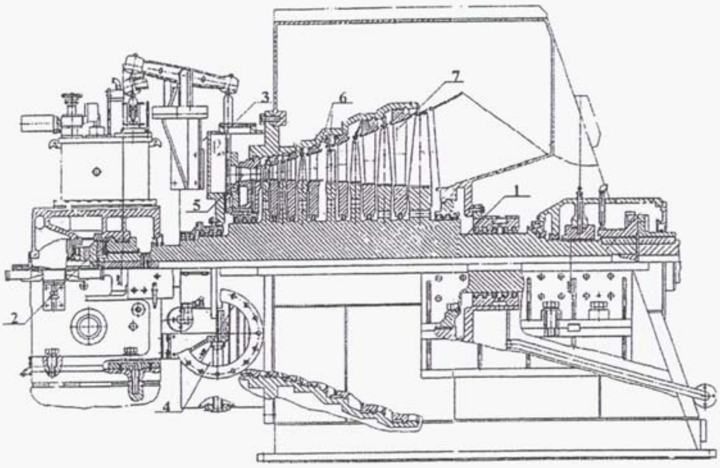

Figure ***6.*** Turbine manufactured at ***SC*** Kaluga Turbine Plant for San Jacinto geothermal power plant of 20-25 MW, p_o = 0,8 ± 0,2 Mpa, and p_c = 0,012 Mpa. (1) Integral-disk rotor; **(2)** lubrication pump and radial-and-thrust bearning; **(3)** steam inlet; **(4)** steam exhaust; (5) regulating (revolving) diaphragm; ***(6)*** moisture-separating turbine stage; **(7)** diaphragm capable of in-channel separation of moisture.

The experience gained in the United States fiom operating the geothermal power stations manufactured in Japan revealed the following serious problems related to the reliability and economic efficiency of the turbines:

- the low efficiency of the separators;
- the formation of corrosion cracks in the metal of the working blades and disks;
- the build-up of salts and aggressive substances in the flow path (fust stages) of the turbines;
- corrosion of the metal during the downtime of the turbine;
- the concentration of admixtures and salts in the basin of the cooling tower and in all of the re-circulated water, and other problems.

Many geothermal power stations in the United States and Japan keep one or two spare turbine rotors.

At present, all firms that manufacture turbines for geothermal power stations use saber-shaped blades that were developed by MEI and implemented by KTZ more than 30 years ago; new technical designs and materials are also being used in modem products.

6. TURBOGENERATOR

By its structure the turbogenerator constitutes of a transportable unit of two-parts: the steam turbine and the generator (Fig. 7). The size of the turbogenerator unit is 10.5×3.8×3.5 m. The weight of the turbogenerator unit is 115 tons (turbine unit – 70 tons; generator – 45 tons).

7. COOLING TOWER

The geothermal power plant is equipped with section type ventilator cooling towers.

Every turbine unit is provided with 5 cooling towers sectioned together; the ventilator is 6.3 m in diameter. The features of the cooling towers (5 sections) are:

- ♦ cooling water flow rate – 10,000 t/h;
- ♦ inlet water temperature - 43°C;
- ♦ outlet water temperature - 33°C;
- ♦ designed temperature of the wet thermometer – 24.5°C.

8. CONCLUSIONS

The San Jacinto-Tizate geothermal field is prospective for installation of a geothermal power plant of total capacity not less than 120 MW.

The Nicaraguan-Russian Company SC INTER-GEOTERM has delivered sufficient geothermal fluid to the surface to generate 30 MW. This allows the construction of the geothermal power plant of 51 MW (2×2.5+2×23) on the basis of the equipment manufactured in Russia such as separators, turbines, generators, etc. and two geothermal power plants of 2.5 MW each. In 18-20 months, Nicaragua can provide power from indigenous geothemal resources.

It is important to unite the efforts of banks and companies fiom different countries for the development of geothermal resources in Nicaragua.

9. REFERENCES

Ostapenko S.V., Spector S.V. and Netesov Y.P. (1998). San Jacinto-Tizate Geothermal Field, Nicaragua: Exploration and Conceptual Model. ***Geothermics.***

Kiryukhin V.I., Taranenko N.M., Ogurtsova E.I., et al. (1987). ***Steam Turbines of Small Capacity Manufactured by the Kaluga Turbine Works***. Energoizdat, Moscow.

Geothermal Modular Installations, in the Advertisements of KTZ and of the GeoMEI Scientific-and-Educational Center. (1993). ***Teploenergetica, no 3.***

Povarov O.A. - Tomarov G.V.(1995). ***Geothermal Power Plants for Electricity Generation and Heating Purposes from Russia.*** Proc. World Geothermal Congress, Florence.

Povarov O.A. and Lukashenko Y.L. (1997). Turbines and Separators for Geothermal Power Stations. In: ***Thermal Engineering,*** Vol. 44, no.1, 1997, pp.42-48.

Povarov O.A. (1980) Problems of Separating Moisture in the Turbines of NPSs. ***Teploenergetica,*** no 2, pp. 84-86.