MODERN RUSSIAN GEOTHERMAL ENERGY TECHNOLOGIES

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KEY WORDS

Geothermal power plant, separator, turbine, equipment, production, technology, control system, binary power plant, geothermal heat supply.

ABSTRACT

After 30 years Russia enters again the circle of countries producing geothermal equipment and technologies. First in Russia geothermal power plant – Pauzhetsky GeoPP constructed in 1965 is still generating the cheapest electric power at Kamchatka. Growth of prices for organic fuel and, consequently, of tariffs for electric power and heat stimulated again the interest towards use of heat of the Earth for electric power generation.
Due to considerable scientific-technical potential of power engineering industry and long-term fundamental researches in the field of wet steam in Russia, during recent 10 years highly effective separators, turbines and other energy equipment for GeoPP were created, new GeoPPs were built at Kamchatka and Kuril islands.
Experience of separators and turbines for NPP production and shipbuilding allowed to create compact modular units for "San Jasinto" GeoPP in Nicaragua. The units are delivered to construction site being assembled and after factory testing at 100% load.
Created, constructed and reliably working in most complicated natural-climatic conditions unit-modular Verkhne-Mutnovsky GeoPP is the entirely environmentally friendly power plant. The waste geothermal fluid including NCG is injected completely into reservoir.
Reliability of work of GeoPP is defined in many respects by quality of steam coming to turbine. Horizontal steam separators are created in Russia, and by their efficiency (99,99%) and mass-dimension characteristics they considerably leave behind the vertical cyclone type separators widespread in the world.
Long-term scientific researches of two-phase flows, creation of in-channel systems of moisture removal in turbines and of special turbine phase-separators allowed to create reliable and highly efficient turbines with major vacuum in condenser with capacity of 25-30 MW for Mutnovsky GeoPP. Due to this the best indices in the world by specific steam flow rate (6,5 kg/KW h at the most) and power plant efficiency (more than 20%) for GeoPP were achieved.
High level of automation of Mutnovsky GeoPP allows its unmanned operation. MGeoPP satellite communication and remote monitoring system was created for the first time in the world that allows controlling the technological process of power plant at Kamchatka from Moscow (center in "Nauka" SC).
Prospective direction of Russian geothermal energy is the creation and construction of new generation binary GeoPPs, the idea of which were proposed and realized by Soviet scientists for the first time in the world at Paratunka geothermal sources.

1. INTRODUCTION

First geothermal power plant – Pauzhetsky GeoPP built in 1965 is still generating the cheapest electric power at Kamchatka. Growth of prices for organic fuel and heat stimulated again the interest towards use of heat of the Earth in Russia for electric power generation.
Russia, together with enormous resources of minerals, is very rich with geothermal resources that may and must be use for the welfare of the people. 47 geothermal reservoirs are explored at the territory of Russia with thermal water reserves allowing getting more than $240x10^3$ m^3/day of water and steam-water fluid reserves with capacity of $105x10^3$ m^3/day. Practically at all the territory of Russia there are reserves of heat of the Earth with temperature of 30-40^0 C, and in some regions there are geothermal reservoirs with temperature up to 300^0 C. Use of heat of the Earth for electric power generation, heating and hot water supply allows to save considerable resources of organic fuel and to reduce the discharges of contaminants and CO_2 into atmosphere.
During recent 10 years new geothermal power plants at Kamchatka and Kuril islands were constructed. Principal equipment for these power plants was worked out and manufactured in Russia. This became possible due to unification of efforts of newly created companies "Intergeotherm" SC, "Nauka" SC, "Geotherm" SC, "Energy" SC that, in cooperation with scientific centers – SEC Geo of Moscow Power Engineering Institute (MPII), VNIIAM and factories – "KTZ" SC, "PMZ" SC, "Privod" SC, "ChMZ" SC, foreign companies – "Siemens" etc. worked out and created modern energy equipment for geothermal electric power and heat plants.
Researches, technologies and production possibilities of conversional enterprises producing equipment for NPP, shipbuilding and other branches of industry formed the base of these developments.

2. PECULIARITIES OF GEOTHERMAL FLUID.

The working fluid of geothermal power plants (GeoPP) and heat plants (GeoHP) is the geothermal fluid the chemical composition of whish is formed in deep layers of the Earth. This circumstance defines specific quality and diversity of its operational and environmental properties. [1].
Geothermal fluid suitable for electric power generation at GeoPPs in Russia is mostly water-dominated and has following main differences from working fluid of traditional technologies of getting electric power and heat on organic fuel: relatively low heat potential; low pressure and temperature; high moisture content in steam; large specific volume; increased admixture content causing corrosion, erosion and salt sediments; presence of non-condensable gases that cause metal corrosion and other problems.
Thermodynamic parameters of steam-water mixture ay wellhead correspond to following indices: enthalpy up to 1500 KJ/kg, pressure 2-20 bar, temperature 110-250^0 C.
Chemical compositions of geothermal fluid strongly differ at each geothermal reservoir and even at each well. Indices of pollution and humidity extent of geothermal steam are many times more than similar indices of fresh steam at traditional heat power plants. It is characterized by content of dozens of various chemical elements and compounds were ions of calcium, potassium, sodium, chlorine prevail. In gas content (2-5% of volume fractions) carbonic acid and hydrogen sulphide prevail and also ammonia, hydrogen, methane, radon and other gases are present.
Peculiarities of physical-chemical properties of geothermal fluid are the reason of a number of technical problems that must be solved during designing and manufacturing of geothermal power equipment.

3. EQUIPMENT OF STEAM PREPARATION SYSTEM: SEPARATORS, STEAM-COLLECTORS, EXTENDERS.

Reliability and effectiveness of work of GeoPP is to a great extent determined by quality of steam coming to turbine. Purity of steam depends mostly on effectiveness of phase separation as the dissolubility of admixtures in first phase at pressure about 1,0 MPa typical for GeoPP is negligibly small (coefficient of distribution 10^{-15} - 10^{-4}), and their most part is concentrated in liquid phase. So extent of steam dryness as the index of salt contents is used as the criterion of steam purity. It should marked however that high steam dryness and even small superheating can be reached not only by phase separation but also by predrying in the process of throttling, for example due to pressure losses in pipeline. At the same time, in spite of absence of considerable amount of moisture in steam, its salt contents can prove to be high enough.
Vertical cyclone separators widespread in the world have small effectiveness of separation (steam humidity at outlet can reach 1,0%). In the practice of GeoPP operation separating ability of long pipelines from separators to turbine is often used. Moisture with salts contained in it, moving in steam flow, forms sediment on pipeline sides as the skin and is drained along the length of pipe. Such method of purification undoubtedly decreases the salt contents of steam downstream of turbine but can't be controlled and provide reliable work of turbines completely.
Highly effective separators (steam humidity extent at outlet is 0,05% at the most), extenders and steam-collectors manufactured by "ZIO-Podolsk" SC (see tab. 1), worked out in "Nauka" SC with participation of SEC Geo of MPII, VNIIAM, are principally new separators of horizontal type; their creation is based on the experience of designing similar devices in nuclear power engineering using mechanism of gravitational sedimentation of liquid particles.

Tab. 1. Technical characteristics of separators, extenders and separator-steam-collector manufactured by "ZIO-Podolsk" SC.

Name of device	Steam pressure, bar	Humidity extent at inlet, %	Humidity extent at outlet (at the most), %	Steam flow rate t/h	Hydraulic resistance, (at the most), bar	Mass, kg
Separator S-55	5,0-9,0	15-80	0,05	55,0	0,1	7500
Separator S-85	5,0-9,0	15-80	0,05	85,0	0,1	9500
Separator S-115	5,0-9,0	15-80	0,05	115,0	0,1	10500
Separator secondary with steam rinsing S-180	5,0-9,0	0-2	0,01	180,0	0,1	17000
Separator two-stage S-45	5,0-9,0	15-80	0,05	45,0	0,1	9700
Extender R-23	9,0		0,05	23,0	0,1	7500
Separator for well testing SS-100	1,0	0-100	0,05	100	-	7000

With more effectiveness of moisture removal the worked-out separators prevail the foreign analogues of other types by such indices as compactness and steel intensity. Advantage of gravitational separators is also their insensibility to steam contents of separated steam-water mixture whereas effectiveness of centrifugal separators depends on steam contents of flow and drops with its decrease. At gravitational separation systems dependence between steam load and humidity is also preferable; it is characterized by continuous decrease of humidity as the load decreases. Centrifugal separation systems work effectively only in calculated regime, and deviations from it towards both increase and decrease of load lead to deterioration of separation effectiveness and increase of finite humidity.

Design of gravitational type separator is presented at Fig. 1. Unlike cyclone type separators that are as a rule provided with separate separate-collector (vertical or horizontal) and float safety valve, in this separator all devices are located in single case.
Separation of moisture is successively implemented at dash plate, then in water volume, at separation panel and at last in separation volume.
In front of dried steam outlet perforated stilling plate is put for aerodynamic leveling of flow.
At Fig. 2 calculated characteristics of effectiveness of gravitation type separators are presented. Regime of work of separators is chosen so that at nominal flow rate the steam humidity doesn't exceed 0,05%.
Specific requirements towards purity of steam coming into the turbine are determined by the fact that admixtures contained in it form a sediment in flowing section and lead to decrease of its economy, and besides danger of corrosive-erosive effect upon metal of turbine and other equipment appears.

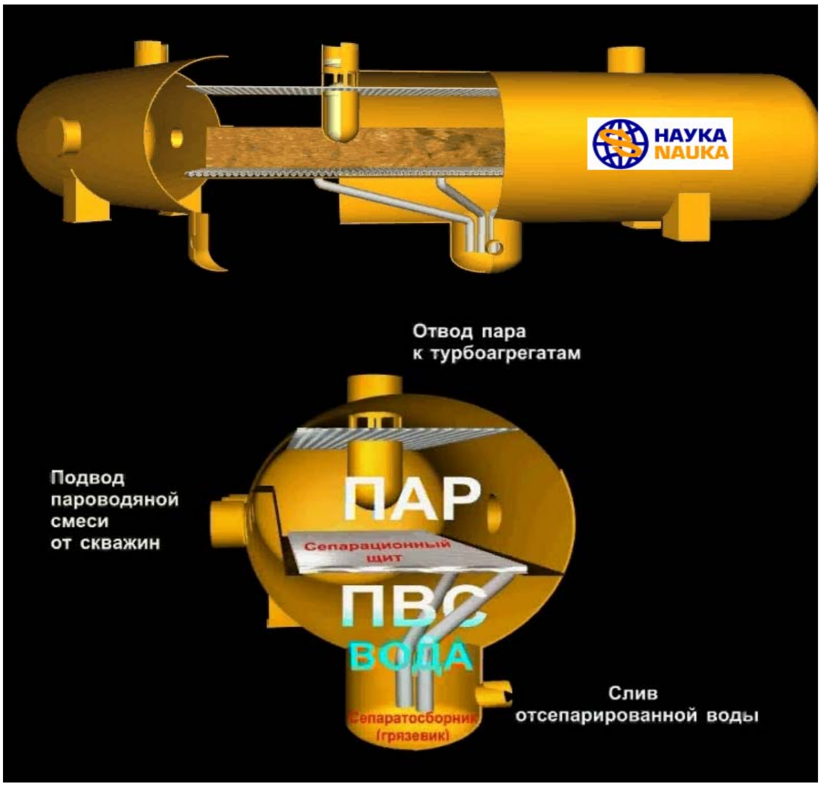

Fig.1 Horizontal gravitation type separator in profile

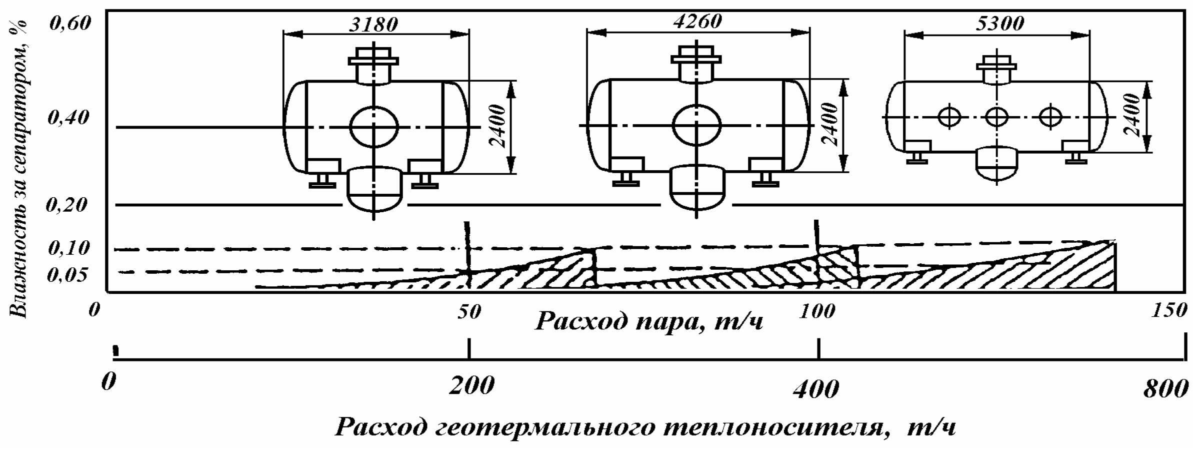

Fig.2 Calculated effectiveness of horizontal separators for GeoPP

For decrease of admixtures amount in steam two-stage separation system is used, with steam rinsing by pure condensate in second stage separator.
Such scheme of steam preparation with two-stage separation and steam rinsing is realized at Mutnovsky GeoPP (Fig. 3).

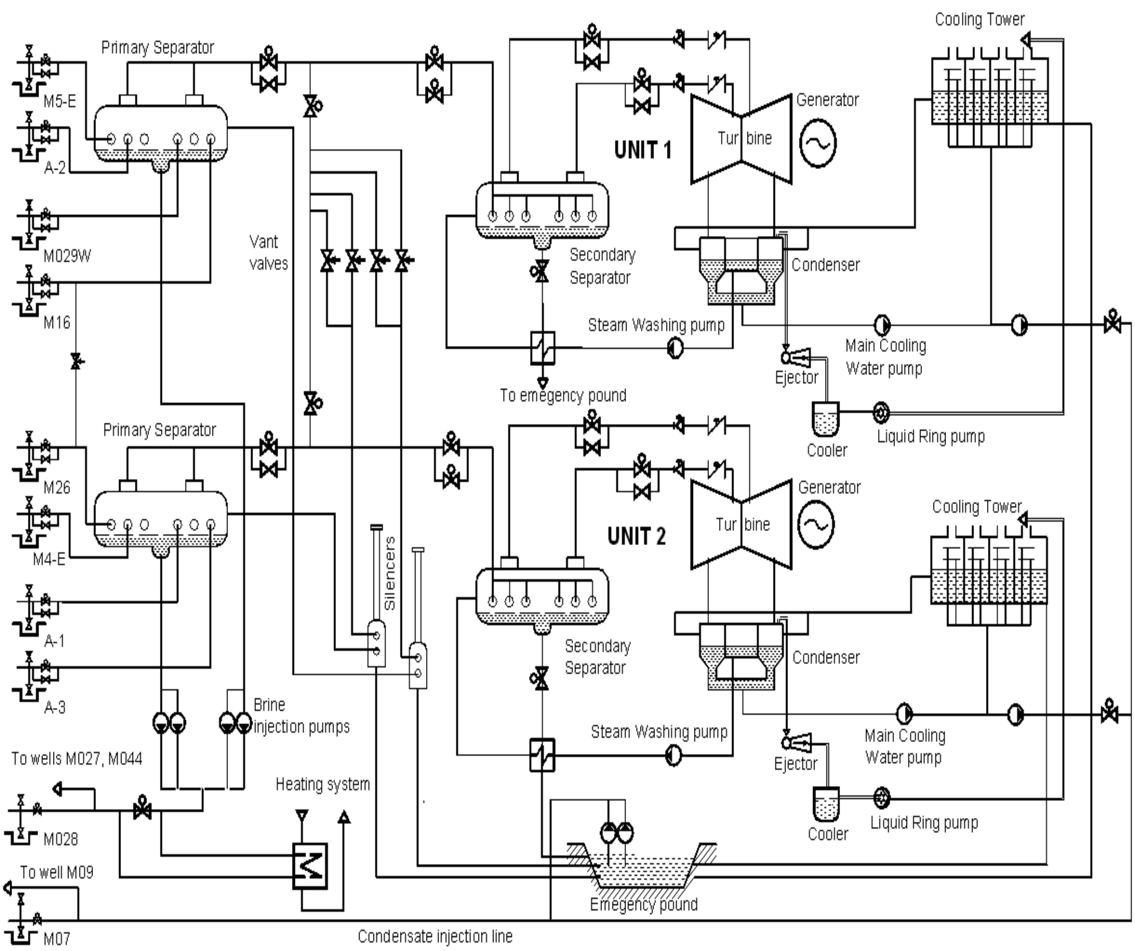

Fig.3. Thermal scheme of MGeoPP-1

Steam-water mixture with weight contents of steam from 30 to 100% comes from 7 production wells by separate pipelines into two I stage separators located in separator building (Fig. 4).
Separators are provided with protection systems against pressure excess and level excess. Level in separators is regulated by the work of separate reinjection pumps having variable-frequency drive.
In case of level excess in separator over admissible level the emergency valve of separate discharge into silencer is opened automatically. For prevention of water discharge into steam pipelines the separator design includes float valves closing steam outlet at emergency filling of separator by water.

Fig. 4 I stage separators of Mutnovsky GeoPP in separator building

Steam after I stage separators with humidity x > 0,9998 gets into collector from which through two pipelines by scaffold bridge is supplied to power units located in main building of GeoPP. Nominal steam pressure in collector is –6,5 bar. Steam pressure in the system is regulated by relief valves having fast-acting electric drive. Pressure regulation system allows maintaining pressure in steam system even during complete switch-off of one or two turbo-generators. At this moment pressure deviation in transition process doesn't exceed ± 0,4 bar.
Before supply to turbines the steam passes rinsing and secondary separation in II stage separators located in GeoPP main building. Pure condensate formed in flowing section of turbine is used for steam rinsing.
Separated water with temperature about 160^0 C is used for heating of network water in MGeoPP heat supply system and then at temperature 145^0 C is injected into reinjection wells.
Steam condensate is also injected into separate reinjection wells, and presence of non-condensable gases in steam at that, and first of all CO_2 and H_2S, leads to the fact that pH index for steam condensate may have the value pH=2-2,5. Such environment is obviously highly aggressive and requires use of special materials. In MGeoPP Project for condensate reinjection pipeline **pipes made of basalt fiber** are used for the first time. Such pipes are cheaper than those of stainless steel, they are able to withstand high technical loads, not subject to corrosion and very prospective for use at GeoPPs.

4. LOW-POWER UNIT-MODULAR GeoPPs

Low-power unit-modular GeoPPs were worked out with support of Ministry of Science and Technologies by joint efforts of "KTZ" SC, Scientific-Educational Center of MPII, "Nauka" SC, VNIIAM and other Russian organizations.
These GeoPPs, delivered to construction site in coach type containers with 100% factory availability, don't require considerable construction works and can be installed in short time in

hard access regions with severe climatic conditions be assigned for work both in power system and in autonomous conditions.

First such GeoPP "Omega-500" was manufactured and delivered to Kunashir island (Kuril islands) in 1993 [3]. Turbo-generator was done without condenser, with discharge to atmosphere and designed for initial pressure 7 bar, steam flow rate – 10 t/h. All equipment of unit GeoPP "Omega-500" installed beside the well at the bottom of Mendeleyevsky volcano showed high reliability and successfully stood hard earthquake in 1994.

"KTZ" SC worked out and produces now the backpressure turbo-generators for unit-type GeoPPs with capacity from 0,5 to 2,5 MW (see Tab. 2).

Table 2. Technical characteristics of backpressure turbines for geothermal power plants worked out and produced by "KTZ" SC

Names Indices	OMEGA-500	TUMAN-2	TUMAN-2,5
Power, *MW*	0,5	1,7	2,5
Inlet pressure, *bar*	7,0	5,0	7,0
Pressure downstream of turbine, *bar*	1,0	1,0	1,0
Steam flow rate, *t/h*	10,0	38,0	40,3
Rotation frequency, *Hz*	50	50	60

It is seen from Tab. 2 that turbo-unit data can be created with 50 and 60 Hz turbo-generators. The peculiarity of these turbines is that they are connected with generator directly without reducer. Turbine together with generator is installed on common frame that is an oil-tank at the same time. Oil coolers and other auxiliary equipment are also installed on the frame.

Four unit GeoPPs with backpressure turbines and capacity 1,7 MW each are manufactured in 1994 and delivered to Kuril islands for "Energy" SC.

The peculiarity of turbines production at Kaluga Turbine Works is that all produced turbo-generators pass the stand testing with full and partial load.

Two unit-type GeoPPs with turbo-generators with capacity 2,5 MW each for 60 Hz in tropical fulfillment (Fig. 5) were manufactured for GeoPP "San Jasinto" in Nicaragua [4].

The peculiarity of unit-type GeoPPs manufactured at "KTZ" SC is the presence of starting oil pump with drive from separate small turbine working on geothermal steam and small auxiliary loads, that allows to implement their autonomous start-up without external power sources and to use them as emergency start-up generators for GeoPPs with large capacity. Start-up turbine (turbo-pump) provides the main turbine without electric feeding and its regulation system with oil under pressure efficient for start-up of main turbine having its oil pump-regulator directly on rotor. The main pump starts working after reaching of fixed rotation frequency.

Geothermal power plants with turbines working without condenser, with discharge to atmosphere, are less economic in comparison with condensation type plants as the heat drop during steam expansion in turbine is 20-30% less. But such unit-type GeoPPs has their advantages:

- lower cost of installed KW of capacity (by 30-40%);
- compactness and 100% interblock equipment assemblage at manufacturing factory;
- simplicity of design, transportability, easiness and short time of assemblage make these turbo-generators especially attractable for use at geothermal reservoir at the stage of mastering and GeoPP construction;
- possibility of installation directly at geothermal well site without laying long pipelines;they don't require large expenses for GeoPP construction and so with time they can be moved to new geothermal steam field.

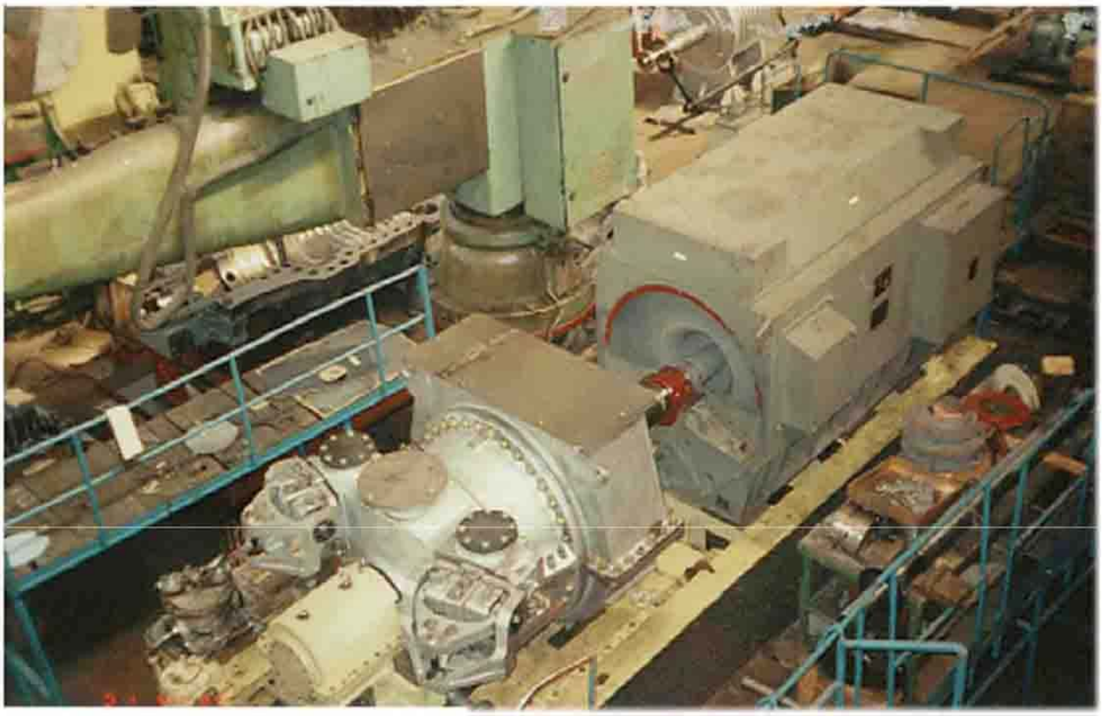

Fig.5 2,5 MW turbo-generator for GeoPP “San Jasinto” at factory stand.

Such GeoPPs with backpressure turbines can be easily transformed into combined cycle power units by “tuning” of binary part. At the same time steam downstream of turbine isn’t discharged into atmosphere but is directed to condenser that is the evaporator for low-boiling second circuit working fluid, i.e. isopentane, ammonia, freon etc. Generation of additional electric power in binary part turbo-generator allows to bring economy of such GeoPP up to the level of GeoPP with condensation turbine.

5. ENVIRONMENTALLY FRIENDLY VERKHNE-MUTNOVSKY GeoPP

“Geotherm” SC established for realizing geothermal Projects at Mutnovsky reservoir began creating Verkhne-Mutnovsky GeoPP as the pilot Project; it was put into operation in 1999 (Fig. 6).

Difficulty of access to construction area and short (4 months a year) construction period, absence of infrastructure and severe climatic conditions determined the concept of Verkhne-Mutnovsky GeoPP construction – unit-modular power plant with location of all equipment in coach-type modules-containers connected with each other by covered passages [5, 6].

For improving the GeoPP economy 4 MW condensation type turbines with air condensers were created.

Technological scheme of Verkhne-Mutnovsky GeoPP is presented at Fig. 7.

Steam-water mixture from 3 wells at pressure of 8 bar comes into steam preparation device containing of 4 modules manufactured by “ZIO-Podolsk” SC; they include I and II stage separators, steam extender and silencer. The separate after primary separators comes into extender where it boils up at pressure of 4,0 bar. Steam acquired in extender at 4 bar is used in ejectors of NCG bleed and the separate from extender is directed to injection well.

Fig.5 Environmentally friendly Verkhne-Mutnovsky GeoPP

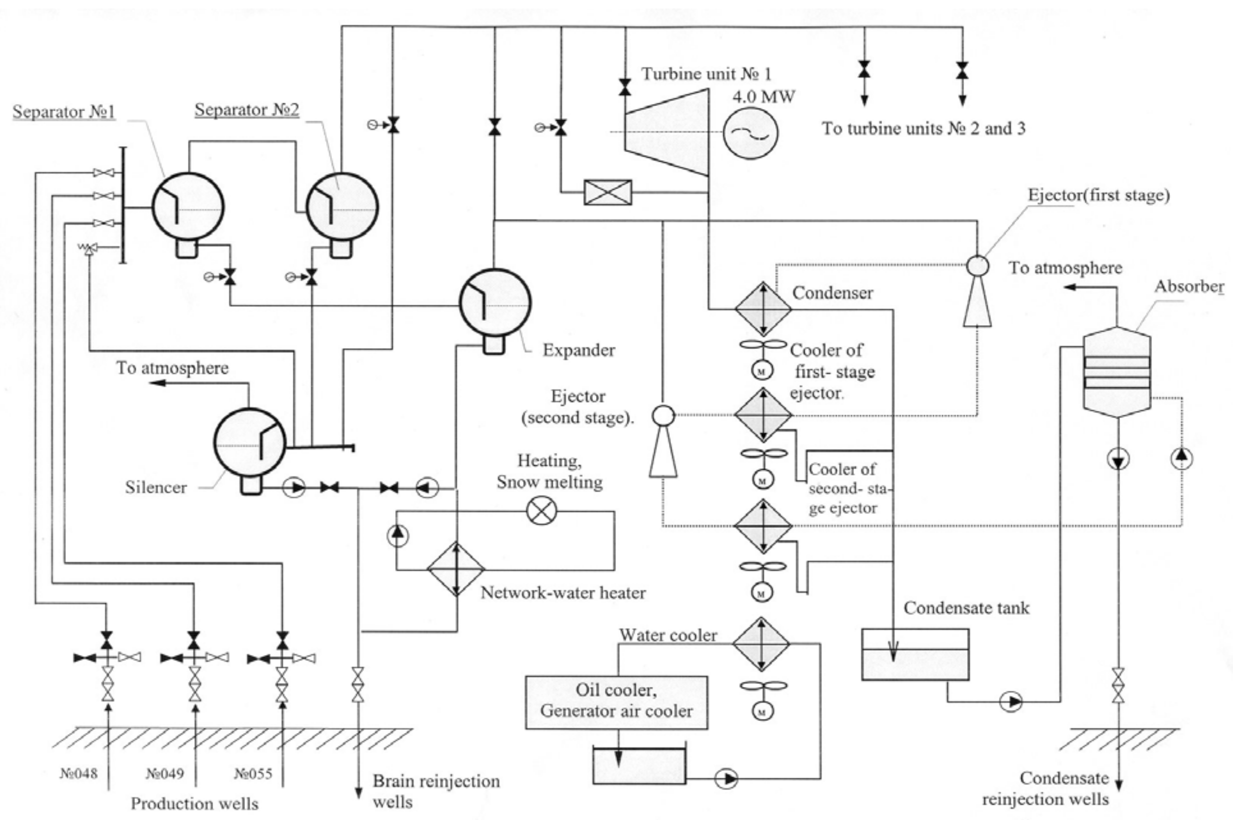

Fig.7 Technological scheme of Verkhne-Mutnovsky GeoPP

Application of air-cooled surface type condensers allowed to create environmentally friendly GeoPP where all geothermal fluid includes separate, steam condensate and non-condensable gases extracted from the Earth and after working in GeoPP scheme is injected into reservoir.

6. MODULAR TURBO-GENERATORS WITH CAPACITY UP TO 25 MW

Most prospective direction of geothermal plants development is today the creation of compact (modular) turbo-plants that are delivered to construction site being already assembled. Capacity of such condensation turbo-plants may be different and reach 25 MW. It was this concept of creation and construction of GeoPP series in Nicaragua that was chosen by Russian-Nicaraguan stock company "Intergeotherm" according to recommendation of "Nauka" SC and MPII.

By assignment of "Intergeotherm" SC two turbo-generators with 60 Hz frequency for GeoPP "San Jasinto" with capacity of 23 MW each were manufactured at "KTZ" SC [4, 7]. During creation of turbines latest technical achievements and also long-term experience of operation of KTZ turbines at Pauzhetsky GeoPP were considered. Russian metals were used that are applied in energy including nuclear energy and in shipbuilding.

Prototype of such turbines are "KTZ" SC turbines that are used widely and for a long time for feeding pumps drive at NPP [8]. These turbines are characterized by high economy of flowing part (according to testing at power plants efficiency = 88%) and reliability (during 20 years of operation they had no blade breakages, rotor destruction and other breakdowns).

Modern domestic scientific-technical achievements allowed creating the compact, light and reliable turbo-generator.

General view of 23 MW turbo-generator is presented at Fig. 8. Turbine and generator are installed on common frame. Turbine has discharge down. Waste steam from turbine at pressure of 11 KPa comes by discharge steam pipeline into mixing type condenser. The condenser has barometric cooling water drainage into the basin of circulation pump station from which the water comes for cooling into 4-sectional ventilator cooling tower.

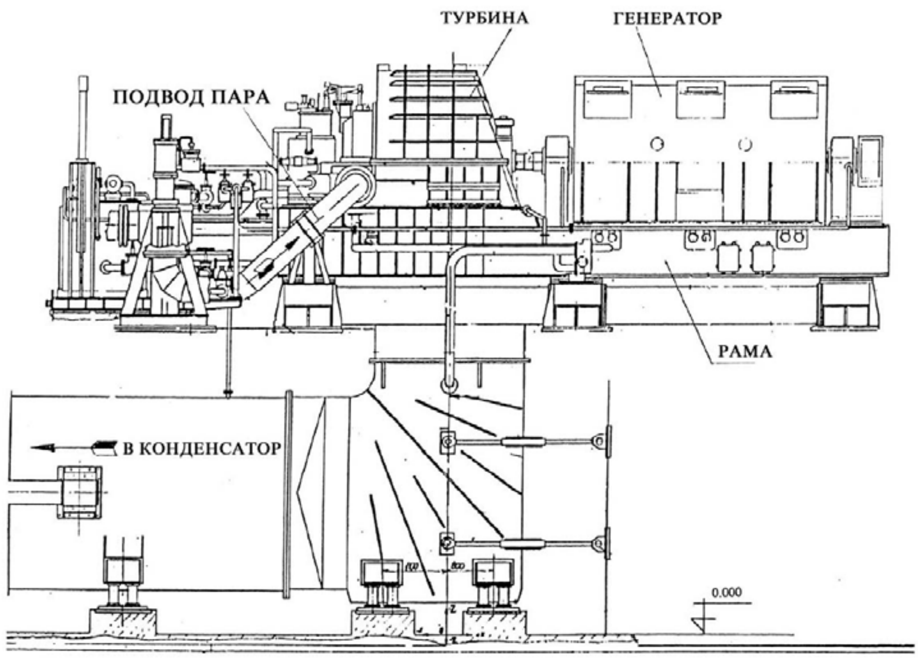

Fig.8. 23 MW turbo-generator for 60 Hz for GeoPP "San Jasinto"

Removal of non-condensable gases (NCG) is implemented by steam-jet ejectors installed on condenser sections. Steam-gas mixture supercooled by 9^0 C is exhausted by ejector first stages and directed to mixing type coolers. From coolers NCG is exhausted by second stage ejectors or,

at mass gas contents more than 0,8%, by water-circular pumps and after this is discharged into cooling tower torch.
High economy and reliability of “KTZ” SC turbines for GeoPPs were achieved due to use of highly economic profiles of nozzle and working blades, steam inlet devices and discharge pipe branches, and also developed system of moisture removal (separation) from turbine flowing part [9-11].
Turbine flowing part consists of seven stages. For increasing turbine economy and reliability special turbine stage-separator is installed at the place of fourth stage; its use allows, depending on working regime, to remove up to 20-80% of moisture from the flowing part.
Turbine stage-separator itself in comparison with common stage has a little decreased efficiency. But moisture removal from turbine flowing part (upstream of fifth, sixth and seventh stages) increases turbine efficiency in general by 2-4% in average (depending on working conditions).
For in-channel separation of moisture hollow nozzle blades are used that provide synchronous moisture exhaust through outlet edges and gaps located at profile back in the oblique cut zone.
Application of developed system of moisture removal in turbine flowing part allows not only to increase turbine internal relative efficiency due to decrease of steam humidity and correspondingly losses because of humidity. Besides, effective moisture removal allows to decrease the pressure downstream of turbine without any risc of errosional damage for last stages.
This circumstance is most important as for geothermal Projects in the countries and regions with cold clinate it gives the chance to increase essentially the heat drop for turbine and correspondingly power plant efficiency.

7. MUTNOVSKY GeoPP

Ewperience of creation and operation of pilot Vrkhne-Mutnovsky GeoPP, construction of 200 KV power line, electric substation “Avacha” and road allowing to deliver heavy and large dimension equipment to construction site, allowed to begin imoplementing the Mutnovsky GeoPP Project. Long-term geological exploring works give the estimation of poewr potential of Mutnovsky reservoir 300 MW_e at least.
Investment Feasibility Study carried out in 1997 by request of EBRD confirmed economical feasibility and techical realizability of Project by dividing its implementation into two stages. First stage of construction envisaged construction of 40 MW power plant at Dachny area using 320 t/h of geothermal steam. Provision of credit for construction by EBRD and investments of Russian Project participants allowed to create modern entirely automated geothermal power plant.
In international bidding for MGeoPP construction arranged by “Geotherm” SC in 1999 leadiong companies from Japan, Israel and Russia took part. Main struggle for Contract awarding began between Japanese company “Sumitomo Corporation” which proposed turbo-generator manufactured by “Fuji Electric” and Russian Foreign Trade Association “Technopromexport” with turbines of Kaluga Turbine Works. Russian tenderer who proposed more effective technology and lower price won the bidding.
In October 2002 Mutnovsky GeoPP was put into operation. At fixed steam flow rate from geothermal field of 320 t/h the electric capacity generated by MGeoPP is 50 MW.
At Fig. 9 the results of analysis of effectiveness of various GeoPPs are presented. Power units with turbo-generators of 15-35 MW capacity were analysed. The following indices were chosen as the effectiveness indices:

- specific “net” steam flow rate for electic power generation determined as proportion of steam flow rate per power unit and “net” capacity (power generated by generator minus power unit auxiliary loads)

➢ “gross” power unit efficiency determined as proportion of electric power at generator clamps and available heat capacity of geothermal steam supplied to power unit

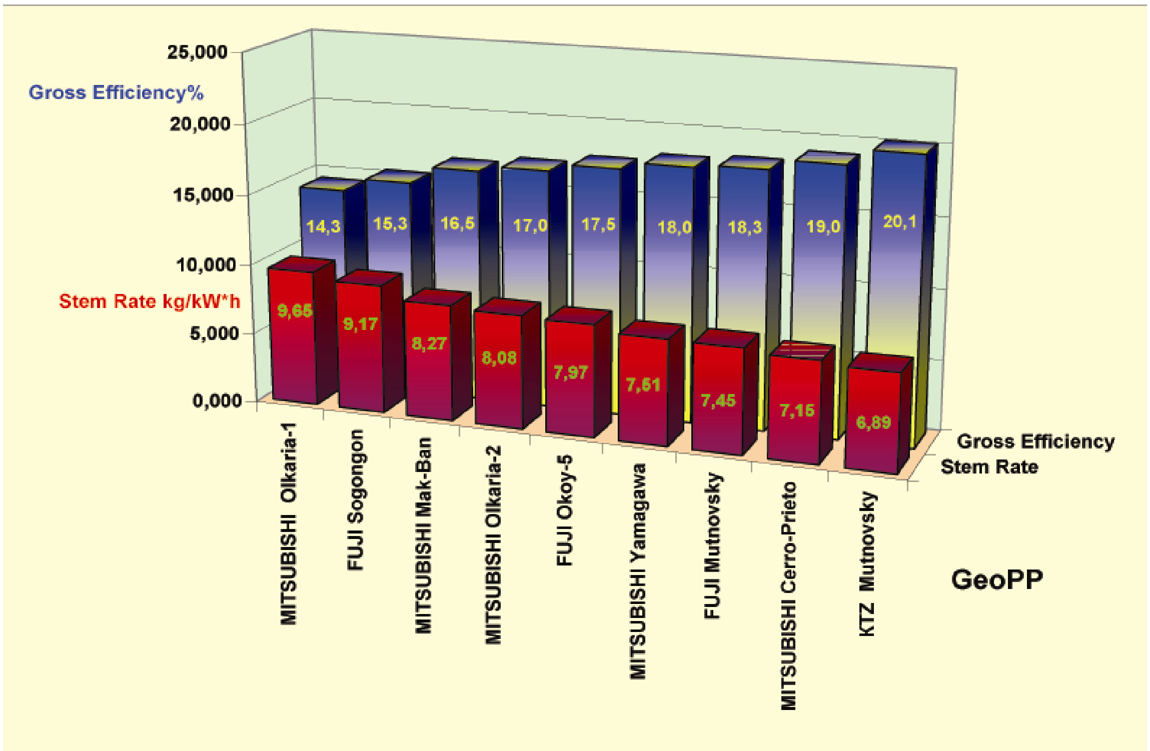

Fig. 9 Indices of effectiveness of various GeoPPs

As the presented graphs show, power units of Mutnovsky GeoPP have the highest efficiency and lowest steam flow rate for electric power generation. Reaching so high indices became possible due to creation of new double-flow steam turbine working reliably at major vacuum in condenser (Fig. 10).

Fig. 10. 25 MW steam turbine worked out and manufactured by “KTZ” SC for Mutnovsky GeoPP.

Working-out and creation of such turbine became possible due to long-term active creative links of Kaluga Turbine Works with the Chair of Steam and Gas Turbines of Moscow Power Engineering Institute which carried out numerous scientific researches on optimization of "KTZ" SC turbines flowing part. As a result of these researches design decisions allowing to increase essentially the economy of flowing part and its reliability at work in wet steam were found, theoretically substantiated, experimentally confirmed and introduced at "KTZ" SC turbines [9, 10].

Main technical characteristics of turbine

Turbine type	К-25-06-Geo
Nominal electric power at generator clamps	25,0
Nominal calculated steam and cooling water parameters:	
- steam pressure, MPa	0,62
- steam dryness extent upstream of turbine	0,9998
- non-condensable gases contents in steam (by mass), %	0,4
- steam pressure in condenser, KPa	5,0

Turbine design and applied blade instrument allow increasing power generated by turbine up to 35 MW. With increase of length of last blade in this body it's possible to get capacity up to 50 MW.
Turbine slit is presented at Fig. 11. The turbine is double-flow, one-shaft, single-bottom, active type. Each flow has 8 stages. First four stages are made with over-trend labyrinth compaction.

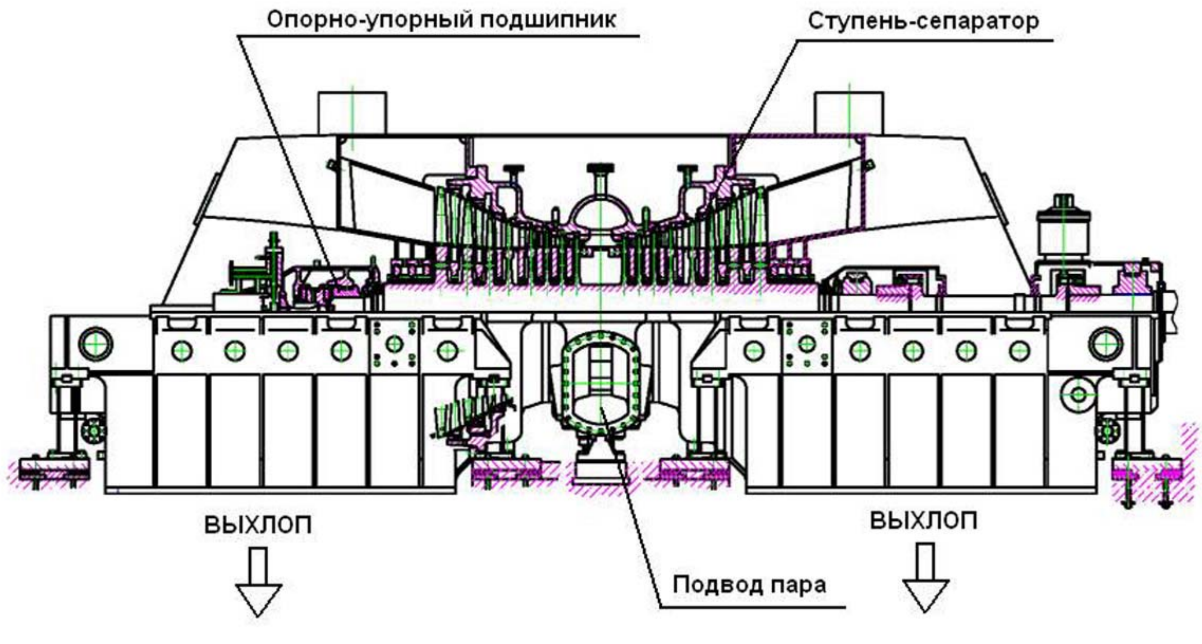

Fig.11. Slit of double-flow steam turbine with capacity of 25-35 MW for GeoPP

Developed system of PERIPHERAL MOISTURE SEPARATION is applied in turbine flowing part beginning from 4th stage.
In 7th and 8th stages IN-CHANNEL SEPARATION on nozzle blades is applied. One of most effective methods of moisture removal is the use of special turbine STAGE-SEPARATOR that is also worked out by the scientists and engineers of MPII and "KTZ" SC.
Main advantage of mentioned separation methods is that they remove practically all the large-dispersed moisture that causes erosion of working blades. Besides, application of stage-separator allowed to increase efficiency of the whole turbine almost by 2,0%.

For decreasing power losses in discharge pipe branch downstream of last stage highly effective axial-circular diffuser with oblique cut.

8. RUSSIAN BINARY TECHNOLOGIES.

Creation of Paratunka GeoPP – first binary cycle power plant in the world - by Soviet scientists in 1967 [12] opened the possibility of getting electric power from low-potential heat sources. This idea became wide-spread, and today all over the world hundreds of units using bunary cycle technology work at geothermal fields. After more than 30 years works on creation of binary power plants are actively carried on again in Russia.

Israeli company "ORMAT", contemporary leader in binary GeoPP construction, uses flammable and highly explosive hydrocarbon compounds (butane, pentane, isopentane) as working fluids, and this determines the open layout of power units located outdoors. Such design decisions may be realized in the countries with hot and moderate climate but are unacceptable for Russia with lasting and snowy winters.

At the same time use of organic working fluids that don't freeze at low temperatures in binary cycles allows to use maximally severe climatic conditions of Russia for increase of thermal efficiency. "Nauka" SC worked out the project of new binary power plant (Fig. 12) that can use low-potential heat from various sources (geothermal water, hot water of heat supply system, waste heat of industrial enterprises etc.) for electric power generation, and at present is working over creation of combined cycle IV power unit of Verkhne-Mutnovsky GeoPP which will allow to increase plant capacity up to 18 MW [13].

Fig. 12 Binary power plant

The peculiarity of BPP worked out in "Nauka" SC is the circular location of air condenser sections allowing using wind power for cooling optimally, regardless of its direction.

Energy plant is completely automated and controlled by unmanned technology from remote control panel.

9. FIRST SATELLITE COMMUNICATION AND GeoPP CONTROL SYSTEM

Mutnovsky GeoPP is the completely automated power plant supplied by distributed control system based on programme-technological complex Teleperm ME of Siemens company.

Algorithms and step-by-step programs worked out by Russian company “Interautomatics” allow to start-up or shutdown power units by pressing one key.

“Nauka” SC proposed and together with specialists of United Design Bureau of MPII and Siemens company created the space communication and MGeoPP control system (Fig. 13) allowing to carry out monitoring of technological process and equipment of power plant and geothermal field status in regime of real time [14].

The system consists of:

- Operators workplaces and local networks of process control centers (PCC Geo) in Moscow (“Nauka” SC) and Petropavlovsk-Kamchatsky (“Geotherm” SC).
- WEB-server included into distributed control system of power plant and connected with space communication station “VSAT”;
- Space segment made on the basis of small earthly station of data transmission network using satellite “Horizont 96,5”
- “Virtual connection” – local network of PCC Geo – Center of space communication “Medvezhyi ozera”

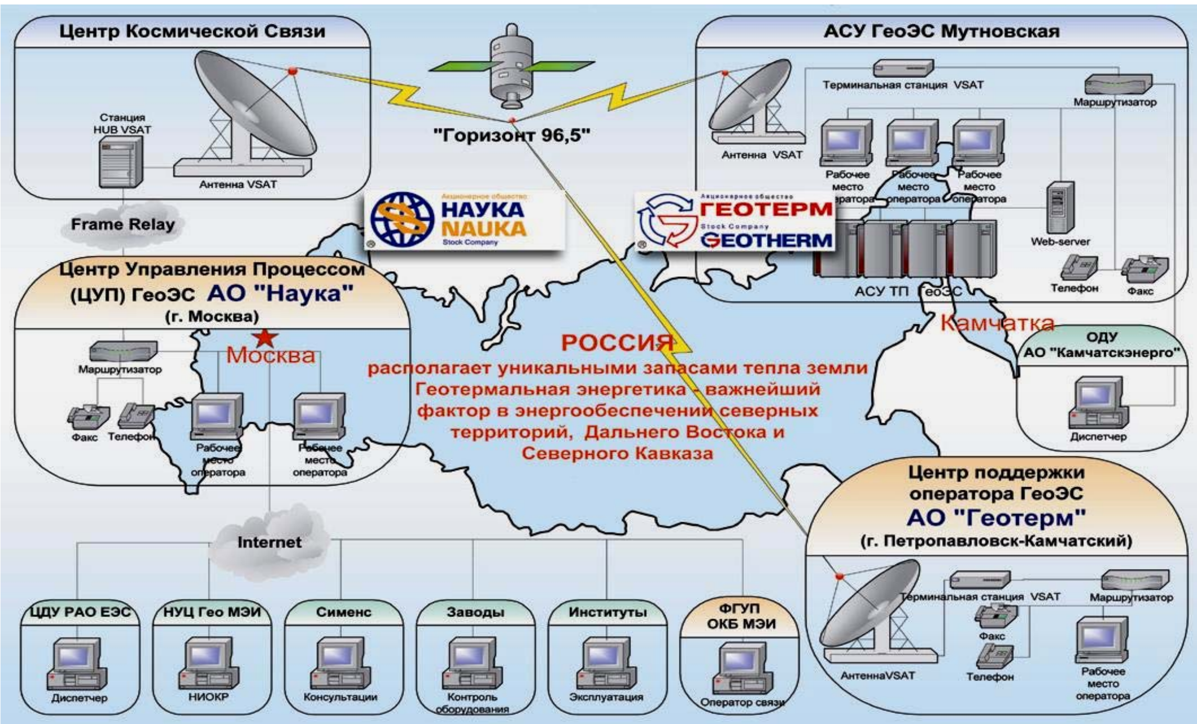

Fig.13 Satellite communication and control system of Mutnovsky GeoPP.

The system allows, except transmission of data on technological process, also to transmit the image from 16 dirigible video cameras located at power plant, and provides telephone communication by two channels.

PCC Geo operators can get any information to the monitors of their computers in the form of videograms similar to those that operators at power plant have.

Created system allows to provide constant support to GeoPP operators, especially necessary during the period of mastering of new equipment and technologies, by leading specialists of manufacturing works, design and scientific organizations.

10. CONCLUSIONS

Long-term fundamental researches and scientific-technical developments of Russian scientists, unification of efforts of leading institutes, companies and manufacturing works (MPII, VNIIAM, “Nauka” SC, “KTZ” SC, “ZIO-Podolsk” SC etc.) introduced Russia again into the row of countries able to develop independently and produce all equipment for geothermal power and heat plants and most advanced geothermal technologies.

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