（№１　２００３年９月８日号目次）

特集：ロシアにおける新エネルギー開発その１

今号より３回にわたり、ロシアの新エネルギー開発についてご報告いたします。
炭化水素資源の代替となるエネルギー開発は世界的に注目される分野ですが、資源大国であるロシアは特に炭化水素資源への依存度が高く、地方のエネルギー不足問題も深刻なため、風力発電をはじめとする新エネルギー技術開発が行われています。
今号では風力発電、地熱発電の開発の現状と、各分野の優良プラントをご紹介いたします。

概観：ロシアにおける新エネルギー開発

ロシアのエネルギー消費（燃料と電力）を概観すると、標準燃料に換算して年間約12億tに相当する。うち、再生不可能エネルギー源（石油、ガス等）は98%に達している。世界に冠たる資源大国といえども、この値は高すぎると言えよう。

しかも、これら資源の開発、輸送、加工は環境に負荷を与え、有害物質を生成することも多い。そして、いずれの炭化水素資源も有限であり、枯渇するのが30年後か、50年後か、あるいは70年後かという時間の問題でしかない。

一方、ロシアのようにあまりにも国土が広大な場合、燃料や電力の輸送はコストのかかる課題であり、国民の15%、国土の70%が燃料または電力の不足に悩んでいるという現実がある。ロシアの場合、寒冷地が多いので、暖房や給湯の需要も大きく、エネルギーの確保は、生活に不便といったレベルではなく、まさに死活問題となる。

したがって、他の先進国同様、ロシアにとっても再生可能で、環境に負荷をかけない新エネルギーの開発は急務となっている。

具体的には、地元にあるエネルギー源の活用が研究されている。地熱発電、風力発電、太陽光発電、バイオマス等である。

ロシアが潜在的に持っている新エネルギー源の能力は、一般に次のように評価されている。

太陽	2兆3,000億標準燃料t
風力	267億標準燃料t
バイオマス	100億標準燃料t
地熱	40兆標準燃料t
小規模水力	3,600億標準燃料t
海洋	300億標準燃料t

これらの潜在力は、現在の需要を大幅に上回るものであり、将来のエネルギー源になるとともに、環境問題をも解決する有効な方策である。

ロシアの新エネルギー開発の現状と将来を研究することは、世界のエネルギー需給の観点からも重要なテーマと言えよう。

１．ロシアの風力発電

Russia possesses large resources of wind energy, including those in the regions lacking centralized power supply. The Arctic coast, Kamchatka, Sakhalin, Chukotka, Yakutia, as well as coasts of the Baltic (Gulf of Finland), Black, and Caspian seas are noted for high average annual wind velocities. The spreading of wind energy resources allows its rational use both by autonomous wind power plants (WPP) and WPP as part of local grids.

Wind energetics is the most developed sector of the Russian market of renewable energy sources. First WPP of 3-4 kW capacity appeared as long ago as the 1930s. In the 1950s, annual manufacture of WPP for agriculture, forestry, hunters, and geologists reached tens of thousands.

However, because of the changed strategy of energetics development and transition to the construction of large power plants and setting of a unified energy system, the above activity was greatly reduced. As a result, WPP failed to compete with giant power stations incorporated into a nationwide system.

Interest to wind energetics was revived in the early 1990s, after Russia's transfer to market economy.

Available developments, enthusiastic work of R&D organizations and some manufacturers resulted in the design, fabrication, testing, and (in some cases) start of serial production of quite a number of modern WPP of a wide range of capacities: from 100 W to 1 MW.

Among WPP designers and manufacturers are such large enterprises and research institutes as Electropribor Institute, Tushinsky Machine-Building Plant, Moscow Machine-Building Plant "VPERED", Rybinsk Machine-Building Plant, State Research Center "V. Makeev Design Office", Design Office "Raduga", Research Institute of Agriculture Electrification, as well as various companies – VetraStar, Vetrotok, Invest-PROFIT, and joint ventures (e.g. LMV Vetroenergetika).

As regards WPP development and manufacture, the following examples shall be given:

- Since 1998, the V. Makeev Design Office has been developing a WPP with the vertical axis of rotation. In 2001, pilot samples of VEU-30 wind power plant of up to 30 kW capacity were made.
- Research & Production Association (RPA) "Elsib" has designed and offers a VES-10TM wind power plant of up to 300 kW capacity for supplying power both to remote consumers and those covered by power grids as an emergency energy source.
- The Raduga Design Office (federal state unitary enterprise - FSUE) has designed within the conversion program a wide range of WPP with capacity of 700 W to 1,000 kW. Worth mentioning are autonomous WPP "Raduga-001" and "Raduga-008" of 1 and 8 kW capacity, respectively, intended for energy generation and supply to customers.
- Dolina Joint-Stock Company (JSC), a big machine-building enterprise (Orenburg Region), produces VEU-2 and VEU-5 WPP for autonomous and reserve power supply.

WPP successfully operate in various Russian regions and in CIS, some of them are exported.

However, demand for WPP is much higher than their supply. According to some estimates, the WPP market potential till 2005 is 100,000 plants of various capacity. Of special importance is the use of WPP in regions with decentralized power supply, by farms and small industrial and construction enterprises.

The following factors hamper a wider spreading of WPP:

- lack of financial resources;
- lack of information about WPP design features;
- absence of governmental support of the wind energetics.

The existing surplus of power generating capacities greatly slackens WPP competitiveness as against conventional power plants. Newly built WPP demand new investments and extra operating costs, whereas thermal power plants feature only fuel and maintenance costs. As a result, the annual output of WPP-generated power in Russia does not exceed 20 million kW·h. Favorable conditions for the progress of wind energetics will be created in case the existing capacities fail to meet the rising energy demand thus facilitating the construction of new power plants.

The main promising trends for the wind energetics in Russia are as follows:

- Making WPP part of “large” energetics, taking into account inevitable reduction of cost of WPP and increased prices for conventional fuel;
- Creating small-capacity WPP for solving energy problems of far-instant and isolated areas. The progress of wind energetics can be achieved by updating small-capacity (up to 30 kW) WPP isolated from large grids. For compensating the major WPP shortcoming (time variable power generation) joint operation of those plants with diesel-generator ones is planned.

The RF Government and JSC “EES of Russia” fully realize the importance of wind energetics. Respective federal programs for 2003-2010 envisage the construction of 694 WPP of the aggregate capacity of 232 MW in 28 Russian regions.

２．優良風力発電プラント

①VEU-50 ROTOR-TYPE WIND POWER PLANT BASED ON THE MAGNUS EFFECT

The VEU-50 rotor-type WPP based on the Magnus effect is intended for supplying power to objects not connected to a grid in weak wind areas.

VEU-50 can be operated jointly with diesel generator plants (DGP) of up to 500 kW capacity.

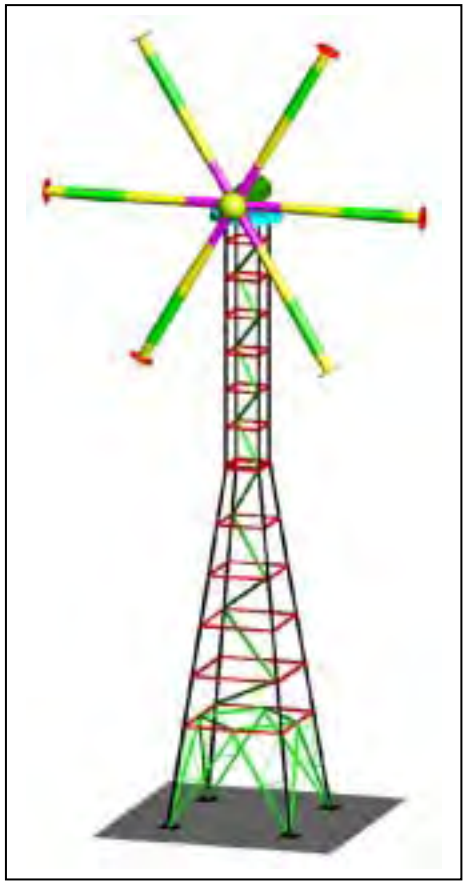
Additionally, VEU-50 can be operated as follows:

- jointly with solar cells;
- as part of a grid.

Principle of operation. The cylinder rotation gives rise to a cross flow force perpendicular to the air flow velocity vector, similar to the blade lifting force but much stronger. That ensures a large torque value of the wind wheel, which provides for efficient use of low, most frequently repeated wind velocities. VEU-50 starts operating at the wind velocity equal to 2.5 m/s (blades operate at the air flow velocity not less than 5 m/s). The primary cost of 1 kW·h on VEU-50 is 0.02$ against 0.04-0.05$ on blade plants.

VEU-50 specifications

Capacity at 6 m/s wind velocity, kW	10
Capacity at 8 m/s wind velocity, kW	30
Capacity at 10 m/s wind velocity, kW	50
Wind turbine diameter, m	15
Number of rotors	6
Initial wind velocity, m/s	2.5
Height of support, m	25



VEU-50 basic units

- Tower;
- Wind wheel;
- Generator;
- Cylinder

Economic effect achieved by:

- Decreased specific fuel consumption while operating jointly with a DGP
- More efficient (as compared with blade plants) use of wind energy;
- Increased operating period in percent of the yearly service period

VEU-50 was designed at the Institute of Theoretical and Applied Mechanics, Siberian Branch of the Russian Academy of Sciences. It is manufactured at the Aerospace Association “Polyot”, which in 2001 signed with the above Institute a license agreement and acquired the right for VEU-50 design, development, and sale.

While making rotor working surfaces, specialists of the “Polyot” Association usually make use of fiberglass plastic usually applied in spacecraft, which raises the efficiency factor from 10% to 42%.

The approximate cost of VEU-50 is $50,000. The ”Polyot” specialists estimate an annual capacity of the Russian market at 60,000 pcs.

Organizations:

Designer:
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②VEU-30 WIND POWER PLANT

In the last years, Russian organizations were engaged in the development of 15-30 kW WPP. As a result, they designed some pilot samples of WPP with the 12 m rotor diameter, a 15-kW pilot sample (Central Design Office, St. Petersburg), three pilot samples of 16-kW capacity (Vetro-Star Company, Moscow).

After analyzing shortcomings of the 15- and 16-kW WPP, as well as considering foreign analogues, the layout design of a 30-kW WPP (VEU-30) was proposed (at the request of the Invest-PROFIT Company).

At present, the Invest-PROFIT Company has made pilot samples and is about to start a lot production of regulated three-blade WPP of 30-kW capacity.

VEU-30 are intended for supplying power to autonomous customers located far from grids. Those WPP generate two kinds of energy: standard type and that used for water heating.

VEU-50 specifications

Rated capacity, kW	30
Rotor diameter, m	11.5
Number of blades	3
Blade material	Fiberglass plastic
Wind velocity range, m/s	3-25
Design wind velocity ensuring rated efficiency, m/s	11
Admissible wind velocity, m/s	50
Power generator	Synchronous, contactless
Current	Three-phase A.C.
Voltage, V	380/220
Frequency, Hz	50
Wind wheel rotation regulation	Centrifugal spring governor
Braking system	Blade feathering
Multiplier (number of steps)	1:12.8 (two)
Orientation toward the wind	Weathercock
Operation mode	Automatic, long-term
Tower height, m	18
WPP mass, kg, including: o housing o tower	1,600 2,400
Service life, years	20
Maintenance interval	Annual inspection
Temperature range, ^{o}C	From -50 to 40

Basic components set:

- VEU-30 wind power plant;
- Three-section tower with the hoisting boom, guys, and turnbuckles;
- Connecting electrical cabinet with the generator excitation control system;
- Rectifying electrical cabinet with the battery charge control and load regulation systems;
- Storage battery, up to 560 A·h capacity, 150 V;

- Three-phase inverter, 10.5 kW, overload capacity of 15 kW for a period of up to 30 min and 35 kW for a period of up to 10 s.

Design features:

- Fiberglass plastic blades;
- Centrifugal spring rotation governor;
- Orientation toward the wind: weathercock.
- Rotor-to-generator connection: via reducer;
- Generator: synchronous contactless;
- Tower: pipe with guys;
- The electric system incorporates as follows: capacious accumulatorc, inverter comparable with WPP by capacity (from 10 to 30 kW), and tubular heating for removing surplus capacity. (The said WPP is actually a charger for storage batteries). For ensuring trouble-free power supply, it is recommended to use a diesel generator as a reserve source. The diesel generator capacity can range from 10 to 30 kW, similar to the inverter.

VEU-30 features a simple and reliable design: direct-acting centrifugal spring governor with blade feathering; high quality unattended reducer with non-changeable synthetic grease; contactless synchronous generator.

Thanks to low mass indices of some joints, VEU-30 can be operated in difficult-to-reach and far-away areas; mounting can be effected without crane facilities.

Organizations:

Manufacturer:
Invest-PROFIT Company
St. Petersburg, Russia
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Website: http://www.invest-profit.ru/

③VEU-10 WIND POWER PLANT

Starting from the 1980s, specialists from the Research Institute of Power Constructions (RIPC) are investigating WPP with the vertical axis of rotation (orthogonal). Under consideration were variants from one to three blades, as well as multi-blade systems.

Numerical models helped in designing WPP of any capacity in a free flow. Existing pilot samples of plants of up to 10 kW capacity show the efficiency factor value of about 35%.

The VEU-10 plants are intended for regions with the average annual wind velocity exceeding 4.5 m/s.

Advantages: no necessity of orientation toward the wind, low blade rotation frequency, low noise level.

VEU-10 can be used both by individual consumers (farms, gardens) and as part of grids.

Basic application: generation and accumulation of energy.

VEU-10 plants can be used as reserve energy sources.

VEU-10 shall be mounted on an open site on the foundation with guys.

VEU-10 specifications:

Installed capacity, kW	10
Rotor diameter, m	6
Blade height, m	5
Minimal wind velocity, m/s	4
Design velocity, m/s	11
Maximal velocity, m/s	35
Regulation	Aerodynamic
Output voltage, V	Three-phase 380 V

RIPC has patents for the said plant.

The plant can be supplied together with electrical equipment for autonomous operation, as well as with an energy accumulation system. Besides, wind power plants of lower capacity (from 1 kW) can be offered, having smaller dimensions and a lower value of the design wind velocity (from 8 m/s).

Organizations:

Manufacturer:
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Website: www.niies.ru

④MUSSON F-30 WIND POWER PLANT

Musson F-30 wind power plant was designed by the Wind Energetics Company with the attraction of St. Petersburg design organizations. Russian weather and climatic conditions were taken into consideration.

Musson F-30 is intended for converting kinetic energy of wind into electric energy in a low-velocity range (from 3.5 to 25 m/s).

Since the F-30 designers considered reliability as one of the most important factors, they made some design solutions for enhancing reliability. In particular, the future plant was to function without the reducer.

Jointly with one of the leading design institutions in the field of electrical machines the F-30 designers developed a permanent magnet generator ensuring the rated capacity at low rpm of the wind wheel, i.e. low wind velocities. Apart from that, using the said generator made it possible to get rid of the brush collector.

For maintaining the design rotation frequencies, the F-30 designers applied the centrifugal spring governor acting via a system of drives on the blade turning mechanism, which is used rather seldom in plants of the given capacity. The said system in a set with the starting/stopping device enables remote or (at the customer's request) automatic start and stop of the plant.

The Musson F-30 wind power plant is of the so-called stern wind type, i.e. wind incoming to the wind wheel takes place from the side of the tower. The plant orientation to the wind occurs by the wind acting on the wind wheel, which at the same time serves as a weathercock. For reducing loads on the plant component parts (on blades in particular), during rotation around the support use was made of the hydraulic damping system limiting the angular turning velocity to 0.5 rad/s.

The blades are made from wood laminate on a somewhat unique computer-aided woodworking machine using the 3D model. For facilitating the initiation of the wind wheel and of the plant as a whole and thus reducing the starting wind velocity, all bearings of the said plant are specially treated for decreasing the friction moment and ceasing the use of consistent greases, which greatly enhances the efficiency of wind power plants under low temperatures.

While developing the plant, its modifications were also considered. For example, the frame of the swivel head placed in the housing and bearing all basic units of the WPP is designed so that it enables placement of 30- and 50-kW generators without any alterations. As regards the placement of generators of a higher capacity, only insignificant increase of linear dimensions will be necessary.

The design of the plant units is protected with patents and author's certificates.

Musson F-30 specifications

Rated capacity, kW	30
Wind wheel diameter, m	11
Number of blades	3
Blade material	Plastic
Wind velocity range, m/s	3.5 - 25
Design wind velocity ensuring rated efficiency, m/s	12
Admissible wind velocity, m/s	30
Power generator	On permanent magnets
Current	
Voltage, V	380
Frequency, Hz	50±0.2
Wind wheel rotation control	
Braking system	Electromechanical and parking brakes
Multiplier (number of steps)	Absent
Orientation toward the wind	Self-control
Operation mode	
Tower height, m	26
WPP mass, kg, including:	
housing	2,500
Tower	6,500
Service life, years	20
Maintenance interval	Annually
Annual ratio of WPP efficient operation	0.85-0.9

Estimated cost: $80,000.

The cost of 1 kW·h of energy generated by the Musson F-30 plant makes up $0.11, which is half as much for a consumer as against that generated by a diesel power plant.

Organizations:

Manufacturer:
Wind Energetics Company (part of the ElectroSphere Association)
Bldg. 2a, 61 B. Sampsonievsky Passage, St. Petersburg 194044, Russia
Tel: (812) 324-48-88
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E-mail: dir@esk.spb.ru
Website: http://www.esk.spb.ru

⑤VVEU JET-TYPE WIND POWER PLANT

The NOTEKA Company has designed VVEU – a principally novel WPP where uniform wind flow is converted into jets.

The VVEU plant is intended for converting wind energy of heat-induced ascending air flows into electric energy, 12-24 V DC.

The VVEU advantage consists in possible use of relatively low air velocities. VVEU produces design capacity at the wind velocity of 4 m/s whereas impeller plants reach the same result at 8 m/s.

Owing to that, the annual throughput of VVEU-generated energy is two- or threefold as high against impeller plants. Besides, VVEU can be successfully used in regions where the prevailing wind velocity is not over 8 m/s.

The VVEU jet-type wind power plant is a new development in wind energetics protected with Russian patents. At present, the Company has made a sample, conducted tests in the wind tunnel. The design documents on VVEU, 100 W capacity, is being elaborated nowadays. After finishing the R&D work for the said plant, researchers shall turn to preparing design documents for plants of 2.5, 5.0, 25.0, 50.0 kW capacity.

KNOW-HOW: jet generator, a device where uniform wind flow is converted into jet flows. Besides, the said generator accumulates the energy of wind and low-potential heat flows (similar to natural processes when kinetic energy of wind distributed in a large volume of air is concentrated to giant values in the tight nucleus of a tornado).

Advantages (as compared with traditional impeller plants):

- Reduced (1.5-2 times) design value of wind velocity, dimensions, and mass;
- The “rotor-generator” excludes the shaft and the impeller, the “wind setting” device is also absent;
- The VVEU design envisages its modular version;
- Simple automatics: rotor frequency stabilization shall be performed only by changing the width of the air intake nozzle.

Design characteristics

Rated capacity, kW	0.5	2.5	5.0	20.0	50.0
Operation mode	Autonomous, long-term				
Design wind velocity, m/s	4.0				
Wind velocity range, m/s	3.0-40.0				
Plant height, m	0.8	4.0	2.8	3.5	5.5
Plant diameter, m	1.8	1.8	4.0	5.5	8,0
Plant mass, kg	50	200	250	275	450

VVEU can be mounted on air pits of buildings or fireplace chimneys, which enables using the energy of ascending air flows.

VVEU shall be installed individually with due account of local energy demands. Each equipment set includes as follows:

- inverter of capacity ensuring lighting and work of household appliances;
- set of storage batteries, 12-24 V and capacity ensuring trouble-free power feed to the given object;
- automatics and control equipment.

Organizations:

Manufacturer:
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⑥Raduga-1 (R-1) WIND POWER PLANT

The Raduga-1 WPP is intended for generating electric energy as part of wind power stations or independently for power grids or separate power units. Besides, the said WPP can be used for autonomous or parallel (jointly with other WPP) as part of wind power stations without connection to power grids.

Raduga-1 specifications

Generator rated capacity, kW	1,000
Output voltage (three-phase), V	6,000 (10,000)
Rated frequency, Hz	50 (60)
Wind velocity range, m/s	5 to 25
Wind wheel diameter, m	48
Tower height, m	38
Number of blades	3
Wind wheel rotation frequency (variable), rpm	21 to 42
Maximum permissible wind velocity, m/s	60
Range of operation temperatures, ^{o}C	From -50 to 60
Rated seismicity, points	8
Design service life for the basic units, years	25
Design service life between overhauls, years	5
Mass, t	127 to 130

The WPP is fully automated and can be used independently or as part of a wind power station (WPS) and can be connected both to grids and to separate power units. It is also rated for separate loads.

The control system: (a) ensures the wind wheel orientation toward the wind; (b) diagnoses the condition of the basic WPP units; (c) governs the value of a blade setting angle; (d) provides for automatic start and braking; (e) issues commands for a rated WPP connection to and disconnection from a power grid; (f) issues algorithms for emergency braking; (g) processes remote control commands; (h) ensures manual operation of a WPP form a local control terminal.

The Raduga-1 plant is an all-metal tower of 36 m height consisting of three 12-m sections. The tower accommodates the support-rotating units turning the housing installed thereon at an angle of 300 deg relative to the wind. All-metal blades manufactured from special alloys turn around their axis at an angle of 90 deg, orienting towards the wind.

Now the said plant serves as a prototype for constructing the Kalmytskaya WPS of the 23 MW capacity. The first WPP was mounted 30 km from the city of Elista and in 1995 was connected to the Kalmykia power grid. The said plant operates in the round the clock mode.

The plant is designed so that at one and the same mechanics and blades its capacity may be increased 1.2-1.5 time with only insignificant modernization, which leads to sufficient reduction of initial energy costs.

The present-day cost of WPP of the given class is estimated at $900,000.

The blades of this WPP were noted with the gold medal at the 45th World Salon of inventions, researches, and industrial innovations Eurica-96 in Brussels.

Organizations:

Designer:
"Raduga" Design Office
2a Zhukovsky St., Dubna 141980, Moscow Region
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Manufacturer:
Tushinky Machine-Building Plant
35 Svobody St., Moscow 123362, Russia
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Fax: (095) 497-4825
E-mail: jsctmz@mail.ru
Website:http://utep.ru/e/jsctmz

⑦その他の主要風力発電プラント設計・施工会社（or 研究所）

No.	Name of an enterprise	Range of products	Address of an enterprise
1	WINDEC Engineering & Research Center	WPP "Windec-0.2" (0.2 kW) WPP "Windec-0.5" (1,2 kW) WPP "Windec-1" (2 kW) WPP "Windec-5" (5 kW)	17 Radio St., Moscow 107005 Tel/fax: (095) 263-44-87 E-mail: WINDEC@tst.ru Website: http://windec.mail333.com/gener.html
2	Vetromotory	WPP "VP-3.72"	Cheliabinsk Tel: (3512) 72-55-33, 75-22-30 Fax: (3512) 75-10-48 E-mail: electric_wind@euro.ru. Website: http://electric-wind.euro.ru/
3	VetraStar Scientific & Production Company	WPP 16 (16 kW) WPP 30 (30 kW)	15 Entuziastov Passage, Moscow 111024 Tel: 8-(901) 700-59-63,8-(901) 791-75-92 E-mail: vest@online.ru Website: http://vetrastar.narod.ru
4	Vetrotok Scientific & Production Company	WPP-16 (16kW) WPP-5-4 (4.2 kW) Heat accumulators for WPP	Yekaterinburg 620151, P.O.B 54 Tel: (3432) 39-98-19 Fax: (3432) 53-14-60 E-mail: art@uralinfo.ru
5	Research Institute for Agriculture Electrification	VFEU (0.2, 0.6, 1.2 kW)	2 Pervy Veshniakovsky Passage, Moscow 109456 Tel: (095)171-14-23, 171-19-20 Fax: (095)170-51-01 E-mail: viesh@dol.ru
6	“Electropribor Research Institute” – Russian Research Centre	WPP UVE-500 (0.5 kW) WPP UVE-1000/220-3.3(1.0 kW) WPP UVE-300/24-2.2 (0.55 kW) WPP UVE-40 (0.1 kW)	30 Malaya Posadskaya St., St. Petersburg 197046 Tel: (812) 232 59 15, 238 78 01 Fax: (812) 232 33 76. E-mail: elprib@online.ru Website: http://www.elektropribor.spb.ru
7	VPERED Moscow Machine-Building Plant	WPP "Forward-0.5" (0.5 kW)	15 Entuziastov Passage, Moscow 111024 Tel: (095) 273-66-33, 273-66-55 Fax: (095)273-46-34 E-mail: vperedm@online.ru

8	LMV Vetroenergetika Joint Venture	Wind power stations and combined power systems of the LMV series (capacity from 0.25 to 10 kW)	26 Pavlovich St., Khabarovsk 680030 Tel: (4212) 21-73-52 Fax: (4212) 22-13-84 E-mail: lmw@winde.khv.ru Website: http://ovis.khv.ru/
9	Iskra Special Design Office	WPP WW-500 (0.5 kW)	20 Kulakov St.,. Moscow 123592 Tel: (095) 757-65-10 Fax: (095) 757-48-33 E-mail: iskrawind@iskrawind.ru Website: http:// www.iskrawind.ru
10	Kaspiy Research & Industrial Corporation	WPP "VTES-32"	12 Sovetskaya St., Astrakhan 414000 Tel: (512) 24-59-25, 22-82-49 E-mail: fond@mail.astrakhan.ru
11	Vetroenergomash Company	WPP AVEU6-4M (4kW)	3 Brestskaya St., Astrakhan 414000 Tel: (512) 3-57-11
12	Academician V. Makeev Design Office	WPP "VA05" (30 kW), WPP "HR-40" (40 kW) jointly with Magnet Motors (Starnberg, Germany) WPP "VDES-100" (100 kW)	1 Turgoyakskoe Highway, Miass 456300, Cheliabinsk Region Tel: (35135) 2-63-33, 2-60-47 Fax: (35135) 6-61-91, 4-12-33 E-mail:src@makeyev.ru, vladimir@mmz.miass.chel.su
13	Raduga Design Office	WPP"Raduga-001" (1 kW) WPP "Raduga-008" (8 kW) WPP "Raduga-1" (1000 kW)	2a Zhukovski St., Dubna 141980,Moscow Region Tel/fax: 7 (095) 268-43-49
14	Rybinsk Instrument-Making Plant (FSUE)	WPP "Sheksna-1" (0,5 kW) WPP " Sheksna-2" (1 kW) WPP "VETEN-0.16" (0.16 kW) WPP "VTN8-8" (8 kW) Wind pumps of the Vodeley series	89 Serov Prosp., Rybinsk 152907, Yaroslavl Region Tel: (0855) 55-02-98 Fax: (0855) 55-45-24 E-mail: pribor@yaroslavl.ru Website: http://rzp.narod.ru/
15	ELSIB Company	WPP “VES-10-TM" (10 kW)	56 Sibiriakov-Gvardeitsev St., Novosibirsk 630088 Tel: (095) 925-98-16, (383-2) 42-00-66 E-mail: elsib@elsib.ru Website: http://www.elsib.ru

16	Moscow Institute of Heat Engineering (FSUE)	Mobile WPP “Zhavoronok” (30 kW)	10/1 Berezovaya Alley, Moscow 127276 Tel: (095)907-15-00 Fax:(095) 402-58-53
17	Elmotron Company	WPP “VES-1” (1.0 kW) WPP “VES-1” (2.0 kW)	Room 113, 20/2 Marx Prosp., Novosibirsk 630092 Tel: (383-2) 46-13-71
18	Vetro-Svet Company	WPP 0.25-0.6 kW WPP 1-4 kW	21 Gzhatskaya St., St. Petersburg 195220 Tel: (812) 535-21-89 E-mail mail@vetro-svet.spb.ru Website: http://vetro-svet.spb.ru
19	Dolina Company	WPP-2 (2.0 kW) WPP- 5 (5.0 kW)	5 Shkolnaya St., Kuvandyk 462220, Orenburg Region Tel: (35361) 67-6-06, 67-5-05
20	Research & Planning Institute of Agriculture Electrification	Wind-and-solar power plant UVGE-500 (0.5 kW)	14 Lenin St., Zernograd 347720, Rostov Region Tel: (86359) 32-4-98, 32-2-80

３．ロシアの地熱発電

Practically any Russia region has large geothermal heat capacities. Heat capacities suitable for industrial use are primarily located in the Kamchatka Region. Their potential energy estimated at about 1,000 MW is sufficient for meeting the said region's power demands.

The peak of the geothermal technologies development in the USSR fell on the 1960s. In 1965, the country's first Pauzhetskaya geothermal power plant (GPP) of 11 MW capacity was commissioned on the Kamchatka Peninsula. In that very year, S. Kutateladze and L. Rosenfeld from the Novosibirsk Institute of Heat Physics developed a unique binary cycle technology for power generation. Two years later the said technology was successfully applied at the Paratunskaya GPP. Ten countries acquired from the USSR the patent for applying the given technology, and at present more that 500 power plants operate under that principle.

Since the 1970s, because of low prices for organic fuel, the progress of geothermal energetics decelerated and stopped, till the 1990s.

Activity in the field of geothermal energetics was facilitated by some Russian regions (Kamchatka, first of all) being short of traditional energy capacities, as well as by the opportunity of exporting equipment and technologies abroad.

At present, the experimental Verkhne-Mutnovskaya GPP of 12 MW capacity (three modules, 4 MW each, manufactured at the Kaluga Turbine Works) operates in the Kamchatka region. The Mutnovskaya geothermal heat power plant (GHPP) of 80 MW capacity is under construction (two 25-MW units already function). It is planned to bring the total capacity of the said plant to 200 MW.

The contract concluded by Russian organizations (Kaluga Turbine Works, BurgazGeoTherm, ZiO, and other companies) envisages the construction of the San Jacinto GPP of 115 MW capacity in Nicaragua.

Russian companies GeoTherm, MosInterGeoTherm, Nauka, supported by the Research Educational Center of geothermal energetics of the Moscow Power Engineering Institute, have arranged within the Russian State Scientific & Technical Program "Ecology friendly energetics" a lot production of GPP with capacities from 0.5 to 25.0 MW and GHPP having 8.8 and 20.0 MW capacities.

Geothermal heat supply also effected in the North Caucasus, Krasnodar and Stavropol Territories, Kamchatka Region.

Sectoral institutes continue research work aimed at solving such problems as salt deposits in the duct, corrosion/erosion of equipment, increase of specific energy generation while using full-flow turbines, enhancement of cooling systems efficiency. Special steam-preparation equipment designed in Russia is in no way inferior to the best world samples as regards steam dryness at the output (being 0.999) and corrosion/erosion resistance. Air capacitors are applied at the Verkhne-Mutnovskaya GPP – first time in the history of Russia.

Thus, Russia has again become one of the leading nations capable of independent development and manufacture of all power equipment for geothermal plants.

The RF Government and “EES of Russia” Company fully realize the importance of geothermal energetics. Federal programs for 2003-2010 envisage the construction of geothermal plants with the aggregate capacity of 68.3 MWe and 16.5 thou. Gcal, which, taken altogether, shall provide for organic fuel substitution equal to 133.84 thou. t of equivalent fuel.

The current Program for supplying power to the Kamchatka Region includes as follows:

- Bringing the Mutnovskaya GHPP capacity to 200 Mw;
- Constructing the Pauzhetskaya GHPP of 18 MWt and 35 MWe capacity;
- Creating the Verkhne-Paratunskaya geothermal complex of heat supply of 30 MWt capacity;
- Developing new geothermal fields in the Kamchatka Region (Koshelevskoe, Bolshe-Bannoe, Nizhe-Koshelevskoe).

The following basic geothermal projects shall be fulfilled in various Russian regions:

- Buryat Republic: two GHPP, 1 MW total capacity;
- Kamchatka Region: two plants, 56 MW total capacity;
- Krasnodar Territory: geothermal heat supply to Ust-Labinsk, 1 Gcal/h capacity;
- Omsk Region: five plants for heat and hot water supply, 1 Gcal/h total capacity;
- Sakhalin Region: three GHPP, 10.8 MW total capacity;
- Stavropol Territory: geothermal systems of 1.5 Gcal/h total capacity for heat supply to farms.

The next important aspect in the given field is the development of low-potential waters resources, especially those in Russia’s central part, which have no local fuel and energy resources, as well as the use of water-bearing horizons as underground accumulators.

４．優良地熱発電プラント

①MUTNOVSKAYA GPP (50 MW CAPACITY)

In 1999, the GeoTherm Company commissioned the Verkhne-Mutnovskaya GPP of 12 (3x4) MW capacity, and that year marked the fast development of Russian geothermal energetics.
The said GPP was built and operates under the most severe climatic conditions at a height of about 1,000 m above the sea level.

The Nauka Company as the designer of the project and of the basic equipment (separators, fittings, noise suppressors etc.), as well as manufacturers and suppliers of turbogenerators, air capacitors, and other equipment – Kaluga Turbine Works, Perm Motor Works, Chekhov Power Engineering Plant have managed to create a GPP having better technical characteristics as against foreign analogues, namely:

- Ecological purity achieved by the absence of direct contacts between geothermal heat carrier and environment owing to the use of air capacitors and 100-% injection of spent heat carrier back to the ground;
- Deliveries of ready-made modules and units together with complete manufacturer's testing of turbogenerators and other basic equipment greatly cut the volume of construction and erection work and made it possible to construct the GPP actually during two short (three-four months) summer seasons;
- The most acute problem concerning GPP protection against corrosion and salt deposits is almost solved by applying film-forming amines.

For over three years, the Verkhne-Mutnovskaya GPP (V-M GPP) shows reliable and trouble-free operation, generating at that cheap energy (initial cost of 1 kW·h being about $0.015). Experience gained during the said GPP construction and operation was used while constructing the Mutnovskaya GPP.

At present, the Verkhne-Mutnovskaya GPP is outfitted with a number of unique testing units and is actually a Russian proving ground for improvement and perfection of national geothermal power equipment.

The "EES of Russia" Company jointly with the GeoTherm Company are planning to built in the nearest future unit IV of the Verkhne-Mutnovskaya GPP with the binary cycle, which shall help increase the geothermal heat carrier efficiency by 20-25% and the GPP capacity, by 6.5 MW.

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Kaluga Turbine Works
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GeoTherm Company
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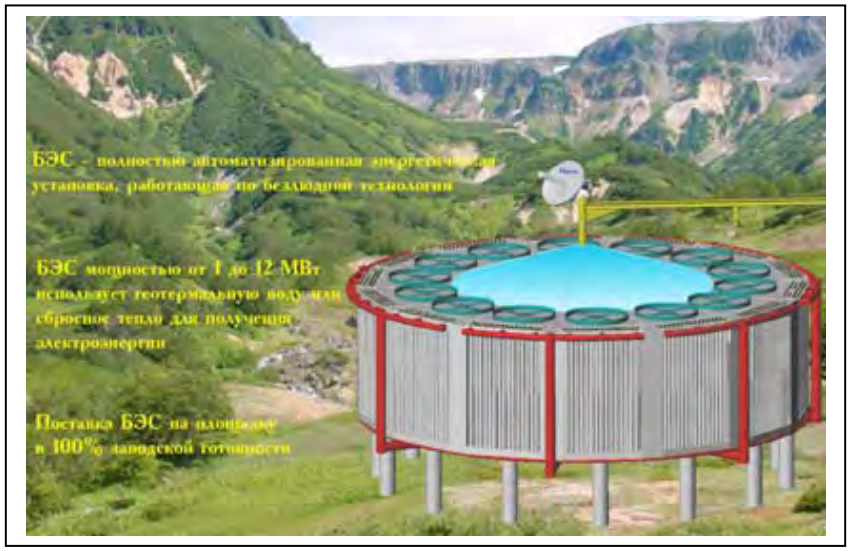
②BINARY POWER PLANTS (BPP)

The idea to generate power in turbogenerators with the aid of substances having a low boiling temperature was proposed by Russian scientists in the 1960s. The world's first geothermal binary power plant (Paratunskaya GPP) was constructed in 1965-67 in the Kamchatka Region. It was the first industrial technique for generating energy from hot geothermal water with the temperature less than 100 ^{o}C. Freon converted into steam by heat water was delivered to the turbogenerator transforming heat into electric energy. At present, the said technology is used in almost 50 countries where function over 500 power units and plants with the binary cycle with capacity from several kW to 130 MWe.

At present, the Nauka Company in association with the Moscow Power Engineering Institute, research institutes VNIIneftemash and VNIIkholodmash-Holding, GeoTherm Company etc. are developing power unit IV with the binary cycle for the Verkhne-Mutnovskaya GPP. The three other power units of 4-MWe capacity each successfully operate on geothermal steam under the traditional cycle.



Severe climatic conditions of the Kamchatka area (snow cover of up to 8 m and wind velocity reaching 45 m/s). dictate, on the one hand, special requirements for BPP, and facilitate a high efficiency of the thermodynamic cycle, on the other hand.

The BPP module has the shape of a cylinder with the walls acting as an air-cooled capacitor. That design enables to use wind, typical of the Kamchatka area, for cooling. In still weather use is made of exhausters located in the upper part of the BPP module. All equipment is accommodated inside.

BPP is a fully automated plant operating in the unattended mode. It can resist any frosts because the working fluid freezing point is -140°C.

The greatest power-saving effect from using binary plants can be obtained by incorporating them into their local grids. Such binary heat and power plants can use heat from nuclear-powered water boilers, hot geothermal water with the temperature over 90°C, heat recovery boilers, and other waste heat sources from power, metallurgical, cement, and other productions.

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③MODULAR GEOTHERMAL HEAT POWER PLANTS

Modular-type geothermal heat power plants (GHPP) ensure centralized supply of heat to customers located near geothermal fields.

GHPP of 6 and 20 MW heat capacity are factory-assembled units and modules. Heat exchangers are made from materials featuring high corrosion resistance.

Specifications

Type of a plant	GTS-350P	GTS-350	GTS-700P	GTS-700
Heating capacity, MW	6.0	6.0	20.0	20.0
Heat carrier	Steam	Water	Steam	Water
Heat exchanger material	brass (nickel silver)	titanium	brass (nickel silver)	titanium
Heat carrier temperature at the input, ^{o}C	104	95	104	95
Water temperature at the output, ^{o}C	92	95	92	95
Mass, t	25.4	23.0	35.0	32.0

At present, two sets of GHPP are installed within the SakhalinEnergo grid.

Organizations:

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Website: http://www.ktz.kaluga.ru/

④MODULAR GEOTHERMAL POWER PLANTS (GPP)

Modular geothermal power plants (GPP) are used as energy sources in locals grids, using a high-temperature geothermal potential.

GPP are factory-assembled units and modules, which greatly reduces labor costs during the equipment installation, as well as decreases the plant commissioning terms.

The generation of electric and heat energy on those plants is integrated in a common thermodynamic process.

Specifications

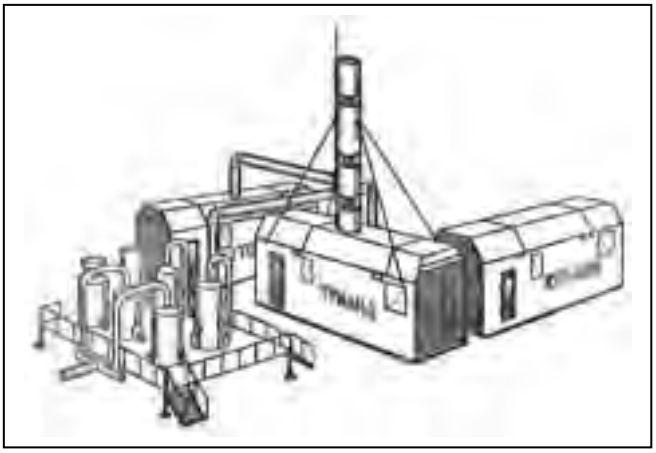
Type of a plant	Small-capacity GPP				Medium-capacity GPP			
	Omega-500	Tuman-2	Tuman-2, 5	Tuman-4K				
Capacity, MW	0.5	1.7	2.5	4.0	6.0	12.0	20.0-25.0	23.0
Pressure at the input, bar	7.0	5.0	7.0	8.0	2.0	6.0	7.0	7.0
Pressure behind the turbine, bar	1.0	1.0	1.0	0.11	0.1	0.085	0.12	0,12
Steam consumption, t/h	10.0	38.0	44.0	32.0	75.0	90.0	147.0	170.0
Rotation frequency, Hz	50	50	60	50	50	50	50	60

Tuman 4-K turbogenerator for the Verkhne-Mutnovskaya GPP

Omega-500 and Tuman-2 plants are operated within the SakhalinEnergo grid.

Tuman-4K plants function in the Kamchatka area, near Verkhne-Mutnovskoe geothermal field. The San Jacinto GPP is being constructed in Nicaragua.

Tuman-2 plant. General view



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Website: http://www.ktz.kaluga.ru/

⑤SEPARATORS, EXPANDERS AND STEAM COLLECTORS FOR GEOTHERMAL POWER PLANTS

Separators, expanders, and steam collectors of up to 180 t/h throughput serve for separating steam-water mix (SWM) phases at GPP for obtaining steam of a high degree of purity and dryness.

A high efficiency of apparatuses is ensured by the gravitation principle of separation under optimal operating parameters. They are mounted near the wells or close to the power unit.

S-55 separators are installed at the Verkhne-Mutovskaya GPP in the Kamchatka Region

Specifications `

Type	Steam pressure, bar	Steam content of in SWM at the input, %	Steam humidity at the output, % , max.	Capacity, t/h, max	Hydraulic resistance	Mass, kg
Separator S-55	5.0-9.0	15-100	0.05	55.0	0.1	7,500
Separator S-85	5.0-9.0	15-100	0.05	85.0	0.1	9,500
Separator S-115	5.0-9.0	15-100	0.05	115.0	0.1	10,500
Separator – steam collector SP-180	5.0-9.0	15-100	0.05	180.0	0.1	17,000
Two-stage separator SV-45	5.0-9.0	15-100	0.05	45.0	0.1	9,700
Expander R-23	4-8	0	0.05	23.0	0,1	7,500

Organizations:

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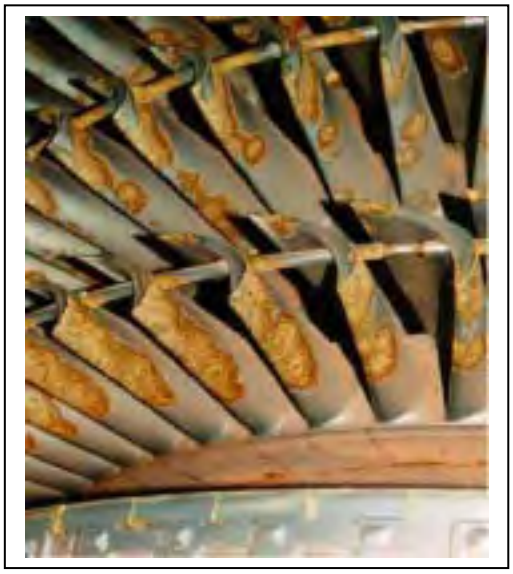
⑥PROTECTION OF TURBINE PLANTS AGAINST CORROSION

Energetics is in need of a wide application of methods protecting metal against corrosion because of long-term idle periods of power plants. Steam turbines not protected against corrosion during idle periods cause the greatest concern.

Metal protection is especially vital for geothermal power plants: heat carrier may contain about 2,000 admixtures and gases.



The proposed protection method consists in using film-forming amine as corrosion inhibitor. The said technique is applied during equipment operation, before and after withdrawal for repair or reserve. Being put in operation, equipment will be reliably protected by amine film against all kinds of corrosion and wear-out.

Using film-forming amines as an anticorrosive agent for inner metal parts of equipment at power and heat plants enhances their reliability and efficiency. In particular, it enables as follows:

- Protect from corrosion for at least a year practically all surfaces of a turbine plant (turbine flowing area, capacitor, capacitor feed circuit, heaters, pumps, and fittings);
- Reduce the threat of emergence and development of corrosion-induced cracking of metal parts of turbine blades and disks;
- Remove the deposits of salts and corrosion products from the turbine flowing area and the capacitor feed circuit;
- Enhance the turbine plant efficiency by 1.5-2% within first two-three months after the power unit commissioning, enhance the efficiency of the whole power unit.
- Reduce the erosion of input and output edges of rotor blades by 15-20%;
- Extend the plant service life by five years or more;
- Guarantee metal protection against corrosion with the help of film-forming amine when the turbine plant is mounted or repaired, both open and closed;
- Reject the sand jet cleaning of the turbine parts from sediments
- Reduce and prevent metal corrosion and erosion during the first two-three months of operation in the capacitor feed circuit of the power unit;
- Remove sediments and corrosion products inside the boilers;

- Protect boilers and steam superheaters against corrosion during idle periods for at least a year.

At present, technologies elaborated by scientists and researchers from the Moscow Power Engineering Institute, Research Institute of Nuclear Power Engineering, Nauka Stock Company, ODATECH Company, as well as from some heat and nuclear power plants, with the assistance of the "EES of Russia" Company (Department for development strategy and scientific & technological policy), are used at more than 100 power units. The said technology is being introduced at the Verkhne-Mutnovskaya and Mutnovskaya GPP for protecting metal parts of equipment used in geothermal fields and in power units.

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⑦GEOTHERMAL PLANTS WITH JET PUMPS

Geothermal plants using either steam-water mixture going direct from a geothermal well or steam after GHP separators, and jet pumps serve for supplying heat and hot water as well as for re-injecting drain water into the ground via injection wells. The can sufficiently (two- or threefold) reduce salts mineralization in water thanks to mixing with cold and low-mineralized water from surface springs.

The jet pump is used for delivering spring water to the customer; it can heat water and change its mineralization. Intensive heating of water takes place in the jet pump mixing chamber being an effective heat exchanger. The jet pump has the steam and liquid nozzles, the mixing chamber, and the diffuser. It does not require attendance, is rather inexpensive and easy in manufacture and operation. The jet pump has no friction parts, which guarantees a long service life.

The jet pump operates in the following manner. After expansion in the steam nozzle a steam-water mixture with a low initial steam quality is rather quickly mixed with cold liquid fed to the mixing chamber. As a result of mixing and steam condensation, rather low pressure (vacuum) is formed in the mixing chamber, enabling sucking in spring water, including warm water with admixtures. That allows the use of the said pump for pumping hot mineralized water. After the end of the steam phase condensation in the diffuser and a sharp change in the flow structure, a considerable rise of pressure (four- or fivefold, as in the given case) is observed as against its value at the pump input.

Design features of the jet pump enable its application in a wide range of modes and geometric parameters. The pump is rated for different consumptions of liquids and mixes and various values of steam quality at the input, while for regulating output parameters changeable set of the diffuser throats are applied.

A particular feature of jet pumps in geothermal plants is that for pumping hot water use is made of the jet 2nd stage or holes in the second half of its mixing chamber (usually used at starting). In that case jet pumps can replace expensive and large-size electrically-driven inclined rotor pumps applied for hot mineralized waters.

Specialists from the Krzhizhanovsky Power Engineering Institute (ENIN) developed jet pumps of various design and capacity, which were successfully used at the Pauzhetskoe geothermal field (Kamchatka area) for pumping up to 60 t/h of cold and half as much of hot water.. The total capacity of all pumps operating simultaneously makes up 120 t/h. The flowsheets for water- and brine-pumping plants as well as those for jet pumps themselves were protected with the Russian and US patents. The Kamchatka pumps delivered a steam-water mixture from wells not used any longer for feeding mixture to separators of the Pauzhetskaya GPP.

Thus, in the geothermal plants under consideration, heat energy of a steam-water mixture from wells after being converted into mechanical energy in a jet pump is used for obtaining cold (hot) liquid from springs, its delivery to consumes, or pumping back into the ground.

Geothermal plants with jet pumps can deliver hot brines to enterprises for extracting valuable raw materials therefrom. Such plants eliminate environmental contamination (both thermal and salty), are noted for a simple design, reliability, efficiency, low cost, and small mass of the jet pump – the plant's principal element.

Basic characteristics of geothermal plants with jet pumps in the Kamchatka region

Jet pump dimensions, m - length - diameter	 1.5-3.5 0.3
Jet pump mass, kg	5-150-350
Capacity, t/h	20-60
Steam quality in a mixture from a geothermal well	 0.03-0.3
Pressure: - mixture prior to the jet pump, MPa - liquid at the input to the 1st and 2nd stage of the jet pump, MPa - in the pump mixing chamber, kPa - after the jet pump, MPa	 0.1-0.25 0.05-0.25 10-20 0.25-0.8
Liquid temperature, ^{o}C: - initial at the 1st stage input - at the 2nd stage input - at the jet pump output	 10-25 10-95 40-95

Organizations:

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⑧TECHNOLOGY FOR EFFICIENT USE AND RECOVERY OF GEOTHERMAL WATER ENERGY

One of the problems restricting the progress of geothermal energetics is associated with the fact that low and medium temperatures of most of geothermal springs reduce their competitiveness as compared with traditional power sources.

Specialists from the Institute of Geothermy, Dagestan Research Center, Russian Academy of Sciences, have found the way for efficient use and recovery of geothermal water energy. The novel technology can be used for supplying heat to various objects and is quite competitive with traditional power sources.

Specialists from the Institute of Geothermy found out that mouth excess pressures in many geothermal fields exceed 5-10 MPa. Such water usually contains a large amount of dissolved gases of the organic origin reaching 4-5 m^3/m^3. The researchers have discovered that the content of methane in that water is over 90%. Up to the present, the said sources of energy have not been recovered properly.

The above Institute specialists have developed a technology for optimal recovery of geothermal water energy and succeeded in raising the thermodynamic effectiveness of the said process.

It was achieved by transferring the geothermal water energy to the secondary heat carrier via intermediate heat exchangers using chemical energy of dissolved gases as an additional power source.

Energy is transferred by applying the primary and secondary separators. The said technology is noted for the use of potential energy of geothermal water as an extra source. For potential energy conversion use is made of the expander and the compressor (on the one shaft), the energy of dissolved gases is released via a gas holders and a gas-distribution point.

Organizations:

Designer:
Institute of Geothermy, Dagestan Research Center, Russian Academy of Sciences
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⑨その他の主要地熱発電プラント設計・施工会社（or 研究所）

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2	VNIPIenergoprom Association	2/1 Semenovskaya Emb., Moscow 105094 Tel: (095) 360-76-40 Fax: (095) 366-3625 E-mail: vnipienergoprom@hotbox.ru.
3	Research & Educational Center of geothermal energetics of the Moscow Power Engineering Institute	14 Krasnokazarmennaya St., Moscow 111250 Tel: (095) 362-75-60 E-mail: universe@mpei.ac.ru Website: http://www.mpei.ru/
4	Institute of Heat Physics, Siberian Branch of the Russian Academy of Sciences	1 Academician Lavrentyev Prosp., Novosibirsk 630090 Tel: (383-2) 34-34-80 E-mail: aleks@itp.nsc.ru Website: http://www.itp.nsc.ru
5	Turbokon Research & Production Enterprise	43 Komsomolskaya Roshcha St., Kaluga 248021 Tel: (0842) 167-193 Fax: (0842) 55-17-51 E-mail: turbocon@kaluga.ru Website: http://www.turboconkaluga.ru/