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Study and Construction of Geothermal System of Heat Supply of Domestic Buildings and Greenhouses with the Use of Solar Energy and Heat Pumps

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ABSTRACT

250 geothermal boreholes were drilled with summarized heat capacity to 427 MW(t). On most scales geothermal heat supply was developed in Kamchatka, Krasnodar region and Dagestan. Heat capacity of geothermal heat supply of these regions is 122 MW(t), 77 MW(t), 71 MW(t) respectively. Heat supply [110 MW(t)] from geothermal resource use is in second place after green-house heating [160 MW(t)]. In Russia, the Krasnodar region is leading by volume of geothermal heat supply (18 deposits, 86 boreholes, summarized potential heat capacity to 250 MW(t). Business plans geothermal heat supply for five cities, including Labinsk [100 MW(t), 4 MW(e)]. Construction of demonstration geothermal project in settlement Rozoviy (5 MWt) is being conducted. Heat carrier from two boreholes with temperature 100ºC goes to a central heat point, where its temperature potential is extracted down to 30ºC cascaded and goes to ponds (mineralization 2g/l). Reinjection of the used geothermal heat carrier is provided for the second stage. Construction of two solar stations with capacity 30 m^3/day with pump drive from photoelectrical modules is provided to decrease the consumption of geothermal water in summer time. For bad weather there was provided installation of heat pumps of "air-water" heating water after solar stations.

1. INTRODUCTION

The territory of Russia has sizeable geothermal resources. Low-temperature deposits with temperature of heat carrier from 60 to 120ºC prevail. About 36 million m^3 of geothermal water is extracted every year in the Far East and North Caucasus, and in general is used for heat supply. Nowadays in the Russia system of development of geothermal heat supply, the JSC "Rusgidro" is reconstructed and works on research and projecting of geothermal systems are financed. In Krasnodar region and Dagestan works on the modernization of existing heat supply systems are conducted at the initiative of local administration. Realization of a demonstration project of geothermal supply in settlement Rozoviy of Krasnodar region with combined use of geothermal water, solar energy and heat pumps will allow to work out typical decisions for other regions of Russia.

2. RUSSIAN GEOTHERMAL HEAT SUPPLY

Resources of geothermal deposits in Russia have good perspectives of heat supply development. General amount of bored geothermal boreholes in depth to 3 km consists of 250 units with summarized heat capacity to 427 MW(t). Distribution of heat capacities of geothermal deposits of separate regions of Russia is presented in figure 1 and the distribution of their heat capacities and technologies of use is presented on the figure 2. Nowadays in Russia after prolonged stagnation, works on development of geothermal heat supply are activated.

The main organization conducting geothermal research is the JSC "Geoinkom" (Moscow). Practical introduction of these studies is developed in the southern region of Russia – Krasnodar.

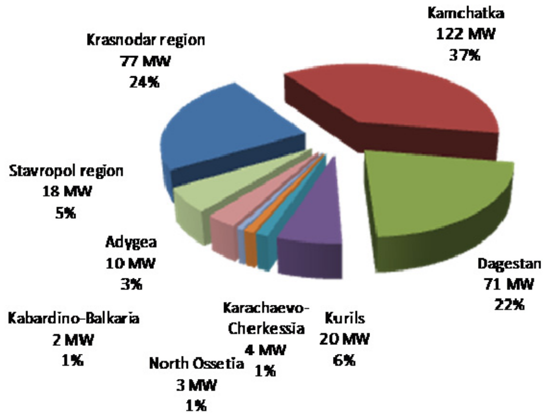

Figure 1: Distribution of heat capacities of geothermal deposits of regions of Russia, totally 327 MWt (100%).

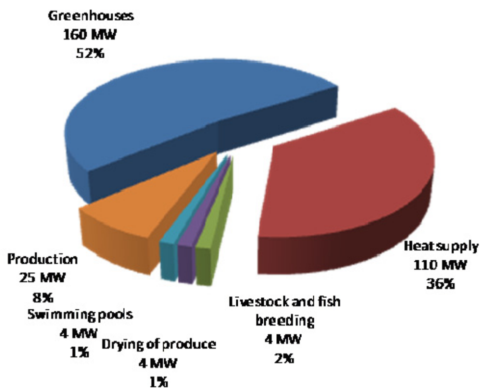

Figure 2: Distribution of heat capacities of separate technologies of use of geothermal water of Russia, totally 307 MWt (100).

2.1 Geothermal heat supply of Krasnodar region

Krasnodar region with the territory in 75.5 thousand km^2 and with population of 5 million people is one the actively developing regions of Russia. A total annual consumption of organic fuel includes 15 mln. tons of conditioned fuel, about 90% of it comes from other regions of our country. The same time on the territory of our region there were developed and exploited 18 geothermal deposits with temperature of heat carrier from 75 to 110ºC with annual extraction about 10 mln. m^3.

86 geothermal boreholes were bored with depth to 3 km. Summarized potential heat capacity can be 902 thousand MWt/h. Data on resource base of geothermal deposits of Krasnodar region are presented in the table, Figure 3.

A map of the given deposits is shown in figure 4, calculating potential heat capacities of separate geothermal deposits and possible heat energy is shown in figure 5.

№	Name of deposit	Amount of boreholes		Deph of boreholes, m	Debits of boreholes, m^3/day.	Temperature on mouth of borehole, °C	Minerali-zation total, g/l	Deter-mined stock, m^3/ day.	Note
		total	exploiting						
1	Mostovskoe	17	13	1650-1850	2000-2500	67-75	0,9-1,9	11100	exploiting
2	Novo-Yaroslavskoe	5	-	2530-2676	485-1000	86-89	2,4-4,3	-	- " -
3	Ulyanovskoe	4	2	1700-1900	2000	75	2	1900	- " -
4	Voznesenskoe	9	4	1900-2650	1260-1685	100-112	0,8-2,8	7250	- " -
5	Yuzhno-Voznesenskoe	6	3	1900-2650	900-2000	100-112	0,8-2,8		- " -
6	Severo-Eremenskoe	2	1	2827-2958	830-2108	107-117	1,3-2,9	2400	- " -
7	Gryaznorechenskoe	1	1	2865	1500	107	3,1	-	- " -
8	Maikopskoe	12	9	1330-1770	500-1500	82-86	3,2-8,9	4980	- " -
9	Otradnenskoe	4	2	1920-2040	750-1080	72-76	1,5-3,6	1864	- " -
10	Priurupskoe	2	1	1940	2250	99-103	1,5-1,7	1700	- " -
11	Poputnenskoe (Voskresenskoe)	4	1	-	1500-2200	115	1,5-3,5	-	- " -
12	Dagestano-Kurgipskoe	3	1	2100-2300	600-1100	81	0,9	-	- " -
13	Uzhno-Sovetskoe	3	1	2810	2890	116	1,4	2200	- " -
14	Labinskoe	4	-	2450-2520	2550-3770	99-103	13-15	-	Out-of-service
15	Hodzevskoe	2	-	2450	1400	86	2,3	-	- " -
16	Mezhchokhranskoe	2	-	2000	800	86	2,9	-	- " -
17	Kharkovskoe	1	-	2700	-	98	1,6	500	- " -
18	Rodnikovskoe	2	-	2800-2950	-	74	-	1000	- " -

Figure 3: Resource base of geothermal deposits of Krasnodar region

Figure 4: Geothermal deposits of Krasnodar region

1-Mostovskoe, 2- Novo-Yaroslavskoe, 3-Ulyanovskoe, 4-Vosnesenskoe, 5- Yuzhno-Voznesenskoe, 6-Severo-Ereminskoe, 7-Gryaznorechenskoe, 8-Maikopskoe, 9-Otradnenskoe, 10-Priurupskoe, 11-Popetnenskoe (Voskresenskoe), 12- Dagestano-Kurdgipskoe, 13-Uzhno-Sovetskoe, 14-Labinskoe, 15-Khodzevskoe, 16-Mezhchokhrakskoe, 17-Kharkovskoe, 18-Rodnikovskoe.

Development geothermal heat supply of Krasnodar region is executed on the basis of regional program. Business-plans of geothermal heat supply of cities Labinsk [110 MW(t); 4 MWt(e)], Ust-Labinsk [42MW(t); 2 MWt(e)], Apsheronsk [41MW(t)]; Anapa [30MW(t)]; Goryachy Klych [20 MW(t)] /1/. At present time construction of demonstration geothermal project in settlement Labinsk district [5 MW(t)].

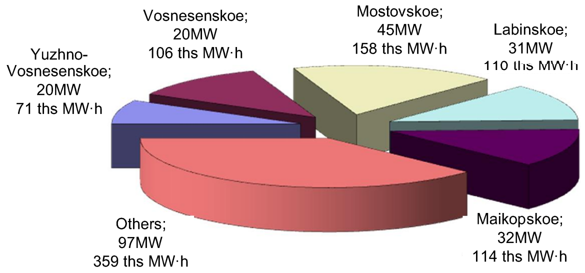

Figure 5: Diagram of geothermal deposits of Krasnodar region

2.2 Geothermal system of heat supply of settlement rozoviy

Settlement Rozoviy is situated 200 km from Krasnodar in the foothills of the Caucasus. The population of 1000 people lives in 192 buildings, including 12 two-storey buildings. Borehole 3T of Voznesenskoe deposit (depth of perforation 2512-2472 m) was drilled for heating of the settlement and green-houses, borehole 4T of Uzhno -Voznesenskoe deposit (2512 – 2472 m) was drilled in 1982. During the period of pressure exploitation without reverse pumping, parameters of the heat carrier at the wellheads of the boreholes changed considerably. In borehole 3T: temperature 100ºC, over 30 years decreased almost by 2.6 times(1750 m^3/day and 836 m^3/day), static pressure by 2.6 times (9.24 kgs/cm^2 and 3.46 kgs/cm^2), dynamic pressure by 3.5 times (0.42 m^3/cm^2 and 0.12m^3/cm^2), however mineralization did not change considerably. In borehole 4T: temperature 100ºC, over 24 years decreased by 1.5 times (1250 m^3/day and 797 m^3/day), static pressure in 1.4 times (4.1kgs/cm^2 and 2.8 kgs/cm^2), dynamic pressure by 3.5 times, mineralization did not change considerably, 0.2 kgs/cm and 1 g/l respectively.

Principal scheme of existing heat supply of settlement was presented in figure 6. Heat pipe networks from boreholes to central heat point (CHP) and to greenhouses are lain under ground in steel tubes Du 150-200 mm without heat isolation with total length of 2 km. Tubes have external corrosive damages and losses. Decrease of temperature of geothermal water from boreholes to CHP consists of 15-20ºC. Tank-accumulators and circulation pumps were installed in CHP. Regulation of temperature of the heat carrier is quantitative, cyclic. After recovering the heat potential of the geothermal heat carrier from 30-40ºC, it is discharged into a pond. Distributive heat networks are double-piped with open water separation of the hot water supply. Heat pipeline networks are under ground and above ground. Diameters of tubes are from 200 to 25 mm. Total extension of distributive heat networks is 12 km.

Heat insulation of tubes is in unsatisfactory condition.

Existed systems of domestic houses heating were made without projects. Heating devices in general are cast-iron radiators M-140. Systems of heating are one- or double-piped ones. Devices of account of heat energy are absent. Summarized calculating heating load of buildings of a settlement made up 2.4 MWt.

In the result of analysis of work regimes of existing geothermal system of heat supply and results of boreholes trials under negative temperatures of air, meanings of calculating debits of boreholes 3T kg/s, 4T – 8.84 kg/s under temperature 100ºC were determined.

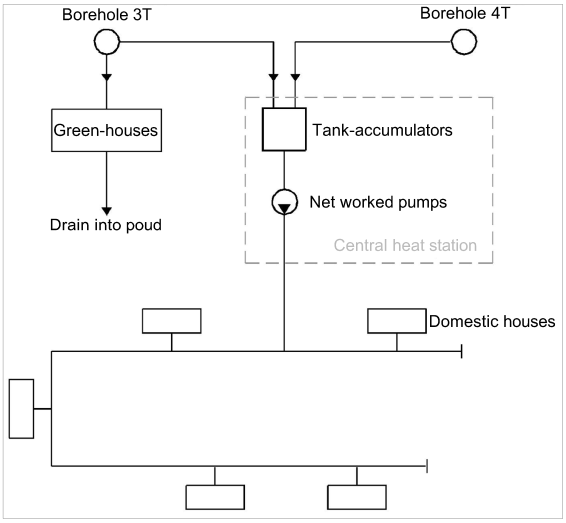

Figure 6: Principal scheme of existing geothermal system of heat supply of settlement Rozoviy.

The task of cascade response of heat potential of geothermal water with temperature 100ºC at the mouth of boreholes consequently in systems of domestic houses heating then in greenhouses, with supply of temperature of runoff water under conditions of ecology to 30 ºC was solved in this project. Temperature graph 90-60ºC and greenhouses 60-27ºC respectively was determined in the result of calculations for heating of buildings.

On the basis of the given general projecting organization JSC "Geoterm-EM"(Moscow), there was worked out a project of modernization of the heat supply systems of settlement Rozoviy. Projecting the re-equipment of geothermal boreholes, heat networks, drain pipeline, pumping station, stations of emergency aftercooling, solar heat pumping installation was made by the company "Teploprojectstroi" (Krasnodar) /2/.

Figure 7 shows the structural scheme of the heat supply system after modernization, including two geothermal boreholes, central heat point (CHP) with capacity 5.3 MWt, geothermal heat networks Du 150 mm with extension 1.6 km, double-piped distributive heat networks of settlement with extension 12 km, drain pipeline Du 200 mm, station of emergency after cooling, heat networks of green-houses Du 150 mm with extension 2.5 km.

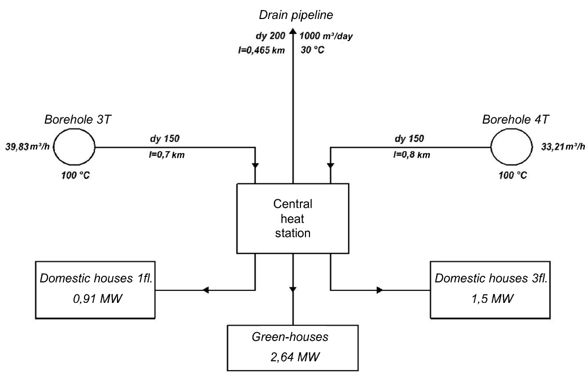

Figure 7: Structural scheme of geothermal heat supply.

Projecting the re-equipment of the geothermal boreholes was made in accordance with Russian Rules of working out of deposits of heat energetic water /3/, norms of projecting VSN 56-87 "Geothermal heat supply of domestic and public buildings and constructions" /4/, technical conditions of an owner of boreholes JSC " Neftegasgeoterm". Instructions on projecting the geothermal heat supply systems of Academy of communal facilities /5/.

Scheme of pipelines of one of the boreholes is given in figure 8.

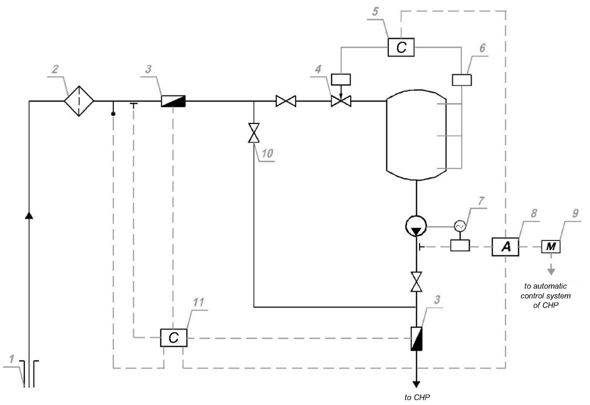

Figure 8: Scheme of pipelines of geothermal boreholes.

Geothermal water from borehole "1" with calculating cost 39, 38 m^3/h through valve of level regulator "4" goes to a tank of spurt rupture with capacity 6 m^3, equipped with sensor of level "6". Controller "5" –"Kontar" MS8 manages with work of valve "4". Possibility of work with open bypass line with valve was provided for under sufficient pressure of geothermal heat supply (spring, autumn) – 2 kgs/cm^2. Discharge of geothermal water to CHP is made of automated pumping station "7" ANU2 ACMS 45-2-2 with frequent regulation on censor of pressure. Stock of geothermal heat supply is executed by a number of devices: flowmeters electromagnetic PREM "3", temperature sensor Pt-100, pressure censor Metran -55-515 MP, heat calculator VKT-5 '11'. Information of controller of tank filling "5", pumping station "7", heat calculator "11" after processing in sluice of automatics "9" due to modem on GSM canal is transmitted to server ASU CHP.

The scheme of pipelines of the geothermal CHP is shown in figure 9. Scheme of switching on of settlement buildings and greenhouses heating is independent and two-level. Geothermal heat carrier of every borehole after mud gutters "1" in one level of laminar heat exchangers "2" F=44.0 m^2 heats heat carrier of a system of heat supply of settlement, in second level laminar exchangers "3" F=164.9 m^2 heats a heat carrier of greenhouses and with temperature 30ºC with pumps "4" goes to drain pipeline into a pond. Drain of geothermal water into pond was projected by automated station with pumps "5" for emergency after cooling. Under increase of geothermal water temperature above 30ºC by signal of temperature sensor Pt-100 a controller "6" operates pumps "5" and closes a regulating valve "7". Temperature regulation of network water on systems of domestic houses and greenhouses heating is executed by the controller "8" of type "KONTAR" on temperature of external air by means of discharge change of geothermal heat carrier with three-inch regulating valve "9" of type VFG34 and regulating valve "10" of type VFG2. Circulation of heat carrier in systems of heating of settlement buildings is executed by the help of pumps "11" of type Hydro MPC-E 3 CRV 45-2 with frequent regulation. Recharge of given contour is executed with chemically purified water in installation "12" of type RFS-1061/50SE-ALT1 during heating season and after solar installations in seasonal period. Circulation of heat carrier in a system of heat supply of greenhouses is made with pumps '13' of type TPE 65-410/2. Recharge of given contour is provided for geothermal water with regulating valve "14" after pump "4".

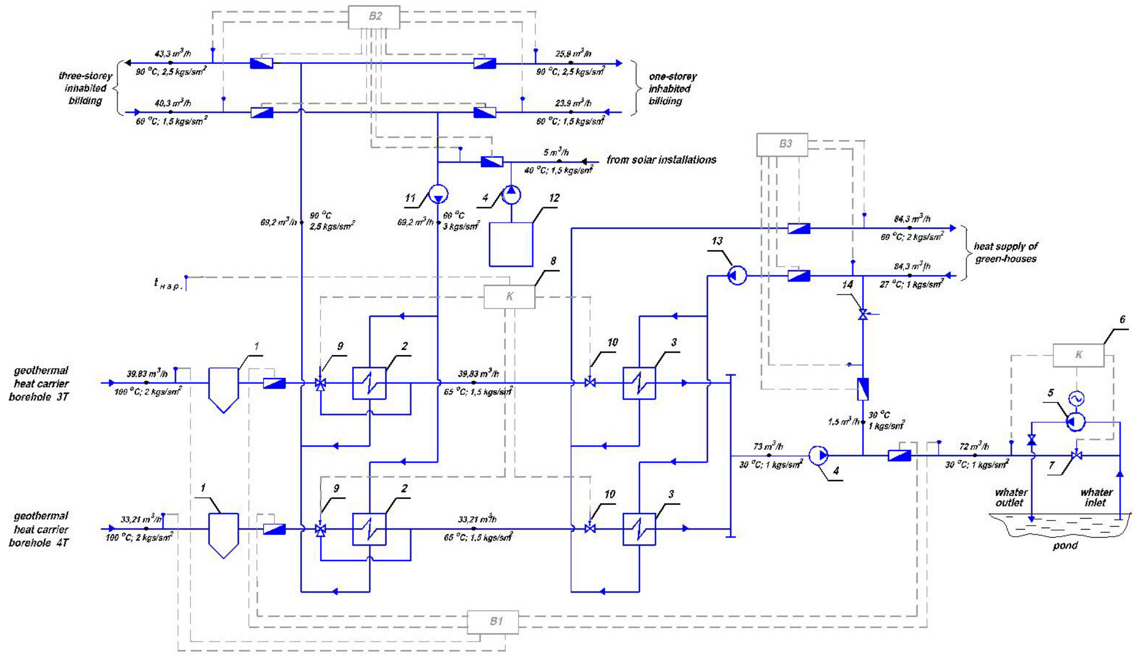

Figure 9: Scheme of pipeline of geothermal water Resource base of geothermal deposits of Krasnodar region.

1-cencor of temperature cooling, 2 – heat calculator cooling, 3 – flowmeter greenhouses, 4 – replenishing pump, 5 – chemical water preparation, 6 – replenishing valve, 7 – network pump of greenhouses, 8 – controller of emergency after cooling, 9 – pump of emergency after, 10 – regulating valve of water,11 – pump of cooling geothermal water, 12 – heat exchangers of greenhouses.

The CHP is equipped with five nodes of heat carrier calculator and heat energy. Heat calculator "V1" accounts costs, temperature, quantity of heat energy of geothermal heat carrier at input into the CHP from each borehole, cost and temperature of heat energy amount of cooled geothermal heat carrier at output from CHP. Heat calculator "V2" accounts costs, temperature, quantity of heat energy supplied into system of heating of three-storey building, replenishing water. Heat calculator "V3" accounts costs, temperature, quantity of heat energy supplied into system of greenhouse heating and replenishing. The equipment of the CHP was projected in construction with sizes in plan 20.75 x18.8 (figure 10).

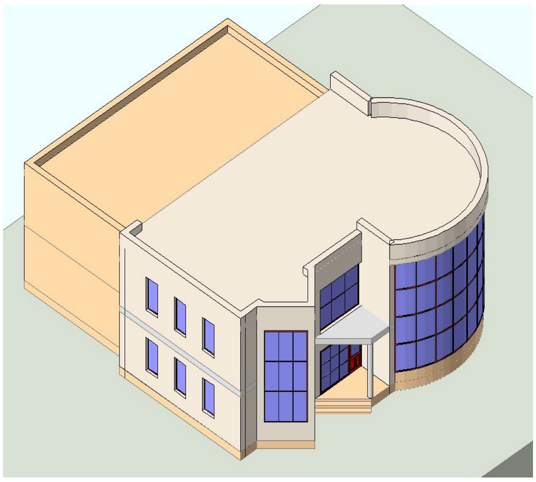

Figure 10: Construction of geothermal central heat point.

Flushing of depleted geothermal water into a pond and its reverse pumping on the second stage are provided for at the first stage of this project. To restore interstitial pressure of the geothermal deposit in summer time, two solar stations were projected for hot water supply with 'air-water' hot pumps for heating of water during nasty weather. The scheme of separately standing one-contour solar pumping installation in 200m^2 with photoelectric drive of pumps is presented in figure 11. Solar collectors are situated on a shelter at a height 3.5-4.2 m above the ground. Photoelectric transformers of installed capacity 1 kW were projected for energy supply to the circulating pumps of photoelectric transformers. Construction of the solar installation is presented in figure 12.

The principal scheme of pipelines of the solar installation on the roof of the geothermal CHP is presented in figure 13. The solar installation is double-contoured. Use of non-freezing liquid glycol is provided for in the solar contour. Heat of glycol occurs in 2 units of plate solar collectors "1" of type "TopSon F3" of the firm "Wolf" (Germany) with total area of 165 m^2. Circulation of glycol in the solar contour is pumped with drive from photoelectric modules "19" of type MSW-150/75. Heat energy of glycol is transmitted on water pipeline in capacity boilers "2" of type "SEM-1" from the firm "Wolf" (8 units).

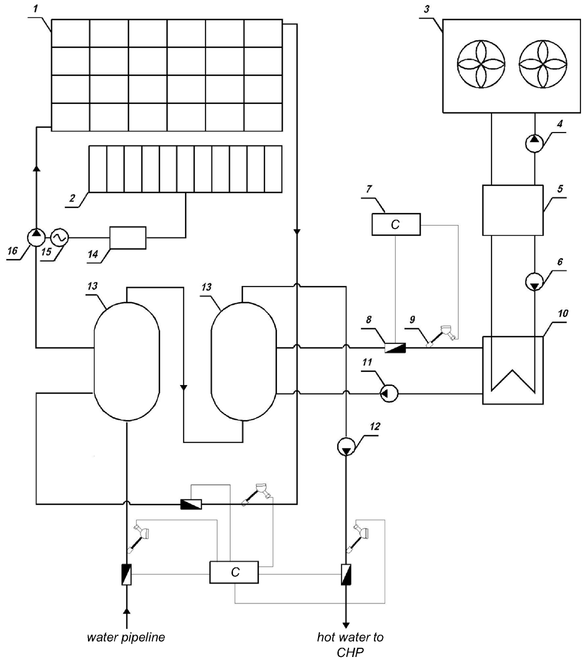

Figure 11: Scheme of pipelines of solar installation of hot water supply.

1-solar collectors, 2-photoelectric transformers (PET), 3-drycoolers, 4-pump of contour TN, 5-heat pump (TN), 6-pump TN (on heat exchanger), 7-heat calculator, 8-flowmeter.

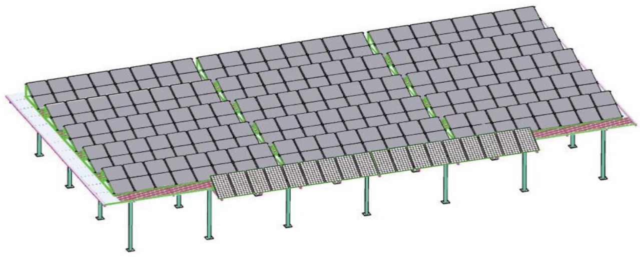

Figure 12: Construction of solar installation of hot water supply

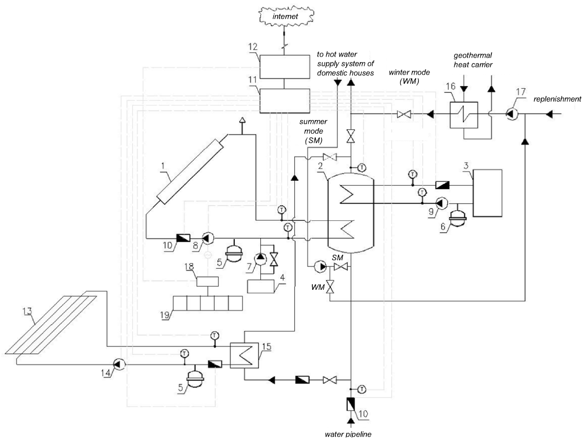

Figure 13: Scheme of solar installation of geothermal heat point on roof

1-collector solar TopSon; 2-boiler SEM-1, V=1000 l; 3-heat pump "air-water" BWL-1; 4-glycol capacity; 5- extension tank solar contour; 6- extension tank solar contour of heat pump ; 7-pump of glycol; 8-pump of solar pump; 9-pump of heating pump contour; 10-flowmeter with impulse output;

11-heat calculator; 12-controllers; 13-collectors piped vacuum TRK ; 14-pump of contour of vacuum collectors; 15-boiler; 16-boiler of geothermal station of heat supply (winter regime); 17- pumps of geothermal station of heat supply (winter regime); 18-bloc of transformers; 19-photoelectric

Separate contour of circulation with heat exchanger “15” is provided for demonstration of characteristics of vacuum piped solar collectors of type TRK (6 units) of the firm “Wolf”. In nasty weather, additional heating of trap water is executed with heating pumps “3” (air-water) of type BWL-1 (4 units) from the firm “Wolf”. Work of the solar installation is automated with transmission of measurements through the Internet. The equipment of the solar installation is presented in figure 14.

3. CONCLUSION

Considerable geothermal resources in Russia and the increase of internal Russian prices of organic fuel to the level of world ones, creates good preconditions for the development of geothermal energy. The prevalence of low temperature deposits (to 120ºC) determines the major development of geothermal heat supply in Kamchatka and North Caucasus. Modern technologies, application of equipment, combined application with solar installations and heat pumps have been determined using the example of construction of the demonstration project of geothermal heat supply in settlement Rozoviy of Krasnodar region. The plan is to apply the experience in other regions of Russia.

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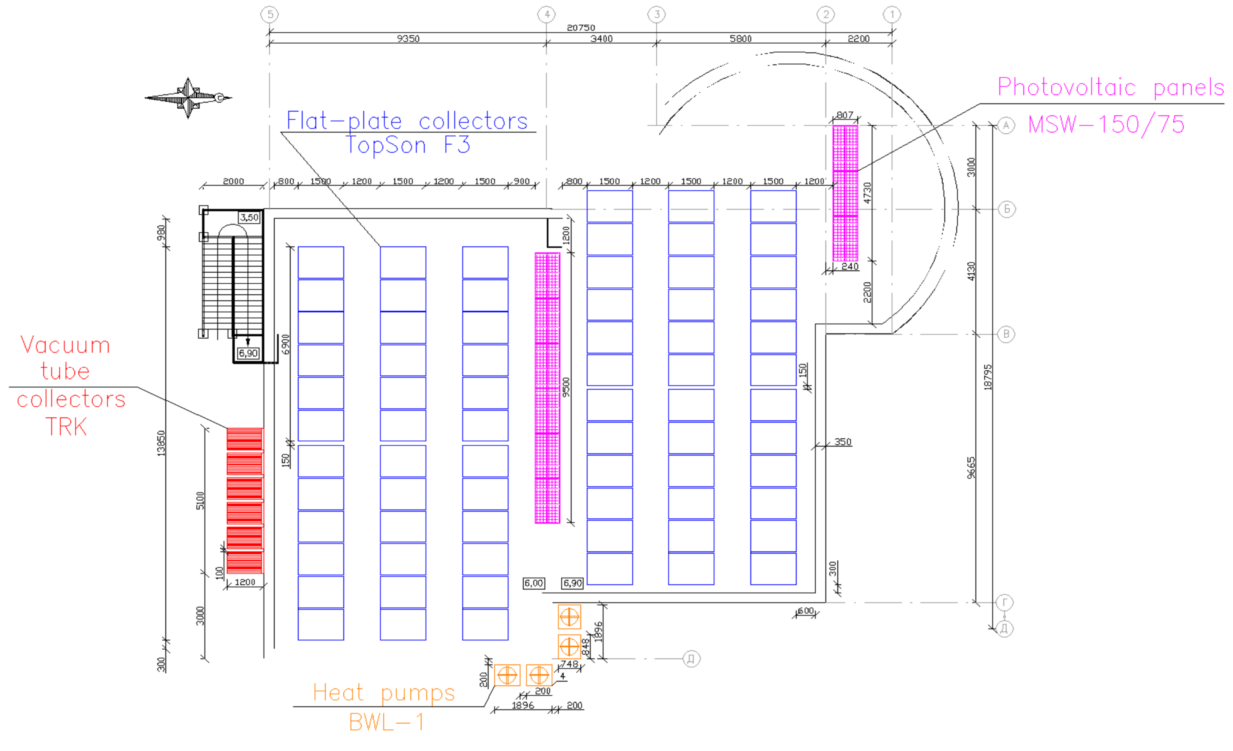

Figure 14: Construction of equipment of solar installation on roof of heat point.