EXPERIENCE TO USE GEOTHERMAL ENERGY IN BELARUS

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ABSTRACT

During the last years a rapid growth of prices for traditional sources of energy, such as the natural gas, oil and petroleum derivatives was observed both in the world and in Belarus. In this relation, the actual problem of power engineering became to use local sources of fuels and renewable energy resources accessible in the country.

The geothermal energy, available within entrails of Belarus, belongs to one of such sources. The nine low capacity geothermal installations, based on the heat pumps technology, were constructed and put into operation in the country. They use groundwater with low temperature, typically below 10 °C. Five installations are under exploitation mainly within water supply works in Minsk and the Minsk district. They use groundwater from shallow boreholes as a primary heat source for heat pumps. The total heat capacity of such installations is around 0.6 MWt. All existing heat pump systems are used for heating of buildings.

One installation is under exploitation in the north-eastern part of the country, near the Polotsk town. It uses the surface water from the Zapadnaya Dvina River as a primary source for a heat pump and one more installation was recently put into operation in the southern part of Belarus in the vicinity of Mozyr town. During 2006 a heat pump installation was put into operation at the frontier point “Novaya Rudnya” at the Belarus – Ukraine border.

The peak capacity of all geothermal installations, operating in Belarus now, is around 1.5 MWt. At present the works are undertaken to create a pilot geothermal station in the western part of the country in the area of Brest town for heating of the greenhouse complex “Berestye”. A deep borehole was drilled there to receive a warm water. Tests showed that it is possible to pump out a fresh water with the content of dissolved chemicals around 0.6 grams per liter from the depth up to 1000 m

with the temperature at the hole mouth around 25 °C. It is planned to project and construct here during 2008 and 2009 a geothermal station with the installed capacity around 1.5 MW.

1. INTRODUCTION

During the last years the Government of Belarus developed a package of works to reduce a country dependence on the import of energy supply from abroad. In result of a cost escalation for natural gas and oil in the world, these steps represent nowadays an essential importance for the successful operation of all sectors of the national economics. Therefore, the maximum utilization of heat resources of the country territory itself is considered as one of the most important directions to provide the energetic safety of the country. These steps were conditioned by the following factors:

- stirring up the governmental policy directed on the effective utilization of all kinds of the energy;
- the permanent growth of prices for the organic fuel and tariffs for the heat energy supply;
- negative impact of expected limitations in the fuel supply;
- low quality of the centralized heat supply and the costs of the reconstruction of old heating systems;
- ecological limitations in using own boiler-houses which burn the imported organic fuel;
- personalization of the living conditions.

The governmental executive measures are subdivided into two main directions. One of them is an essential reduction of the power inputs for industrial and agricultural production, as well as the reduction of energy by transport, communal-general consumption, etc. The second direction is aimed to substitute a part of the imported energy supply for our fuel-energy complex by local fuel and renewable sources of energy, both approved and nonconventional ones. It is planned that the part of them will increase to approximately 25% during nearest few years. The firewood, peat, combustible waste of agricultural products, the offal timber and woodworking are potential sources of energy production on the one hand, and unused resources of wind, solar and geothermal energy are available in the country on the other hand. For climatic conditions of Belarus the following natural heat resources are available: ground water from confined and unconfined aquifers, the soil, and an outdoor air.

The territory of Belarus belongs to the Precambrian East European Platform. It is well known that such platforms are colder comparably to younger ones. For instance, an average heat flow density and terrestrial temperature at comparable depths are higher for geologic units of the so-called Neo-

Europe and Mezo-Europe with respect to the Paleo-Europe. Nevertheless, geothermal energy is available within the territory of each country. But, on average, its much lower resources are typical for old platforms. Here at depths studied by drilling is available warm groundwater and it is possible to construct heat pump installations for direct exploitation of this natural source of energy. The first experience gained to use resources of low-enthalpy terrestrial heat for practical purposes in Belarus is discussed below.

2. GEOTHERMAL INSTALLATIONS

Well-directed efforts to the practical utilization of heat resources within the territory of the country were started since 1996. The experience was already gained on the development and exploitation of installations using low-potential heat of the underground and river waters, the soil and secondary energy resources for the heat supply (Zhidovich, 2004).

According to the available estimates of the density of geothermal energy resources within main geologic structures of Belarus (Zui, 2004; Zui, 2007; Zui, Mikulchik, 2005) it was shown that their values vary in a wide range from a few dozens of kg.o.e./m^2 (kilograms of oil equivalent per meter square) to 3 – 4 t.o.e./m^2 within the Upper Salt thickness of the Pripyat Trough, located in the south-eastern part of the country. Only in some localities the temperature recorded in deep boreholes reaches 100 °C at the depth above 4 – 4.5 km. At shallow depths below 500 m the temperature typically doesn't exceed 20 °C, therefore it is possible to exploit these resources only by means of heat pumps, in particular using vapor compression heat pump systems, for heating of dwelling and buildings of industrial and agricultural sectors.

When doing a heat extraction of 5 °C from 10 m^3 of the underground water with heat pumps it is possible to produce around 80 KWh of thermal energy at the same time using only around 12 KWh of electric energy. It is 1.7 times less of the primary fuel, than heat boilers consume burning an organic fuel. The reliability and the cost efficiency of heat pump systems to produce low-enthalpy heat were proved by the long-term commercial exploitation of such systems under diverse conditions and at different industrial project in the Republic of Belarus.

2.1. Examples of available heat pump installations

There are in total more than 100 heat pumps of the "water – water" and "air – water" types under exploitation in the country with installed capacity ranging from 15 to 1,300 KW. Around 9 geothermal installations are among them. Their total installed capacity is around 1.5 MW. All geothermal heat pump installations are used for heating of different industrial buildings. An example of such a system is shown in fig. 1.

Fig.1 – A heat pump in the process of its mounting (to the right) based on the utilization of a primary heat source, taken from the river water and the building (to the left) heated by this heat pump system (photo done by I. Zhidovich).

This equipment was mounted at a waterworks near Polotsk town, the north-eastern Belarus. A primary contour of the heat pump uses usual river water. The produced energy provides heating of a building shown below. At present the works are undertaken to create a pilot geothermal station in the western part of Belarus.

2.1.1. Heat pump installations at water-supply stations

Heat pump systems were constructed and put into operation at several water-supply stations, located in a rural area around Minsk. We briefly consider only one of them. The heat pump system was put into operation in 1999 instead of an embedded boiler-room using a solid fuel (coal, peat briquettes, etc). Its purpose was to provide the heating of the building with the water supply equipment installed (water pumps, valves, filters, etc). It uses a heat as the primary heat source for a heat pump of actually cold water from a water pipe, supplying it to consumers located in Minsk, fig. 2.

The heat pump system includes a vapor compression heat pump with a heat productivity of 45 KW equipped with an electric drive of a screw compressor, a filter block of deironing and two electric boilers with an electric power of 45 KW. The boilers were included into the system and designed to sustain the positive temperature in the heating system if the emergency heat pump outage will occur. The R407C working substance is used in the heat pump contour.

Fig. 2 – A Heat pump installation at one of waterworks located in the Minsk District, Belarus (photo done by I. Zhidovich).

Piped water with the project discharge rate of 53 m^3/h and the temperature of 8.5 °C from a pressure pipeline feeds the deironing filter and enters the heat pump evaporator. A low-potential heat of a piped water is transformed into a heat necessary to reach heating system parameters of 55/ 48 °C under the project outdoor temperature minus 24 °C and to provide the indoor temperature of 18 °C and 15 °C depending on the room assignment. The temperature in the return pipeline is used as the starting point to adjust the heat carrier parameters which is a season dependent factor. It is done by changing the parameter setting in the heat pump microprocessor. The heat pump was installed in the building of the former boiler-house. Its maintenance is fulfilled by the staff of the water pumping station.

Similar heat pump systems using an artesian water heat are functioning in a few other water pumping stations located in the Minsk District and supplying the drinking water for Minsk.

2.1.2. Heat pump installation at a sewage station

A heat pump system for a sewage station using a ground water heat was installed in 1999. The water was delivered from a shallow (20 m) borehole and used earlier to tighten pressure seals of sewerage pumps. The whole system is used for heating of buildings of the main sewage station located in the vicinity of Minsk. The heat pump installation (fig. 3) was mounted in the engine-hall of this sewage station (Zhidovich, Belyi, 2003). Before this system was put into operation, a separate local boiler-house was used. These boilers consumed a natural gas.

Fig. 3 – A heat pump installation (to the right) based on the utilization of the ground water heat, located in the close vicinity to Minsk and the building (to the left) with a heating supply from this heat pump system. At the background a chimney is shown of the switched off local boiler-house using a natural gas. It is put into operation only when the outdoor air temperature drops below minus 24 °C (photo done by I. Zhidovich).

The heat pump system consists of a vapor compression heat pump with a heat capacity of 360 KW having an electric drive of two screw compressors, a filter block and pump groups. The R134a working substance was used in the heat pump contour.

A cold groundwater from a shallow borehole with a project water discharge rate of 53 m^3/h and the temperature of 8.5 °C is pumped to the heat pump evaporator where it is heating the working substance and being cooled runs from its exit to a reservoir-storage.

The heat pump transforms a low-potential heat of a groundwater into parameters 63/48 °C, needed for the normal functioning of a building heating system. The project value of the outdoor air temperature is accepted to be minus 24 °C and the indoor air temperature of 18 and 15 °C depending on the production area assignment. The control of the heat carrier in the heating system is fulfilled automatically depending on the outdoor and indoor air temperatures. The control panel is mounted in the laboratory room. The whole heat pump system maintenance is fulfilled by the staff of the sewage pumping station.

2.1.3. Frontier point "Novaya Rudnya" at the Belarus – Ukraine border.

The frontier point "Novaya Rudnya" is located in the Gomel Region at the south-eastern border between Belarus and Ukraine. A heat pump installation uses a cold ground water pumped out from shallow boreholes as a primary heat source. The system was put into operation testing in the very end 2005 and was constructed for heating of the custom and frontier control buildings.

The heat pump system consists of a vapor compression heat pump operating in a the "water – water" contour with project heat productivity of 272 KW and of two hot-water boilers 2 x 90 KW using a diesel oil. The power consumption of the heat pump installation is 112.3 KW including a pump drive of 94 KW. It was provided its all-the-year-round operation.

Hot-water boilers are put into operation only when the outdoor air temperature drops during more than 48 hours to 15 °C below zero. Both boilers are also used for periods of corrective maintenance of the heat hump and other extreme conditions. These boilers practically were not used during the last three years of the heat pump system exploitation.

A fuel supply of diesel engines is providing from two reservoirs of diesel oil with the volume of 0.8 m^3 each. They were mounted inside of the heat pump room and the boiler-house, located nearby. A metallic chimney was constructed for the combustion materials removal and the dissipation of smoke fumes into atmosphere. Its height is 8.9 m. All equipment of the heat pump system is mounted inside the exploitation building with dimensions of 12 x 6 x 3 m.

The groundwater it received from three boreholes drilled to the depth of 19.5 m. The flow rate is 20 m^3/h and the temperature at the borehole mouths varies from 7.5 to 10.7 °C. This water feeds the primary contour of the heat pump and being cooled till 4.5 °C at its exit, flows into an accumulating pond and then it runs into the Zhelon river.

The groundwater piezometric surface is 2.3 m below the ground level and the calculated flow rate from boreholes was received under the recession of the level of 5.5 m below the water table. In result the dynamic level was at the depth of 7.8 m. In any case in the process of exploitation it didn't drop below 11 m at the maximal flow rate. A specific yield of ground water is 3.64 m^3/h. This regime doesn't lead to a depletion of the unconfined groundwater horizon.

The heat network, arranged above the ground level, is used to supply heat from the heat pump installation to individual buildings of the frontier and custom point. The project parameters of a heat carrier in the double-pipe scheme are 66.3/48 °C at the estimated outdoor air temperature around 24 °C below zero. A one-pipe system was used to supply warm water with the project temperature of 55 °C. The temperature sensor was installed to adjust the necessary temperature both by the automatic control system and manually when necessary. For the purpose of the reliability growth and to support the conditioned temperature of the warm water from the consumer's side during the time of minimal water consumption, vertical electric water heaters with the volume of 200 liters were installed in buildings. Their electric power is 2.4 KW.

A performance of this heat pump installation for three regimes of exploitation during a year is the following:

- it is necessary to use 0.35 MWh of electric energy and around 0.7 Giga calorie of the underground water heat to produce 1 Giga calorie of thermal energy at the outdoor air temperature above minus 15 °C;
- when the outdoor air temperature drops below minus 15 °C it is necessary to use 0.3 MWh of electric energy and around 0.5 Giga calorie of the underground water heat plus around 30 kg of a diesel fuel to produce 1 Giga calorie of thermal energy;
- during the inter-heating season to produce 1 Giga calorie of thermal energy it is used around 0.3 MWh of electric energy and around 0.75 Giga calorie of the underground water heat.

Normally the heat pump system operates in an automatic regime without the maintenance staff attendance. The information on a faulty condition of the equipment, an operation of the main quick-acting valve at the fuel line, unauthorized access to the heat pump room, a fire alarm actuation, etc are indicated at the operating console, located in the office of the superintendent of exploitation services.

More than 100 heat pump installations are used in Belarus. Most of them transform a waste heat from different technological processes into the so-called secondary heat resources. Only less than 10 geothermal heat pump installations are in the exploitation at different industrial enterprises in a number of districts of the country. The main parameters for several geothermal heat pump installations of the Republic of Belarus are summarized in Table 1. These installations (Zhidovich, 1998) differ by the used primary heat source, thermal performance of heat pumps, types of their compressors, kinds of working substances, as well as their coefficients of performance (COP), etc. There is no absorption heat pumps mounted in geothermal heating systems at the moment.

Table 1. The main parameters for some of geothermal heat pump installations

Locations of heat supply installations	Source of heat	Method of the heat extraction	Number and heat pumps productivity (pcs x KW)	Type and number of compressors in one heat pump	Working substance	Annual coeff. of the HPI (COP)
Minsk district	Artesian water	IHM	1 x 40	Piston, 1 pcs	R22	3.2
Minsk district	Artesian water	DHP	1 x 45	Spiral, 1 pcs	R22	3.6
Minsk district	Artesian water	DHP	1 x 65	Piston, 2 pcs	R407C	3.4
Minsk	Surface water	DHP	1 x 150	Spiral, 2 pcs	R407C	3.2
Minsk	Surface water	DHP	1 x 290	Screw, 2 pcs	R134a	3.8
Polotsk town	River water	IHM	1 x 230	Screw, 2 pcs	R134a	3.1
Brest town	Soil	IHM	3x60	Piston, 2 pcs	R22	2.6
Mozyr town	Surface water	DHP	1x270	Screw, 2 pcs	R134a	3.4
Novaya Rudnya	Artesian water	DHP	1x272	Screw, 2 pcs	R134a	3.4

Abbreviations:

IHM – Intermediate Heat Medium,

DHP – Direct Heat Pick-up (heat transfer in evaporators of heat pumps).

At present works are undertaken to construct a pilot geothermal station in the south-western part of the country for heating of the greenhouse complex "Berestye", located in Brest town. The deep geothermal borehole was drilled and tested. It produces a warm water with the flow rate of 42 m^3/h and the temperature at the mouth of this hole around 24 – 25 °C. Cambrian deposits, encountered at the depth interval of 630 – 1002 m, were used as the fresh water productive horizon with the dissolved chemicals content below 1 g.p.l. It is planned to project and construct here a geothermal station with the thermal installed capacity around 1.5 MW.

3. CONCLUSIONS

The experience gained to develop and to works maintenance of heating systems, using the groundwater geothermal heat, shows the stable interrelation and interdependence of finding conclusions exists on a groundwater geothermal heat take-off, their low-enthalpy heat, its transformation and utilization of the heat produced. A system approach is necessary to find a solution of the following topics:

- a well-grounded selecting of water-bearing horizon which can provide the necessary amount of geothermal water;
- the temperature analysis of a groundwater pumped out of boreholes;
- calculation of the number of water wells to be drilled;
- determining how to use cooled water (to inject it into wells, use as a water-supply resource, etc);
- the analysis of parameters and regimes of local heat supply systems (distant or distributed heating) to which installations of the geothermal heat transformation are technologically combined;
- the available reserve examination of an electric transformer capacity and the electric network throughput.

At the current moment the constraints in the geothermal resources utilization are: high tariffs for electric energy, consumed by heat pumps, a lack of economic mechanism stimulating this renewable energy source utilization and inconsequence in the merit rating of the importance of this new resources by the state departmental administration.

The return on equity for heat supply systems with heat pump installations is determined by costs of its construction and directly influenced by tariffs relationship for consumed electric energy and prices for the marketed heat. The total economic profit directly depends on prices for the saving of fuel.

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