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UTILIZATION OF GEOTHERMAL WATERS FOR SPACE HEATING IN BULGARIA

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ABSTRACT

The Republic of Bulgaria is rich in geothermal waters. The temperatures are in the range of (20°C - 100°C). For about 25 % of the total discovered flow rate the temperature is between 40°C and 50°C and only for 3.6% - the temperature is higher than 80°C (Petrov et al.1998)

Geothermal waters have been used since ancient times. At first they were utilized for healing, bathing, swimming pools and hypocausts (a type of Roman floor heating system). The systematic application of geothermal energy in Bulgaria has began with heating of separate buildings using direct schemes only. As a result of their exploitation scaling and corrosion occurred. The first more contemporary geothermal heating and air-conditioning installations in Bulgaria were constructed after 1980. Schemes with plate heat exchangers and heat pumps have been used. All systems built so far have been designed for space heating of separate buildings or small recreation spa centers.
There are no district heating systems built in Bulgaria due to the insufficient capacity of the reservoirs or number of consumers.

The total installed capacity of the geothermal systems (towards June 1999) is 95.35 MWt. The largest installed capacities (up to 15 MWt) of geothermal systems for space heating and air-conditioning of buildings were realized in Northeast Bulgaria along the Black Sea coast. In Southern Bulgaria the number of geothermal stations is much greater, but all of them are of smaller installed capacity ranging from 0.200 to 1 MWt. Most of the realized schemes for space heating are composed of imported equipment, such as plate heat exchangers, heat pumps, submersible pumps, circulation pumps and control systems from world leading companies. The feasibility analysis of the existing geothermal systems has shown good results with regard to the primary capital investment per unit of installed capacity as well as per prime cost of the produced energy. The basic difficulties in the geothermal energy utilization for space heating and air-conditioning are due to the lack of investments.

1. INTRODUCTION

About 160 geothermal fields have been discovered in Bulgaria with water flow rates of 3000 l/s and temperatures between 20°C and 100°C. About 72% of the discovered flows have temperatures up to 50°C, while 25% of it have temperatures ranging from 40°C to 50°C.

In ancient times geothermal waters were used mainly for healing, disease prevention and bathing purposes. As early as Roman times they were used on a large scale for floor heating in the Public baths.

The first experiments for utilization of geothermal energy were realized in Bulgaria within the period 1950-1980 on the geothermal reservoirs in Southern Bulgaria (the towns of Kjustendil, Sapareva banja, Velingrad, etc.). They were based around the mineral springs and today operate as spa centers year round. Direct schemes for space heating, greenhouses and swimming pools were constructed. The choice of those sites was based mainly on the comparatively high water temperature – (above 70°C).

The first modern Bulgarian systems for complex utilization of geothermal waters were built after 1980. They provide geothermal energy for space heating of buildings, greenhouses and swimming pools. These systems are indirect, and are assisted by plate heat exchangers and heat pumps.

The typical features of the geothermal systems for complex use of geothermal waters are:

- They are designed to provide space heating, domestic hot water and air conditioning to a group of several buildings.
- Most of the existing geothermal wells have comparatively low flow rates (less than 30 l/s) and low temperatures (less than 50° C-60 °C).
- The geothermal stations are commonly built to supply thermal energy to the already existing buildings equipped with radiators.

Towards the middle of 1999 the total installed capacity of the geothermal systems amounted to 95.35 MWt (excluding fossil fuel boilers). The distribution of the installed capacity in the different regions is shown on Table 1.

The total heat capacity of the geothermal waters is estimated to be up to 14 122 TJ/year (440 MWt) (Phare Project,1997).

Two geothermal stations of the highest capacity, built at one of the largest Black Sea resort are considered in this paper. They are in operation year round and provide space heating, air conditioning, domestic hot water and attractive use of geothermal water for showers on the beach and in open-air and indoor swimming pools. These schemes are examples of the most reliable solutions from a technical and economic point of view with respect to the reservoir potential and climatic conditions.

2. DIRECT SCHEMES FOR GEOTHERMAL ENERGY UTILIZATION

These are schemes in which the geothermal water enters directly into the heating equipment of buildings and greenhouses, systems for domestic hot water preparation and swimming pools. Such systems have been built at different geothermal sites all over the country regardless of the water temperature. They have the following principal shortcomings:

- They do not provide the required thermal comfort of the buildings.
- Scaling along the inside surface of the heating systems occurs, which hampers the heat exchange process.
- Corrosion harms the heating systems.
- The chemical composition of the geothermal water for medical treatment changes.
- There is a short lifetime of the heating equipment.

In Bulgaria these systems are commonly used in greenhouses. In spite of the low initial capital investments they are not efficient because of high repair expenses and short lifetime.

3. INDIRECT SCHEMES FOR COMPLEX UTILIZATION OF GEOTHERMAL WATERS.

These systems are implemented with plate heat exchangers and heat pumps and provide cooled geothermal water for balneotherapy, thermal energy for heating, ventilation, air-conditioning and domestic hot water. Such systems are built mainly in existing balneological centers, resorts and public buildings.
Features of the systems:

- They are built at geothermal sites with temperature up to 45°C and sites with temperature above 50°C.
- With small exceptions they are intended for heating and air-conditioning of existing spa buildings, mainly sanatoriums and recreation homes.
- Several types of schemes are applied: with heat exchangers only, with heat pumps only, and with complex use of both – plate heat exchangers and heat pumps.
- Thermal energy is used to supply both conventional radiator systems with heat-carrier of temperature 90°C/70°C and low temperature floor and convector systems with parameters of the heat-carrier 50°C/40°C.

The biggest system for complex utilization of geothermal waters for space heating and air-conditioning has been built in a recreation spa center in the town of Varna (Black Sea coast). Its total installed capacity is 15 MWt, out of which 5.8 MWt is for the heat pumps and 9.2 MWt - for the fossil fuel boiler.

The major reasons for the selection of that region were related to the:

- Thick (up to 500 m) and most productive geothermal reservoir in Northern Bulgaria.

The flow rate from a single artesian well reaches 60-70 l/s and the temperature is in the range of 30°C to 52°C
About 27.2l% of the total flow rate comes from the wells located in this region. There are 12 geothermal sites in the country where wells are of such a high flow rate and 7 of them are located in this region.

- Location of the geothermal sites

They are located in some of the most famous Bulgarian sea resorts on the Northern Black sea coast - Varna, St.Konstantin and Elena, Golden sands and Albena. They are in year round and are visited by many local and foreign tourists.

- Attractive combination of geothermal application for balneology and recreation and sea resort exists.

The climate is very favorable for all the seasons. The average monthly air temperature ranges between 1.2°C (in January) to 22.6°C (in July),Fig.1. The winter reference temperature is -11°C and the summer one is 34°C. The load factor for the installations in the region is high (0.62) and their feasibility parameters are good in spite of the high initial investment costs.

3.1. The Geothermal station at a recreation center of St.Konstantin and Elena resort, (Northern Black Sea coast)

The geothermal station is built on the basis of a bivalent scheme comprising heat pumps and an existing fossil fuel boiler. A principal scheme of the geothermal station is shown on Fig.2.

The thermal energy obtained from the system is used for supplying the radiator system, for ventilation, provision of domestic hot water and warming up of swimming pools.
Two wells are used as thermal sources for the heat pumps. One of them has a flow rate of 35 l/s and a temperature of 43°C, while the other one has a flow rate of 40 l/s and a temperature of 41°C. A submersible pump for pumping water out is used at the second well. A heat-carrier with supply temperature of 90°C (min 72°C) and 69°C (min 51°C) return temperature is delivered to/from the consumers. By the directions of the company SULTZER, a producer of heat pumps, the thermal water passes directly through the evaporators, gets cooled to 27°C – 33°C, and is used for medical bath treatment afterwards.

The basic components of the schemes are: two heat pumps with SULTZER turbo-compressors with a capacity of 2.9 MWt each, 680 kW installed breaking capacity of the compressors and two fossil fuel boilers with a capacity of 4.6 MWt each. The heat pumps cover the heating needs of the site when the average daily temperature is higher than –3°C. When lower temperatures occur a fossil fuel boiler turns on. The average number of days during which the fossil fuel boiler works is 9.3 out of 160 days long heating season. The control and automatic regulation of the system are computerized.

3.2. The Geothermal station at the Sport Hall in town of Varna, (Northern Black Sea cost)

The geothermal station provides thermal energy and cooling respectively for the heating and air-conditioning systems of the buildings. The principal scheme of the geothermal station is shown on Fig.3. A geothermal well with a flow rate of 55l/s and a temperature of 51°C is used as a source of thermal energy for the station. In order to fit in that source all of the equipment at the site was readjusted for a heat-carrier with temperature parameters of 55°C/40°C. The scheme offers a combined utilization of two turbo-compressor heat pumps for winter conditions. During the summer season these two pumps as well as the existing refrigerating unit are used to provide cooling mode. Two CIAT plate heat exchangers (HE1 and HE2) are included in the system. They were installed to prevent the geothermal water from passing through the evaporators of the heat pumps. That was the MC QUAY company requirement aimed to avoid corrosion and scaling. At average daily temperatures higher than 7°C the heating needs of the building are fulfilled by the geothermal source using the plate heat exchangers. When the temperature outside is lower than 7°C heat pumps get turned on. During the summer season the system provides a cold-carrier 7°C/12°C for the air-conditioning of the building. The heat pumps condensers are indirectly cooled through a HE3 plate heat exchanger and four cooling towers with a capacity of 1.17 MW each. The heat pumps have a condensing capacity of 1.43 MWt each at an installed capacity of the compressor of 233 kW. In the region of Varna there are a few more systems for complex utilization of geothermal waters using the stated above schemes, however, their installed capacity is much smaller at 2 MWt.

The geothermal stations are mainly supplied by imported equipment that has been designed and constructed by Bulgarian companies. The French companies VICARB and CIAT have supplied the plate heat exchangers for the geothermal stations. The Bulgarian plate heat exchangers have shown insufficient operating characteristics and shorter lifetime compared to the imported ones. The heat pumps have been supplied by the Swiss company SULTZER and the US companies MC QUAY and TRANE. Two Bulgarian heat pumps with a condensing capacity of 0.25 MWt have been installed as experimental samples in one geothermal station. Since 1998 the Bulgarian company PENGUIN – U.N. Limited, Sofia, has been assembling heat pumps, water to water, and water to air with capacity up to 1 MWt. Compressors of the German company BITZER and DANFOSS control systems are used for them. Those heat pumps will most probably be used in the future geothermal projects.
GRUNDFOS company, Denmark, produces the submersible pumps currently being used in the wells. The circulation pumps are from the companies GRUNDFOS and WILO, and the control systems are produced by SIEMENS-LANDIS & STAEFA DIVISION, DANFOSS and SAUTER.

4. BASIC FEASIBILITY ASSESSMENTS OF THE BULGARIAN GEOTHERMAL STATIONS

The analysis of the existing geothermal stations have shown the following results:
The primary capital costs for the geothermal stations construction are within the range of USD 150 to USD 900 per 1 kWt of installed capacity. These figures include expenses for: geothermal wells, submersible pump, plate heat exchangers, heat pumps, distributing pipeline, system for automatic control and accumulators. The investments do not include the expenses for inner heating and air-conditioning installations. Low primary costs of (USD 300 – 400 per 1 kWt) are typical for most geothermal stations in the country because of state financed drilling in the past and short distribution network. The average geothermal station load coefficient is 46% due to the lack of consumers during the summer season. The heating season in the country lasts between 160 and 180 days.

The heat pump Coefficient of Performance (COP) is within the range of 3.5 – 6.3. All heat pump compressors run on electrical power. The prime cost of the produced thermal energy from the existing stations is ranging from 3.5 USD/GJ to 8.5 USD/GJ. These values are lower than the thermal energy originally produced only by fossil fuel boilers. The growing price of the liquid fuels in the country and the analysis made to the year 2020 (Phare Energy Program, 1997) showed the great benefits from the utilization of the geothermal energy in Bulgaria.

From the total installed geothermal capacity of 95.35 MWt an energy of 1382.9 TJ/year is being produced equivalent to 33051.2 TOE/year, (see Table 1).

5.PROSPECTS FOR UTILIZATION OF GEOTHERMAL ENERGY FOR SPACE HEATING IN BULGARIA

Most geothermal stations for space heating and air-conditioning operating on the indirect scheme assisted by heat exchangers and heat pumps, were designed and constructed during the decade 1980 – 1990. The social and economic changes, which occurred in Bulgaria after 1989, resulted in lack of investments for new projects. In the period 1995 – 1999 a few systems with low installed capacity (0.25 – 0.40 MWt) were built using geothermal energy for space heating, thanks to the PHARE program financial aid. A preliminary project has been completed considering the space heating of the public buildings in the town of Sapareva Banja (SW Bulgaria). This is a geothermal reservoir with water temperature 98^{o}-100^{o}C and central heating system. A geothermal station with a capacity of 10.9 MWt is considered, the construction of which will require USD 2.7 million of primary capital investment. The adoption of the new concept concerning the utilization of thermal waters for different purposes, including space heating, (the Concession law), opens up broad vistas to the development of the geothermal energy utilization in the country.
For the time being the basic difficulties are related to the lack of investments. The increase of foreign investments from the PHARE program and from some World Financial Institutions aimed for the numerous spas in Bulgaria create more favorable conditions for the expansion of the geothermal market. Besides the production of cheap thermal energy, the geothermal plants contribute to the reduction of the environment pollution, which is of great importance for the country.

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Table 1. GEOTHERMAL INSTALLED CAPACITY IN BULGARIA BY REGION (June,1999, at 0.46 average load factor)				
	Region	**Installed capacity**	**Produced energy**	
		MWt	**TJ/year**	**TOE/year**
1	Montana	0.5	7.2	172.1
2	Vratsa	0.0	0.0	0.0
3	Pleven	2.0	29.0	693.1
4	Lovech	3.4	49.3	1178.3
5	Gabrovo	0.0	0.0	0.0
6	Veliko Tarnovo	6.6	95.7	2287.2
7	Rousse	0.0	0.0	0.0
8	Targovishte	0.0	0.0	0.0
9	Razgrad	0.0	0.0	0.0
10	Silistra	0.0	0.0	0.0
11	Shoumen	1.8	26.1	623.8
12	Dobrich	8.7	126.2	3016.2
13	Varna	24.5	355.4	8494.1
14	Bourgas	1.15	16.7	399.1
15	Jambol	0.5	7.2	172.1
16	Sliven	1.35	19.6	468.4
17	Stara Zagora	2.3	33.4	798.3
18	Haskovo	2.9	42.1	1006.2
19	Kardzali	0.0	0.0	0.0
20	Plovdiv	2.7	39.2	936.8
21	Smoljan	1.1	15.9	380.0
22	Pazardzik	14.6	211.8	5062.0
23	Sofia	4.0	58.0	1386.2
24	Pernik	0.2	2.9	69.3
25	Sofia city	4.0	58.0	1386.2
26	Blagoevgrad	8.8	127.6	3049.6
27	Kjustendil	4.25	61.6	1472.2
	Total	**95.35**	**1382.9**	**33051.2**

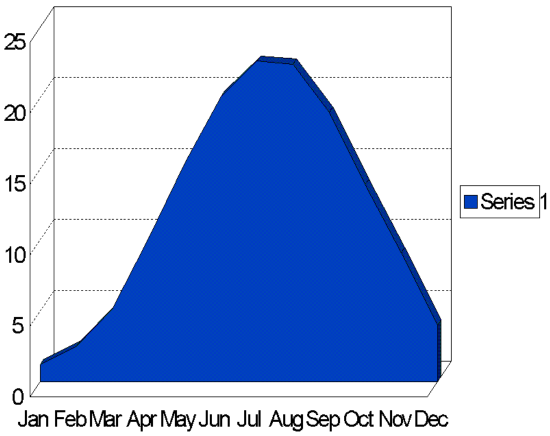

Figure 1.Average monthly air temperature for the Varna area

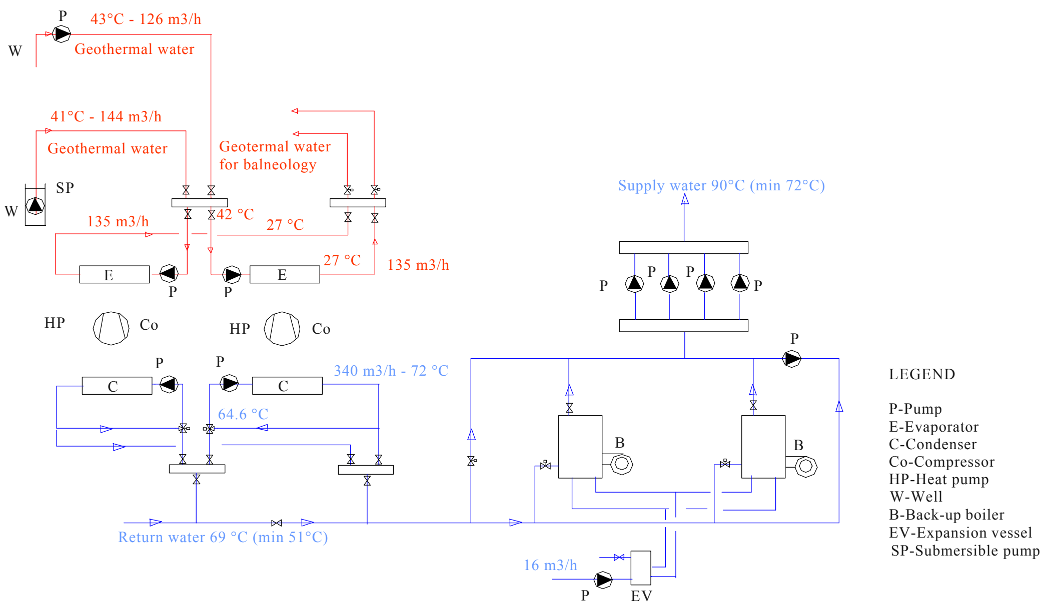

Figure 2.Principle scheme of Geothermal station in a recreation center
(St.Konstantin and Elena Black sea resort).

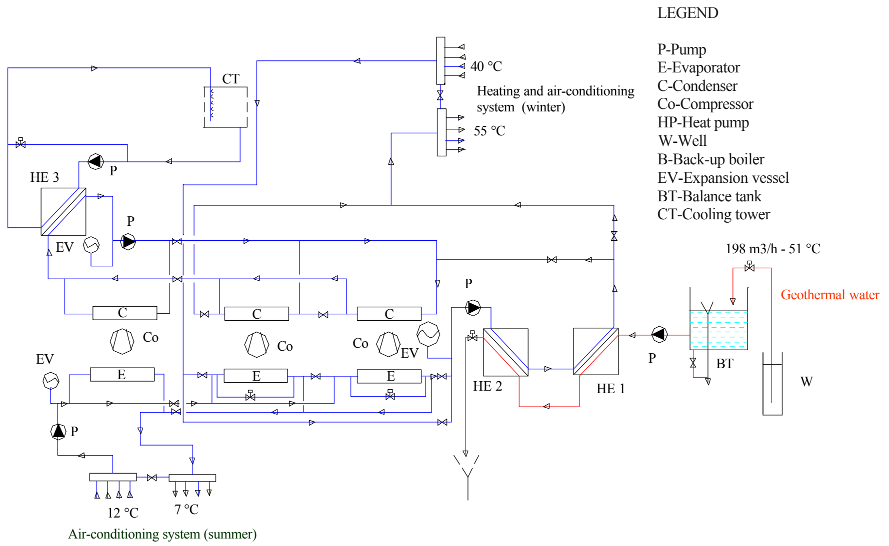

Figure 3. Principle scheme of Geothermal station in the Sport Hall (town of Varna)