Proceedings World Geothermal Congress 2000
Kyushu - Tohoku, Japan, May 28 - June 10, 2000

GEOTHERMAL DISTRICT HEATING SCHEMES IN THE REPUBLIC OF MACEDONIA

Prof. Dr. Konstantin Dimitrov; Ognen Dimitrov
Faculty of Mechanical Engineering, Skopje, Department of Thermal Power Engineering
Republic of Macedonia

Key Words: geothermal, district heating, Kocani Geothermal Project

ABSTRACT

The Kocani geothermal field in Macedonia is the most important energy source for the local county, satisfying energy needs of 18 hectares of greenhouses, low temperature industries, as well as home heating. The main characteristics of the system are a buried, pre-isolated, self-compensated pipeline; sub-stations with the aim of increasing the economy; and the transferring of home heating systems (90/70^{o}C) to the system with an entering water temperature of 65^{o}C.

1. INTRODUCTION

The Republic of Macedonia is a developing country of approximately 25,713 km^2 and 2.1 million inhabitants (Figure 1) located at the Balkan Peninsula. It is situated in the southernmost part of the Bosnian-Serbian-Macedonian geothermal area. The territory is characterized by numerous thermal springs indicating an area of potential sources of geothermal energy.

Its energy supply is based 50% on domestic fossil fuel and hydropower and 50% on imported liquid fuel, coal and electricity. A significant part of the electrical generating capacity is thermal. The different sources of energy utilized in 1994 are given in Table 1.

The development of alternative domestic energy sources had received considerable attention in recent years, including numerous efforts to assess and to develop geothermal energy for greenhouses and space heating. This activity is moderate, because of political conditions in the state, after secession from the former SFR Yugoslavia and the situation in Kosovo.

Until the present, no high-enthalpy geothermal resources have been exploited. However, thermal water occurrences and their therapeutic potential were known a long time ago.

The geothermal exploration and development progressed through two phases:

- A reconnaissance survey designed to identify specific prospect priorities for more detailed investigations (hydrochemistry), interpreted within the framework of regional geology, and hydrology
- Resistivity, gravimetry, magnetometry and temperature-gradient surveys undertaken by drilling shallow drill-holes

2. EFFORTS IN GEOTHERMAL UTILIZATION

About 15 geothermal projects are in operation or under development in the Republic of Macedonia. Four of them are of major importance and have a general influence on the development of direct application of geothermal energy in the country. The most important is the Kocani geothermal project. The Gevgelija and Vinica agricultural geothermal projects and the integrated project in Bansko are also important.

Kocani geothermal project. In the region of Kocani 18 ha of glasshouses and a rice-drying plant (Figure 2) have been heated geothermally since 1982. Noncorrosive water permitted a simple technical design. A successful new borehole, which increased the flow rate to 450 l/s, opened the way for geothermal energy in industry (a paper industry and a factory for producing vehicle parts) and the heating of dwellings. A few other industrial users are preparing to connect to the system. There is development in the Kocani project (re-injection), where the direct application for industry, space heating, rice drying and sanitary warm water preparation has been introduced.

Bansko geothermal project. The use of geothermal energy in agriculture started in Bansko. An old-fashioned glasshouse of 2.2 ha is heated by fluid from the thermal spring. The water is low corrosive and is used directly in the steel-pipe heating installation. The hotels built near the spring now are using thermal water for central heating, sanitary and balneological purposes. The installations for Hotel Car Samuil are properly connected to the source and working more-or-less according to design conditions. Greenhouse installations are connected improperly, thus disturbing the system balance**.**

Gevgelia geothermal project. This project consists of two parts: an agricultural project supplied with geothermal energy from the springs from Smokvica with 15 MW installed capacity, and a balneological project supplying the hotel complex with energy for central heating, sanitary and balneological purposes from another locality, Negorcy, 10 km from Smokvica. Initial mistakes involving the direct connection of 22.5 ha of glasshouses to aggressive geothermal water are still not completely ameliorated. The connection line is very corroded, causing problems in exploitation.

Vinica geothermal project. 14,160 kWh annually is used for heating six ha of glasshouses. The project was never finished. A great part of the connection line and connecting installations is rusted. Heating installations are not designed properly for geothermal energy use.

Unfavorable effects of the rapid growth of fossil fuel prices stimulated much new work aimed at identifying alternative, cheap and renewable energy sources. This resulted in the revision of many previous views about the practicality of using sources of low-grade thermal energy.

The low-grade heat content of geothermal springs, for example, had been considered as uncompetitive with any fossil fuel. The particular characteristics of each spring required a separate technical design, individual choice of materials, specific control systems, etc., resulting in increased capital expenditure and high running costs.

Under the new conditions, however, such complications now become acceptable. If the heat load is carefully selected so that heat demand and consumption are matched to the specific capabilities of the spring or borehole, it is possible to prepare a design, which will be indisputably economic.

Geothermal energy has been used successfully for district heating. Geothermal systems are usually designed as base load systems with peaking and back-up requirements met through the use of thermal storage and fossil fuel boilers. If properly designed, the geothermal portion of the system can provide 80 to 85 percent of annual energy consumption while meeting less than 50 percent of the peak demand. In order to meet peak demand with geothermal energy, the number of wells would have to be doubled with an increase in the diameter of the distribution piping system. When available, geothermal energy can provide an extremely cost-effective source for district heating.

In the case of schemes with moderate temperature fluids and lower thermal gradient, the fluids are not capable of meeting the full heating demands. Developments of the schemes are feasible only because large heat loads are available and connection costs are relatively low. The most economical approach is to use geothermal fluid to meet the base heating loads and fossil fuel fired boilers to supply peak loads.

With coordination of heat consumption by different users an economic improvement of geothermal energy use is enabled. It is already competitive in comparison to liquid fuels, as shown by the example of the Kocani geothermal project. The main consumers, greenhouses, industry, homes and sanitary warm-water preparers have different heat requirements, which vary with time of day and season.

3. MAIN DATA OF KOCANI GEOTHERMAL FIELD

The main borehole (Figure 3) is 328 m deep. It passes through 192 m of unconsolidated fluvial sediments and then from 192 to 314 m penetrates alternating tuff and tuffaceous sand. The sands are consolidated and did not collapse during drilling. Water first appeared at the 240-m depth; pressure rose slowly to the final depth of 328 m when the well began to discharge. Basic characteristics of the main geothermal spring are:

- A constant discharge temperature of 78°C
- A high but variable discharge capacity of 100-250 l/s
- A high but variable water pressure at the discharge point with a mean value of 0.65 MPa
- A non-aggressive water, with low levels of total dissolved solids and a pH = 6.8
- A carbonic hardness of 23.9°C (425 mg/l $CaCO_3$ equivalent)
- CO_2 is in balance with free CO_2 and the water is potable.
- The well is sited in an aquifer with thermally advantageous hydro-geological parameters but with limited dimensions.
- The production well reaches only the upper part of the aquifer and its thickness is still not established.
- The aquifer is bounded horizontally by several aquifers of lower transmissivity, and there are hydraulic boundaries at different distances.

4. GEOTHERMAL DISTRICT HEATING SCHEME

A successful new borehole which improved the possibility of a geothermal source yielding up to 450-600 l/s, opened the way for the introduction of geothermal energy in industry and the heating of dwellings in the town Kocani. Based upon the thermal water needs and the local ground conditions, the following parameters were considered in the optimization of the distribution system:

- The total investment cost of distribution pipe-line (mechanical and civil engineering)
- The total investment cost of pump stations to overcome the flow resistance in the distribution system
- The total cost of heat insulation material and labor
- The total annual electricity cost for the pumping of geothermal water
- The total annual heat loss through the insulation layer

Geothermal water is pumped to the surface by means of submersible pumps, direct to a 1000 m^3 reservoir accumulator. Then, by means of centrifugal pumps (Figure 4) in the pump station, the geothermal water is distributed to the greenhouses and to the town.

4.1 Distribution

The distribution system, which carries thermal energy from the geothermal spring(s) to the customers, is by far the single most expensive capital item in a district-heating network. It can account for anywhere from 35 to 75 % of the total system cost depending upon the size of the network, the customer demand, the temperature of the geothermal water, the piping material selected, and the method of installation. Whatever type of piping is selected, it should provide high thermal efficiency, moisture protection, reliability, corrosion protection, and be economical to install. Many pipe manufacturers imbed two or three sensor wires in the insulating material, which provides leak detection and the control of other equipment by remote control.

The main classification of geothermal district heating schemes can be made on the basis of physical and chemical characteristics of the geothermal water. A one-pipe distributive system is used, because the water does not contain large concentrations of minerals or corrosive activity. The one pipe distributive system is applied when the geothermal water is ejected from pipes, after it was used, but in accordance with two conditions:

- There is no reinjection.
- The spent geothermal water does not influence the environment.

Therefore, the composition of ejected geothermal water is very important and must possess such characteristics as to enable its dumping into sewerage without any harmful consequence on the environment. Under these conditions, a connection of a district heating system with geothermal springs can be made with a long-distance one-pipe distributive system for geothermal water, and closed loops of district heating networks. In the case when the district heating system is very close to the geothermal spring, the scheme with two pipelines can be applied with supply and return mains in a closed loop.

The first 1773 m of the distribution pipe-line, from the borehole and pump-station to the town of Kocani, is mostly underground. A pre-insulated pipeline was chosen. The diameter of the steel pipe was 406 mm and the diameter of the polypropylene-covering pipe was 500 mm. It is very important to emphasize that the under ground pipeline was installed without any compensation for thermal elongation. A pre-stressed method for installing the pipe-line, with the surrounding ground taking all of the strain, enabled the investment cost to be decreased by $US 66,000.

The second part of the distribution pipeline, having a length of 2650 m, was completed in concrete canals through the town of Kocani. The diameter of the steel pipe is 324 mm and the diameter of PP covering pipe is 400 mm.

The heating of dwellings was slowly introduced. As a first step, buildings with existing inside heating installations were connected. The next step was to extend the district-heating network throughout the town and to connect all other private and municipal edifices (Table III).

4.2 Substations

Regulatory issues remain a fundamental problem, since spent geothermal water is ejected into the river. Figure 6 shows a simplified diagram of the customer substation, heat exchanger, and the connection to the hot water space heating loop.

Regardless of the type of heat supplying a building (conventional or geothermal), a substation for connection to the district heating system will be required. This substation generally consists of main shut-off valves, heat exchangers, temperature and pressure instrumentation, and (or) an energy meter. It is generally located in the main mechanical room adjacent to the heat exchanger, circulating pumps, expansion tanks and related plumbing equipment necessary to operate a hot water circulating system (Figure 7).

Two counter flow plate heat exchangers are usually used in geothermal design schemes. The first one is in working condition, and the second is in a condition of maintenance. The temperature and the geothermal water flow rate will remain fixed, if the water is reinjected into the ground. At the same time the return temperatures and the flows from the heating network fluctuate as the heat demands of the users change. In the case when reinjection is not applied, it is more useful to change the geothermal water flow rate according to the heat demands of the users (heat consumption of the district heating network).

Control of the supply temperatures of the district heating network is obtained either by regulating the network supply temperature as a whole or by regulating the temperatures of the fluids supplied to individual buildings from the heating substations (customer stations).

Substations can be classified on the basis of the connections with geothermal district heating network as:

- Indirect customer connection
- Direct customer connection (mixing stations)

The main problem when reconstructing existing heating system (90/70^{o}C) with a geothermal with lower temperature level, is the insufficiency of heating area of installed heating elements. Taking into account projected calculations of heating needs in the dwellings, it was concluded that there is a reserve which can cover the insufficiency of lower temperature level of heating medium, without the need to increase the heat exchanger surface area.

4.3 Thermal Storage

In the geothermal network, which includes mostly commercial and public buildings in comparison to private dwellings and industry, a large proportion of the users may be shut down at night, or during weekends, producing low network flows. In these cases it may be feasible to use fluid storage to smooth domestic water heating loads. A schematic design of a network using storage is shown on Figure 2.

The storage tanks (Figure 8) enable the flow through the heat exchanger to be kept at a constant level when the network flow changes. In the low demand period excess supply fluids are diverted to hot water storage. During high demand periods the network flow is supplemented by adding hot fluid from the storage tank. The overall result is to increase the supply capacity of the network over what would be supplied without storage. This allows more users to be connected to the network and to increase the annual heat load factor.

Thermal storage is rapidly becoming an integral and important aspect of district heating production. The storage medium must have a high heat capacity, and be reasonably inexpensive. Most storage systems rely on water as the storage medium. Another important characteristic of the storage system is its ability to contain the storage medium by providing boundaries against water and heat flow from the facility. Containment can be provided by above- or below-ground steel tanks, rock caverns, or geologic formations.

Short-term storage is usually in the form of above ground steel tanks. The thermal peak is met with heat produced and stored during off peak periods. Long-term storage is used to take advantage of seasonal differences in energy demand and production capability. It usually involves storage in aquifers, open rock caverns, or bore holes in rock. Long-term storage is not used to store geothermal energy, because the ground is its best storage tank.

5. CONCLUSIONS

The design and operation of district heating geothermal systems to obtain optimum performance is a very complex task with multivariant solutions. Meanwhile the main principles governing the basic arrangement can be defined.

Depending on the characteristics of the geothermal water the distributive system must be designed as:

- A one pipe system, or
- A system with heat exchangers and a closed loop for district heating

The two basic rules that must be considered are:

- The network flow through the heat exchanger is always greater than the geothermal flow.
- The network return temperature must be as low as possible.

The geothermal networks have a number of different arrangements relating to:

- The kind of heating substations (mixing, direct customer connection, or indirect customer connection, with heat exchangers)
- The provision of domestic hot water
- The provision of thermal storage

REFERENCES

(Journal Article)
Dimitrov, K. (1987). Experiences with the use of geothermal heated greenhouses in Kocany. *FAO/CNRE I Workshop on the Use of Geothermal Energy in Agriculture*, Skopje, pp.7.

Gasteovski, Lj. 1989. Installation of distribution pipe-line without thermal compensation in kocani geothermal system. *Symposium KGH.* Belgrade.

Dimitrov, K. and Popovski, K. (1990). District and greenhouse heating with geothermal energy. *Second Joint Workshop of the FAO/CNRE-UNITAR/UNDP-ENEL-ENEA-ISES on the Use of Thermal Effluents in Agriculture and Aquaculture*, Como, Italy, IV.3. p.8.

Dimitrov, K., Popovski, K. and Gorgieva, M. (1993). Geothermal energy resources and their use in Yugoslavia. *Energy Sources "Taylor & Francis,"* Volume 15, pp. 117-124.

(Report)
Dimitrov, K. and Armenski, S. 1982. *Geothermal Water Use In The Region Of Kocani.* Study Work, Book 3. *Distribution of Geothermal Water from Springs to the Consumers*, Kocany Sity Council, Skopje. 127 pp.

(Book)
Dimitrov, K. (1994). Geothermal district heating schemes. *Geothermal Energy: District Heating and Industrial Uses, ISS 1994 Course Text-Book*, Editor: K. Dimitrov, Oradea, Romania, 459 pp.

Dimitrov, K. (1997) *Distribution of geothermal fluids, Geothermal District Heating Schemes.* ISS 1997 Course Text-Book, Editor: K. Dimitrov, Ankara, Turkey.

Figure 1. Map of the Republic of Macedonia

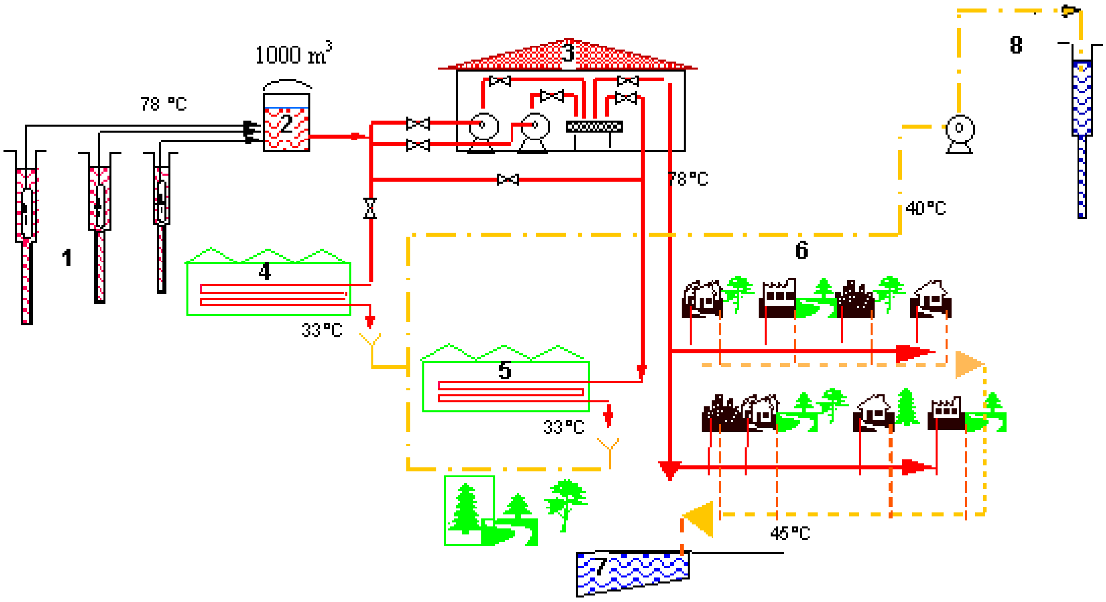
Table 1. Energy Sources

Source	1994		2000	
	10^3 ton	GWh/ year	10^3 ton	GWh/ year
Fossil fuels				
Oil import	1100	14390	840	10988
Coal production	8245	17862	9365	20280
Coal import	135	1083	150	1203
Wood	1080	3250	1100	3310
Gas import $10^6 m^3$			600	5480
Electricity				
Thermopower		5490		6180
Hydropower		1290		3320
Gross		6780		9500
Geothermal energy		141.5		210

Table 2. Summary of Geothermal Direct Heat Uses

	Installed Thermal Power[1)] MW_t	Energy Use[2)] TJ/yr
Space heating	6.275	50.10
Agricultural Drying	1.360	6.18
Greenhouses	52.900	405.14
Industrial process heat	6.860	32.92
Other uses	2.110	15.30
Total	69.505	509.64

1) Inst. thermal power (MW_t) = Max. water flow rate (kg/s) x [Inlet temp. (°C)- Outlet temp. (°C)] x 0.004184;
2) Energy use (TJ/yr) = Annual average flow rate (kg/s) x [Inlet temp. (°C)- Outlet temp. (°C)] x 0.1319



1. Geothermal wells; 2. Sedimentation basin; 3. Circulation pumps; 4. Geothermal complex "Mosa Pijade"; 5. Geothermal complex "Kocansko Pole"; 6. District heating; 7. Swimming pool; 8. Reinjection

Figure 2. Geothermal Project Kocani

Figure 3. The main borehole in Kocani. A technical visit of International Summer School' students

Figure 4. An internal view to the pump station

Figure 5. A view of the over-ground distribution pipe-line

Table 3. End Heat Users

	Consumer	Heat capacity	Diameter of pipeline
1	School "Kiril i Metodij"	930	100
2	Court	146	32
3	School "Mosa Pijade"	320	50
4	Police Department	252	40
5	Administrative building (OSNO)	337	50
6	Administrative building (UJP)	220	40
7	Administration (Culture build-ing)	350	50
8	PTT	380	50
9	Medical Center	4000	3 x 100
10	Shopping Center	836	
11	Block of houses "A"	1139	100
12	Block of houses "B"	2177	2 x 100
13	All houses on the streets "M. Tito", "Dimitar Vlahov" till shopping center "Merkur"	1360	
14	New anticipated	6739	
	TOTAL	**19 190**	

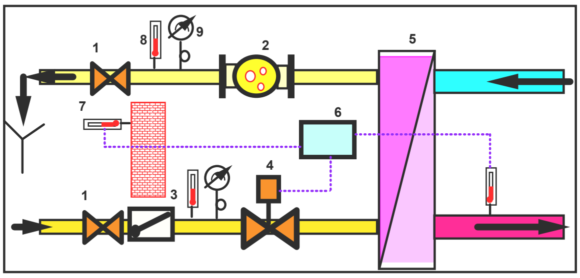


Figure 6. The connecting scheme in the substation

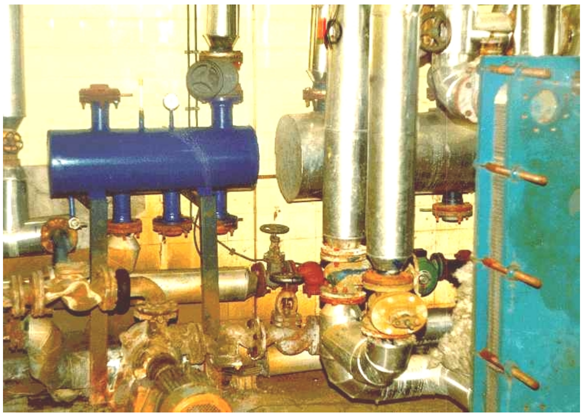


Figure 7. Internal view of geothermal substation

Figure 8. The Storage Tank Applied to the Geothermal Scheme in Kocani