GEOTHERMAL DISTRICT HEATING EXPERIENCE IN TURKEY

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ABSTRACT

Turkey is the 7th richest country in the world in geothermal potential. Most of the development of this resource is achieved in geothermal direct-use applications with 52,000 residences equivalence of geothermal heating (493 MWt) including district heating, thermal facilities and nearly 500,000 m^2 geothermal greenhouse heating. Geothermal water is used in 194 spas for balneological purposes (327 MWt). Engineering design for nearly 300,000 residences equivalence of geothermal district heating has been completed.

By summing up all this geothermal utilization in Turkey, the installed capacity is 820 MWt for direct-use and 20.4 MWe for power production; where, a liquid carbon dioxide and dry ice production factory is integrated with the Kizildere geothermal power plant with a 120,000 tonnes/year capacity.

Geothermal district heating systems (GDHS) are the main geothermal utilization in Turkey, which have an important meaning to the Turkish citizens who make use of this system; since, a clean environment and comfort has been provided to residences in an economic situation.

The district heating system applications were started with large-scale, city-based geothermal district heating systems in Turkey; whereas, the geothermal district heating center and distribution networks have been designed according to the geothermal district heating system parameters. This constitutes an important advantage of GDHS investments in Turkey in terms of the technical and economical aspects.

An annually average of 23% growth of residence connection to GDHS has been achieved since 1983 in Turkey.

INTRODUCTION

As the district heating system installation started with GDHS investments in Turkey, the GDHS are operated very economical, which is the result of optimization of geothermal resource characteristics with the consumer's characteristics, suitable system design and technology.

Turkey is a developing country. There is a continuous migration from rural areas to cities, and there is 2% population increase annually. As a result of this, apartment buildings in cities are continuously increasing vertically and horizontally. The results of the migration are some of the important subjects, which should be considered before the establishment of geothermal systems. Another case is, while some of the buildings have a radiator-heating system, some of them have not. The conversion project should take these types of systems into consideration.

TECHNOLOGICAL ASPECTS

The main units of a geothermal district heating system are geothermal water production, reinjection, heat exchangers, piping system and pumps.

By using the new approaches in determining the heat load instead of classical methods, the initial investment cost has generally been reduced.

Fifteen years of experience showed that real heat loads were approximately three times lower than the heat loads evaluated by theoretical methods. The main reasons for this are as follows:

1. Using outside design daily average temperatures causes an excess calculation of heat load by 20%, which increases the initial cost of the investment.
2. The theoretical heat load evaluation methods are considered as constant, but in reality the heat loss and gain are variable. The main differences in heat load calculations result from the variable effects that are not taken into account.
3. Besides the heating application, domestic hot water supply also exists in geothermal district heating systems. In the classical calculation methods, domestic hot water load is not added directly to the heat load. This occurs for two reasons. The way to maximize utilization of the geothermal fluid is to decrease the return geothermal water temperature to a minimum level. The return temperature from the heating (radiator) is about 40°C (104°F). The domestic hot water temperature is about 45-50°C (113-122 °F). To heat the network water from 15°C to 43°C (59 to 109 °F), no additional load is required and the energy of the discharged water is used for this purpose. The domestic hot water load occurs for a very short time in a day which does not affecting the design load.
4. In addition, heat loss occurs from the outer surface of the buildings. However, there are heat gains from the solar radiation, human beings and electrical devices. But all of them were not taken into account in calculation of the heat load.

To utilize the geothermal fluid to its maximum, the leaving temperature of the fluid should be kept to as low as possible. To achieve this goal, it is necessary to control the radiator return water of the buildings. The control of the radiator return water temperature is done with self-operating, flow, temperature and pressure difference control valves.

Radiator discharge water control means controlling the return to the Heat Center. The less the return water temperature entering the heat exchanger in the Heat Center, the more heat extracted from geothermal fluid, and the more the geothermal fluid is utilized. The circulation pump is controlled by means of a PC network that regulates pumping of the required amount of water to the city.

In the Balçova geothermal district heating system, the newest technologies are used and the operational costs are very low. This system has operated successfully since 1996 and supplies 11,500 residences of equivalence heating. Be-sides, these new approaches, the following technical develop-ments have caused a large decrease in the operational costs.

Heat consumption in GDHS is variable according to the outdoor temperature. Thus, the energy amount supplied to the consumers should also be variable. This variability could be obtained by holding the water temperature to and from the consumers constant, and providing a variable flowrate instead of variable temperature. So, this system prevents damage to the pipes due to temperature variations, and the system replies immediately and provides 100% to the different heat demands of the consumers resulting in much lower operational costs.

To save electricity, geothermal water and chemicals, the related pumps are controlled by variable speed drives. Due to a good operation plan and full automatic control of the variable-speed drive pumping system, the electricity consumption rate decreases to 63% annually.

Heat Exchangers

Heat exchangers are usually the major units of equipment for direct-use applications. All standard types of heat exchangers, shell-and-tube, plate, finned tubes, and downhole heat exchangers can be used for geothermal applications. But, there are several conditions, which must be considered when designing and selecting equipment for geothermal supplies and the different utilizations.

Usually, it is not possible to use the geothermal fluids directly in district heating systems due to their chemical composition and/or their temperature. For this reason, heat exchangers should be used. Heat transfer with a minimum approach temperature, directly decreases the initial investment and operation costs.

Plate-type heat exchangers have many advantages compared to the shell-and-tube, finned tube and downhole heat exchangers:

- Plate-type heat exchangers are especially useful for low-temperature (40-50°C)(104-122°F) heating app-lications. For example, in Kirsehir GDHS, the geo-thermal production temperature is 54°C (129°F). In this case, shell-and-tube heat exchangers could not be used to transfer the heat energy to the clean water, as the discharge temperature of the geothermal water had to be a minimum 7°C (13°F) higher than the city circuit water temperature. So, instead of having a city circuit of 50°C/40°C (122/104°F), the geother-mal water discharge temperature would have to be 57°C (135°F).
- Shell-and-tube heat exchangers have maintenance problems, require large flow volume and temperature difference compared to plate type heat exchangers.
- As the price of electricity in Turkey is high, heat pump utilization is not widespread. The plate-type heat exchangers are suitable for using low-temperature geothermal fluids. For this reason, they constitute an important component of geothermal applications in Turkey.

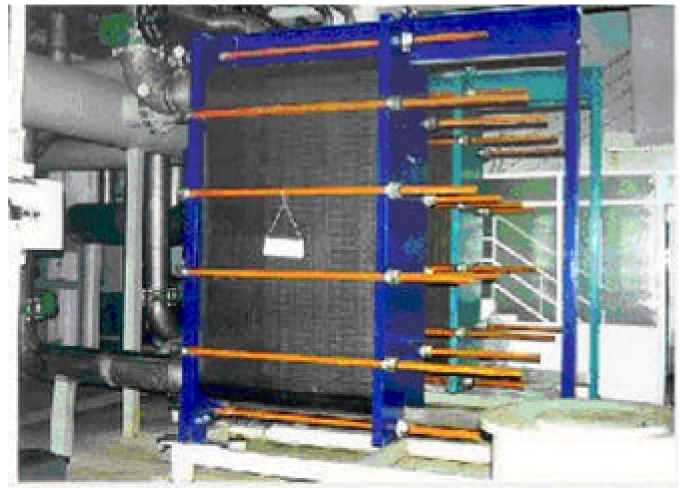

Figure 1. ***Plate type heat exchangers used in Izmir, Balcova Geothermal District Heating System.***

- By using 70°C (158°F) temperature geothermal water and using a shell-and-tube heat exchanger, the geothermal water demand would increase to 2-3 times and the city circulation flowrate 2-6 times. This case also increases the initial investment and operation costs.

Downhole Pumps

Many geothermal reservoirs are non-artesian, so that the wells will not produce without pumping. Deep well pumps are used to bring geothermal fluids to the surface, to the main heat exchanger, and to the reinjection well. In addition, there are many deep well pumps installed in artesian wells to increase the flowrate, to prevent high gas concentra-tion in the wells, and to keep the geothermal water temperature and production pressure above the boiling point pressure line as liquid phase. These pipes are used to pressurize the water so that it will not boil nor release gas.

The benefits of deep well pumps in general are temperature and production control, minimizing of scaling in the well which require less chemicals, and no steam loss or air pollutants (CO_2, SO_2, NO_x) to the atmosphere.

The benefits of the downhole pumps are better generating capacity and no reduction in production flowrate due to well scaling, increased production temperature from each well by lowering of the water level, higher production temperature with no loss to the atmosphere and surface, and better energy recovery.

Piping System

Piping systems used for transportation of the geothermal fluids and energy distribution system in the city have two main differences in comparison to conventional piping systems. The first difference is that these pipes are buried directly in the ground and no concrete anchor blocks are needed. The main advantage of this in Turkey is, as the substructure in the cities already exist, it would be rather difficult, time consuming and costly to put in a more complicated conventional system. As a result, a decrease about 10-20% of total investment cost is obtained.

The second main difference is that these pipes (fiberglass reinforced polyester and welded steel pipes) do not require any expansion joints, as the designed and applied expansion strength due to thermal stress remains below the pipe resistance. The engineering design and application of these pipes requires an expert knowledge about this subject. Fiberglass reinforced pipes are produced 100% locally (except raw material). Fiberglass reinforced resin (FRP) composite material technology has developed very fast in the world.

Figure 2. Pre-Insulated Steel Pipes (Casing is FRP) for geothermal heating network distribution.

Optimization is necessary to select the inner pipe material and the resin types. Up to 90°C (194ºF) temperature, local produced FRP can be used. In the cases where the FRP utilization is not suitable due to temperature and optimization reasons, inner pipes, insulation material and the jacket pipe can be used in different combinations.

Figure 3. Pre-insulated FRP pipes for geothermal water transportation.

In order to prevent corrosion in closed circulation water networks in steel pipes, a special corrosion inhibitor is used. The insulation is covered with a strong jacket pipe. To protect the pipes and the insulation material from leakage, these pipes are installed with a detecting system and controlled continuously from the Heat Center. Also, the insulated steel pipe system requires less maintenance.

CONVERSION OF CONVENTIONAL HEATING SYSTEM TO GEOTHERMAL HEATING SYSTEMS IN TURKEY

The people in Turkey usually live in apartment houses in cities and villages. In these buildings, the heating system is formed by means of a boiler–radiator system for each building or each flat with its own heating system. In Turkey, the heating systems, other than geothermal heating systems, are designed with a 90/70°C (194/158ºF) temperature interval. Local or imported coal, fuel oil or natural gas is usually used in these heating systems. The prices of these fuels are determined in international market conditions and passed on to the consumers.

District heating systems are now being converted to geothermal use in Turkey. Below are the important points related to this conversion:

1. Since the price of geothermal heat is held constant for the entire year, geothermal heating projects are, thus, supported by the consumers.

2. The existing heating systems are connected to geothermal district heating systems directly.
3. The radiator area designed according to 90/70°C (194/158ºF) temperature interval, has not caused any problem at temperature intervals like 80/40°C, 80/45°C and 70/50°C (176/104, 176/113, and 158/122ºF). The result is that the radiator areas have been designed larger than necessary.

The amount of energy required in geothermal district heating systems is determined according to the parameters such as regional meteorological data, physical characteristics of the buildings, and system design temperature.

In Turkey, the main design criteria for heat loss calculations in buildings are expressed by standards TS 825 and TS 2164. According to these norms, Turkey is divided into three main climate regions. The values of the outdoor design temperatures have been given for all the settlement units of these three regions. Dimensions of the heating system should be determined in accordance with these values. Generally, this leads to large radiator surface areas. The velocity of water circulating in the radiator is one of the parameters that determine the radiator heat transfer constant. Thermodynamically, heat flows from a high to a low-temperature state. For buildings, that is, heat loss is a function of difference between inside and outside temperatures. To determine the heat loss of buildings individually, the average of the lowest temperatures is taken into account. This average value compared to the outdoor temperature of the district heating systems is a much lower value. This over design provides an advantage in conversion of classical heating systems to geothermal heating systems. On the other hand, the number and the usage of electrical devices show an increase due to the design of conventional systems. This might be an advantage for the conversion process. The best example for this is Kirsehir geothermal district heating application.

ECONOMICAL ASPECTS

The factors, which lead to more economic geothermal district heating investments, are as follows:

- Using of heat demand based on experimental results.
- Temperature control in the supply and return lines for energy saving.
- Utilization of plate type heat exchanger.
- Utilization of buried pre-insulated piping system networks.
- Utilization of production and circulation pumps with the variable-speed drive.
- Utilization of deep well pumps.

As a result of suitable technology selection and professional application, the investment amount per residence of the GDHS is about 1,500--2,500 US$ in Turkey (radiator installation in the residence excluded). The geothermal district heating investments are paying back in 5-8 years in the conditions of Turkey. Moreover, they have a relatively low initial and operation costs and low selling price of heat in comparison to conventional fuels (coal, lignite, fuel-oil etc.). As an example, the heating price of geothermal is only 1/4-1/7 of heating with natural gas in Turkey.

By applying these technical developments to the GDHS in Turkey, the heating fees (2001 heating season) varies from 14 US$ - 29 US$ (February 2001).

The construction costs for a heating system is 300 US$/kW (installed capacity) in the conditions of Turkey.

About 30-50% of the investment has been paid by the consumers as a connection subscription fee, like a capital investment. As a result, the economy of GDHS investments is in a better position.

RESULTS

Geothermal space heating capacity reached 52,000 residences equivalence (493 MWt) today, with 23% average annual growth, since 1983. This development depends on the following important factors:

- Development and realization of suitable geothermal district heating systems according to Turkey's conditions.
- The participation of the consumers in the geothermal district heating investments by about 30 to 50% without any direct financing refund. No foreign credit has been used in geothermal district heating investments in Turkey yet.
- The introduction of environmental friendly, cheap and comfortable geothermal district heating to the Turkish people.
- The transition from brown lignite stove heating utilization to geothermal district heating systems has increased the social living standard of the people. Therefore, it is a kind of a revolution in Turkey.
- Geothermal heating is about 65% cheaper than natural gas heating in Turkey.
- In Turkey's conditions, the amount of existing district heating investments is equal to three years saving of imported oil.
- 31,500 MWt geothermal heat potential is estimated for Turkey.
- 170 geothermal fields exist in Turkey, which 500 MWe power production and 3,500 MWt (500,000 residences) space heating is targeted for the year 2010.
- With the existing geothermal wells 2,600 MWt geothermal heat capacity is proven.
- Government, municipalities and the people know geothermal energy as an environment-friendly type of energy.
- Due to the reinjection failure in Kizildere, geothermal power plant has created a negative outlook in Turkey for geothermal power production.
- The geothermal district heating investments are supported by the consumers and the people are applying pressure on municipalities to realize and organize geothermal district heating systems in Turkey.

- It is expected that the geothermal power production investment starts and achieves developments with the geothermal law which is expected to be effective this year.
- Turkey's main target is to heat 30% of the residences in Turkey to save imported oil, natural gas and coal.
- Turkey's goal is to be one of the first three countries in the world in geothermal heating applications in the year 2010.
- The number of the existing wells is not enough for Turkey, which has 170 geothermal fields. A minimum of 100 wells yearly should be drilled in Turkey. Turkey is ready for international cooperation and finance for geothermal exploration and field development projects.
- By using experimental results instead of constant heat load values, the initial investment and operation cost is being reduced.
- By heating 52,000 residences equivalence geother-mally in Turkey 516,000 tons of CO_2 emission has not been discharged to the atmosphere. It is equal to canceling 310,000 cars from traffic (as peak emission amount in January).
- Usually in Turkey, the people are using brown lignite coal stoves for heating purposes in their houses. With the geothermal district heating system, which brings radiator heating to their houses, their living standard has been improved.

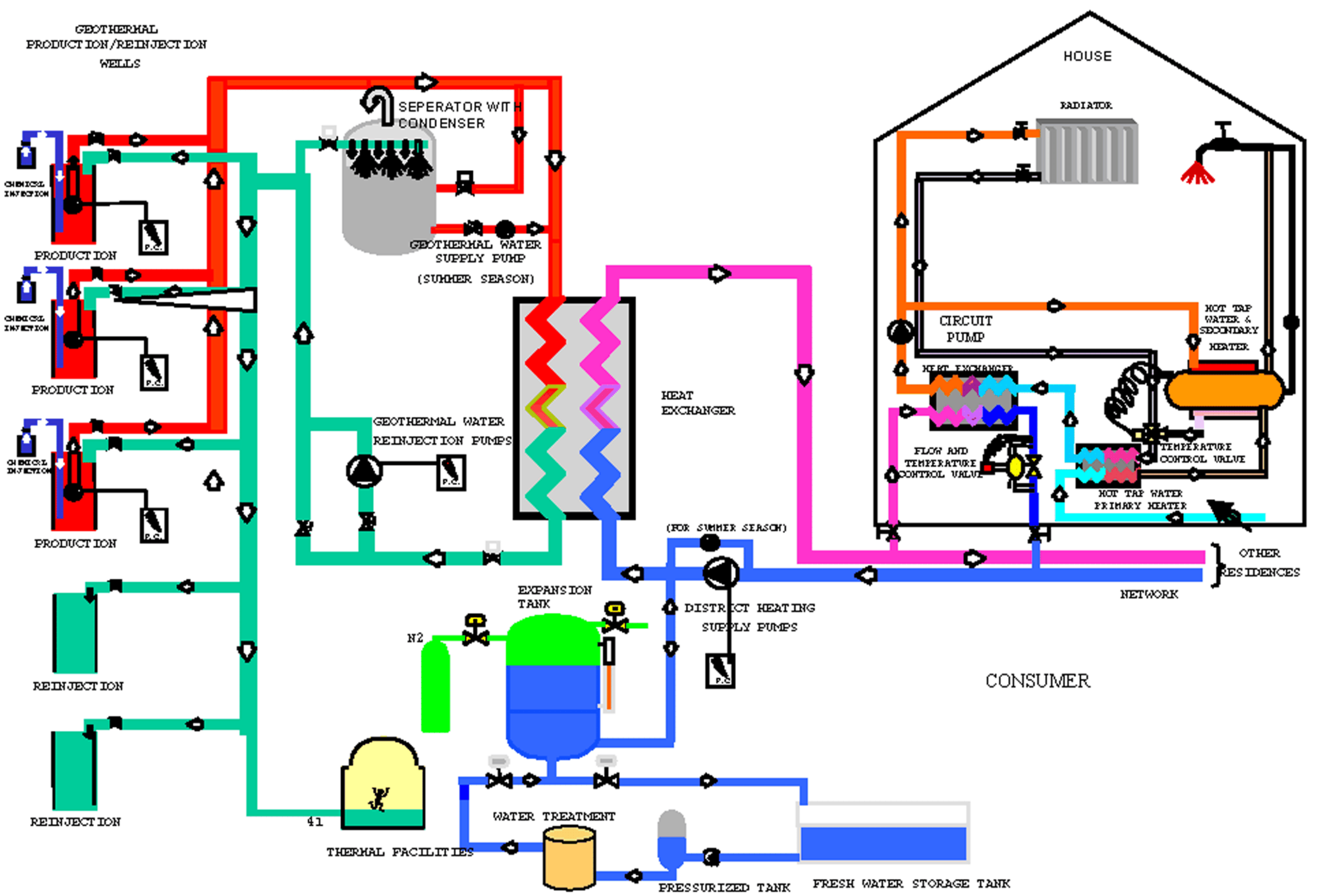

Figure 4. Example of a geothermal district heating system flow diagram (Izmir).