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 is achieved in geothermal direct-use applications with 52,000 residences equivalence 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 of nearly 300,000 residences equivalence geothermal district heating has been completed.

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

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

The district heating system applications have been 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 technical and economical aspects.

Annually average 23% increment of residence connection to GDHS has been achieved since 1983 in Turkey.

1. 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 radiator-heating system, some of them have not. For this reason, the conversion project should be taken into consideration.

2. TECHNOLOGICAL ASPECTS

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

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

15 year experience gave the result that real heat loads are approximately three times lower than the heat loads evaluated by theoretical methods. The main reasons for those are as the following:

a.) The used outside design daily average temperatures are increasing with time and only this causes to a excess calculation of heat load by 20%, which increases the initial cost amount of the investment.

b.) The theoretical heat load evaluation methods are considered as constant, but in reality the heat loss and gain are variable procedures. The main differences in heat load calculations are resulting from that the variable effects are not taken into account.

c.) Besides heating application also domestic hot water supply exist in geothermal district heating systems. In the classical calculation methods domestic hot water load is not added directly to the heat load. This has two reasons: The way of maximum utilization of the geothermal fluid is to decrease the return geothermal water temperature to minimum level. The return temperature from the heating (radiator) is about 40°C. The domestic hot water temperature is about 45-50°C. To heat the network water from 15°C to 43°C no additional load is required and the energy of the discharged water is used for this purpose. Evaluation of the domestic hot water load requires very short time in a day which is not affecting the design load.

d.) In fact, heat loss occurs from the outer surface of the buildings. However, there are heat gains from the solar, human being and electrical devices. But all of them were not taken into account in calculation of the heat load.

To utilize the geothermal fluid in maximum, the leaving temperature of the fluid should be kept in minimum possible. To achieve this goal, it is needed 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 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 leads to pumping of necessary amount of water to the city.

In Balçova geothermal district heating system, the newest technologies are used and the operational costs are very low. This system is operational successfully since 1996 and has reached 11,500 residences equivalence heating. Besides, these new approaches, the following technological developments have been caused to decrease the operational costs enormously.

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 leading variable flowrate use instead of variable temperature. So, this system prevents the damage at the pipes forming due to the temperature differences, replies immediately and 100% to the different heat demands of the consumers and its operational costs are much lower.

To save electricity, geothermal water and chemical substances, the related pumps are running in accordance with the variable speed drivers. Due to good operation plan and full automatic control of variable speed driver pumping system, the electricity consumption rate decreases to 63% annually.

2.1 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, 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 due to their chemical composition and/or their temperature. For this reason heat exchangers should be used. Heat transfer with minimum approaching temperature, decreases directly 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) heating applications. For example, in Kirsehir GDHS, the geothermal production temperature is 54°C. In this case shell and tube heat exchangers could not be used to transfer the heat energy to the clean water. Thus, the discharge temperature of the geothermal water has to be minimum 7°C higher than the city circuit water temperature. So, in case of having a city circuit of 50°C/40°C, the geothermal water discharge temperature has to be 57°C.
- Shell and tube heat exchangers have maintenance problems, require large volume and big temperature difference compared to plate type heat exchangers.
- As the electricity selling price 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 are constituting an important component of geothermal applications in Turkey.

Figure 1: Plate type heat exchangers used in Izmir Balcova Geothermal District Heating System

- By using of 70°C temperature geothermal water, if there would be shell and tube heat exchanger used, the geothermal water demand would increase to 2-3 times and the city circulation flowrate 2-6 times.

  This case increases also the initial investment and operation costs.

2.2 Downhole Pumps

Many geothermal reservoirs are non-artesian, so that the wells will not produce without pumping. Deep well pumps are used to pump geothermal fluids to the surface, main heat exchanger and to reinjection well. Besides, there are many deep well pumps installed in artesian wells to increase the flowrate, to prevent high gas concentration 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 the gas.

The benefits of deep well pumps in general are temperature and production increment, minimizing of scaling in the well which leads to use less chemicals and no steam loss and no 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 water level, higher production temperature and there is no loss to the atmosphere and surface, better energy recovery.

2.3 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 the conventional piping systems. The first difference is that these pipes are buried directly in the ground and no concrete blocks are needed. The main advantage of this case in Turkey is, as the substructure in the cities exist already, it would be rather difficult, time consuming and a high cost event to take the existing substructure into account. 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. Fiber Glass reinforced pipes are produced 100% locally (except raw material). Fiber Glass reinforced (FRP) resin composite material technology develops very fast in the world.

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

Figure 3: Pre-Insulated FRP pipes for geothermal water transportation

Optimization is necessary to select the inner pipe material and the resin types. Up to 90°C 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 variations.

In order to prevent corrosion in close circulation water networks in steel pipes, 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 from the heating center continuously. Also, the insulated steel pipe system requires less maintenance.

3. CONVERSION OF CONVENTIONAL HEATING SYSTEM TO GEOTHERMAL HEATING SYSTEMS IN TURKEY

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

District heating systems have been started with installment of geothermal district heating systems in Turkey. Below are the important points to be notified:

1. As the geothermal heat selling price is held constant for the whole year, the geothermal heating projects are 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 temperature interval, has not caused any problem at temperature intervals like 80/40°C, 80/45°C and 70/50°C. This shows, that the radiator areas had been set 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 buildings, system design temperature.

In Turkey, the main criteria to which the heat loss calculations of buildings should obey individually are expressed in the standards TS 825 and TS 2164. According to these norms, Turkey is divided into three main climate regions. The values of outdoor design temperatures have been given for all the settlement units of these three regions. Dimensions of the present heating instruments should be determined in accordance with these values. Mostly, this leads that the radiator surface should be large. The velocity of water circulating in radiator is one of the parameters that determine the radiator heat transfer constant. Thermodynamically, heat flows from high to low temperature state. For buildings, that is, heat loss is a function of difference between inside and outer temperatures. To determine the heat loss of buildings individually, the average of the lowest temperatures is put 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. At individual heating systems, determined radiator surface is larger. On the other hand, the number and the usage of electrical devices show an increase since the design of conventional systems. This might be an advantage for conversion process. The best example for this is Kirsehir geothermal district heating application.

4. ECONOMICAL ASPECTS

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

1. Using of heat demand based on experimental results
2. Temperature control in the supply and return lines for energy saving
3. Utilization of plate type heat exchanger
4. Utilization of buried pre-insulated piping system networks
5. Utilization of production and circulation pumps with the variable speed driver
6. 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 USD in Turkey (radiator installation in the residence excluded). The geothermal district heating investments are paying themselves 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, heating price of geothermal is only 1/4-1/7 of heating with natural gas in Turkey.

By applying technological developments in the GDHS in Turkey, the heating fees (2001 heating season) varies from 14 USD - 29 USD (February 2001).

The construction costs of heating applications is 300 USD/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 cash in capital. As a result of this, the economy of GDHS investments is getting to better position.

5. RESULTS

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

- Development and realization of suitable geothermal district heating systems according to Turkey's conditions.
- The participation of the consumers to 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 well introduction of environmental friendly, cheap and comfortable geothermal district heating to the Turkish people.
- The transition of brown lignite stove heating utilization to geothermal district heating systems have increased the social living standard of the people. Therefore, it is a kind of revolution in Turkey.
- Geothermal heating is about 65% cheaper than natural gas heating in Turkey.
- In Turkey's conditions, amount of existing district heating investments is equal to 3 years saving of imported oil.
- 31,500 MWt geothermal heat potential is estimated in 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 environment friendly type of energy.
- Due to the fail in reinjection application in Kizildere geothermal power plant has created a negative effect 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 achieve 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 for saving of imported oil, natural gas and coal.
- Turkey's goal is to be one of the first 3 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. Minimum 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 getting very economical.
- By heating 52,000 residences equivalence geothermally in Turkey 516,000 tons of CO_2 emission has not been discharged to the atmosphere. It is equal to cancel 310,000 cars from the traffic (as peak emission amount in January).
- Usually in Turkey, the people are using brown lignite 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 increased.