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# GEOTHERMAL DIRECT USE APPLICATIONS IN TURKEY : TECHNOLOGY AND ECONOMICS

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## ABSTRACT

Geothermal energy is mostly used in direct use (residences, greenhouses, and thermal facilities) and for balneological purposes in Turkey. Today 51.600 residences equivalence is being heated geothermally (493 MWt). Moreover, with the balneological utilisation of geothermal fluids in 194 spa's (327 MWt), the geothermal direct use capacity is 820 MWt. ORME Geothermal Inc has completed the engineering designs of over 150.000 residences equivalence geothermal district heating system (GDHS).

Geothermal district heating distribution networks have been designed according to the geothermal district heating system parameters as there were no large scale district heating system installed in Turkey prior to the GDHS applications. This constitutes an important advantage of GDHS investments in terms of technical and economical aspects.

Due to chemical inhibitors and suitable material selection, use of pumps and heat exchangers, the corrosion and scaling effects of the geothermal fluids are minimised.

Geothermal resource conditions and consumer (residences) characteristics are determining the GDHS design and technology.

## 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 optimisation 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 both 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.

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

Besides direct use of geothermal energy in Turkey, also geothermal power production (Kizildere, 20 MWe installed capacity), integrated liquid carbondioxide and dry ice production (120.000 tons/year) exist.

## 2. TECHNOLOGICAL ASPECTS

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 in two different ways: The first way is to change the supply temperature, which effects piping network worse (piping system cost constitutes ~70 % of the total GDHS investment). Moreover such applications have rather low operation yield and their operational costs are high. It takes a long time to compensate the different heat demands of the consumers in these systems.

The second way is to use variable flowrate instead of variable temperature. In this case the water temperature to and from the consumers is held constant. 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 % per year .

To utilise the geothermal fluid in maximum, its discharge temperature should be kept as low as possible. To achieve this goal, it is needed to control the radiator return water temperature of the buildings which is done with self operating, flow, temperature and pressure difference control valves. Radiator discharge water control means controlling the temperature and flowrate of return water to Heat Centre. The less the return water temperature entering the heat exchanger in the Heat Centre, the more heat extracted from geothermal fluid, and the more the geothermal fluid is utilised. The circulation pump is controlled by means of a PC network that leads to pumping of necessary amount of water to the city.

The benefits of deep well pumps in general are temperature and production increment, minimising 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.

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 utilisation 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 (ORME-Balçova GDHS Feasibility Report, 1996). Evaluation of the domestic hot water load requires only 10 minutes in a day (Isisan,1997).

By using experimental results instead of constant heat load values, the initial investment cost and operation is getting very economical.

### 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 with geothermal fluids. But, there are several conditions, which must be considered when designing and selecting equipment for geothermal supplies and the different utilisations.

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 are used. Heat transfer with minimum loss, 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 and higher than the city circuit water temperature. So, in the 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 $\Delta T$ compared to plate type heat exchangers.

- As the electricity cost is high in Turkey, without using heat pumps, geothermal heating has been utilised by means of plate type heat exchangers.

- By using of geothermal water with 70 °C temperature, 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 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. These pipes are used to pressurize the water so that it will not boil nor release the gas.

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, better energy recovery.

### 2.3. Piping System

Piping systems used for transportation of the geothermal fluids 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 (fibreglass 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. Fibre Glass reinforced pipes are produced 100 % locally (except raw material). Fibre Glass reinforced (FRP) resin composite material technology develops very fast in the world.

Optimisation is necessary to select the inner pipe material and the resin types. Up to 80 °C temperature, local produced FRP can be used. In the cases where the FRP utilisation is not suitable due to temperature and optimisation reasons, inner pipes, insulation material and the jacket pipe can be used in different variations.

In order to prevent corrosion 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 centre continuously. Also, the insulated steel pipe system requires less maintenance.

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

In Turkey, the city district heating system applications has been started by establishing of geothermal district heating systems.

At districts that are heated by conventional heating systems, the decision of conversion into geothermal heating systems depends on low investment and operation costs of the new system. Parallel to the increase of block type flats, ordinary heating system applications are changing from single houses to apartments. This type of application mostly consists of a general heating apparatus and a heating system with water based radiator.

Although the temperature of system design and the size of the project partially depends on the type of the fuel at classical heating systems, they are generally under the control of the contractor. On the other hand, in geothermal systems, the contractor dependant on the physical properties of the geothermal resource. Therefore, type and dimension of temperature units at district ought to be revised according to the geothermal design criteria. In Turkey, most of the present fossil fuel heating systems are equipped with heating apparatus and radiator which are operated individually at a cyclic temperature of 90/70 °C.

Heat load of a space, whatever the amount is, is satisfied by a heater. There will not be any problem in the application, at conversion stage, when the temperature of the geothermal water is equal to or higher than the design temperature of classical heating system. If the source temperature is lower than the design temperature of the present heating system, it is needed to be determined whether a surface increase is required in the heating elements or not, or a temperature peaking should be considered.

The heat transfer surface of radiator depends on the inlet and outlet temperatures of water.

The amount of energy required in geothermal district heating systems is determined according to the parameters such as regional meteorologic 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 Kirşehir geothermal district heating application.

## 4. GEOTHERMAL DISTRICT HEATING APPLICATIONS

Some applications of the geothermal district heating from various parts of Turkey are described below (Figure 1):

**Kirsehir Project (18 MWt) :** Kirsehir geothermal district heating system, where 54 °C temperatured geothermal fluid is used (without heat pump), has been realised in a very economical way. This system includes peaking system, which is used for maximum 2 weeks in a year during the peak load time in winter. The reinjection pipes, some part of the city network return pipes are not insulated. The total cost of 1 kWh heat in Kirsehir GDHS is only 0,65 cent. 1800 residences are heated in Kirsehir since 1994.

As the production temperature of the geothermal fluid is 54 °C in Kirsehir, it is impossible to use shell and tube heat exchangers. But, by using plate type heat exchangers, the heat energy is transferred to clean water in Kirsehir and the return temperature of the geothermal water is decreased down to 41 °C. With the use of 200 kg/s geothermal water 10,8 x $10^6$ kcal/h heat energy is obtained.

**Sandikli Project (45 MWt) :** The geothermal water transportation pipeline of Sandikli GDHS is 9318 m and the heat centre is located 90 m above the production wells. Downhole pump is used for geothermal production, where the dynamic level is approximately 20 m. With the used technology maximum 2 °C temperature loss exist during this long transportation pipeline. The geothermal fluid is produced by downhole pump, whereas the downhole pumps are working with variable speed drivers. 1600 residences are heated in Sandikli since 1998. The house connections are continuing.

Sandikli GDHS is a good example for a good designed variable speed driver system. The location and position of the pumps are as follows:

a. Pumping station (in 100 m distance to the geothermal wells)
b. Booster station (in 4600 m distance to the geothermal wells, +35 m level)
c. Pumping station (inside the heating centre, in 4618 m distance to the booster station, at + 95 m level)

**Kizilcahamam Project (25 MWt) :** Due to the geography of Kizilcahamam landscape, there exist very frequent elevation differences. For this reason two heat centres and substations were built in Kizilcahamam geothermal district heating system. The geothermal water temperature used is 80 °C in average and totally 2500 residences equivalence are heated geothermally in Kizilcahamam since 1995.

**Izmir Project (100 MWt) :** In Izmir 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 more than 10.000 residences equivalence heating in Balcova and Narlidere Towns. The residence connections to the system will continue until 15.000 residences equivalence.

In Izmir GDHS variable speed drivers are used in every downhole and supply pump. This leads to a very low electricity cost of heating, 1 Million kcal requires 26 kWh electricity that costs only 2,5 USD. The used downhole pumps are working at 140 °C.

We use two types LSP (USA origin Lineshaft Pumps) deep well pumps in Turkey. For the shallow wells, the local manufactured pumps are installed (Installation depths are about 70 – 80 m). For the deep wells, Icelandic design deep well pumps are needed. (Installation depths are about 150 – 200 m, capacity as 40-45 kg/sec, and operating temperature is 150 °C (ORME-Baçova GDHS Feasibility Report, 1996), (Figure 2).

By utilising deep well pumps in Balcova, a large-scale GDHS could be realised. Before the application of deep well pump, downhole heat exchangers were used in this geothermal field and totally 6 MWt was produced from 9 shallow wells. To date, we produce 60 MWt from 3 shallow and 4 deep wells by means of downhole pumps.

In order to prevent scaling of calcite, scale inhibitor according to European Specification ISO 9002, has been injected into the well below the pump by using special chemical injection line.

Moreover, Dokuz Eylül University Medical Faculty and Campus, 100.000 $m^2$ greenhouses and Thermal Facilities are heated from Balçova geothermal field (total 131 MWt).

**Çesme Project (10 MWt) :** In Çesme; thermal tourism and geothermal heating has been integrated and the very salty and corrosive geothermal water (TDS is around 36.000 ppm, where 20.000 ppm is Cl) will be transported by single pipe to the hotels and residences.

The geothermal water transportation and city distribution network pipelines buried directly under the soil are resistant against corrosion (economic life is 30 years), friction resistance is very low, heat insulation is very high.

In four applications in Turkey (Rize-Ayder, Sivas Sicak Çermik, Afyon-Oruçoglu Thermal Facilities and Haymana Mosque Heating) the geothermal fluid has been used as low as 40-45 °C (without heat pumps). In Haymana mosque heating, due to the suitable chemical properties and conditions of the geothermal water, no chemical inhibitors, no pumps and no heat exchangers are used.

## 5. ECONOMICAL ASPECTS

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

1. Using of heat loads based on experimental results
2. Temperature control in the supply and return lines for energy saving
3. Utilisation of plate type heat exchanger
4. Utilisation of buried pre-insulated piping system networks
5. Utilisation of production and circulation pumps with the variable speed driver
6. Utilisation of deep well pumps

As a result of suitable technology selection and professional application, the investment amount per residence of the GDHS is about 1500 - 2500 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 (ORME-Balçova and Sandikli GDHS Feasibility reports, 1996, 1995). 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 those of heating with natural gas in Turkey.

By applying technological developments in the GDHS in Turkey, the heating fees (1999/2000 heating season) varies from 15 USD-32 USD. For example, in Izmir the selling price of heat is 1,4 cent/1000 kcal (Acc. January 2000, 1 USD = 560.000 TL).

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. Moreover, the consumers are receiving the benefit of not to pay anything for heating for 1-2 years after subscribing to the geothermal district heating system.

## 7. ENVIRONMENTAL AND SOCIAL ASPECTS

By heating 51.600 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.

## 8. RESULTS

Turkey is one of the 10 countries with the richest geothermal potential of the world. Although, geothermal energy has a wide utilisation area according to different temperatures, its utilisation area in Turkey is mostly district heating. The most important point is that city based district heating systems in Turkey has been installed by means of geothermal utilisation.

While converting classical heating system to geothermal heating system, it is required to compare the design criteria of these two systems and after deciding on the conversion procedure to perform the operation. Otherwise, while some buildings are overheated, some are not heated sufficiently. The management structure of permanent operation period should be formed at start up period of operation.

Correct design, application and suitable technology selection are bringing economy to the initial investment and operational costs of the GDHS.

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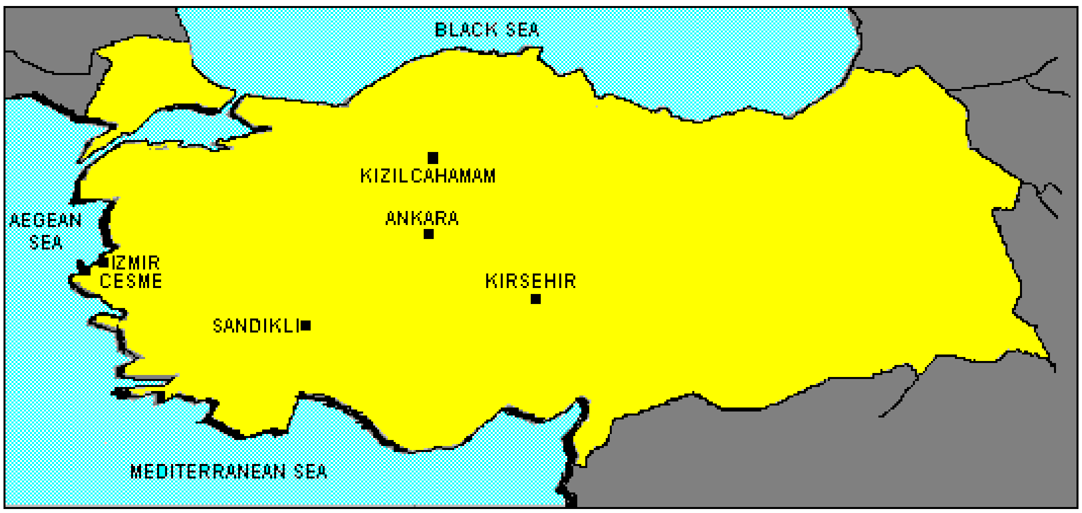


Figure 1: Some geothermal district heating systems in Turkey (those which are explained in the text)

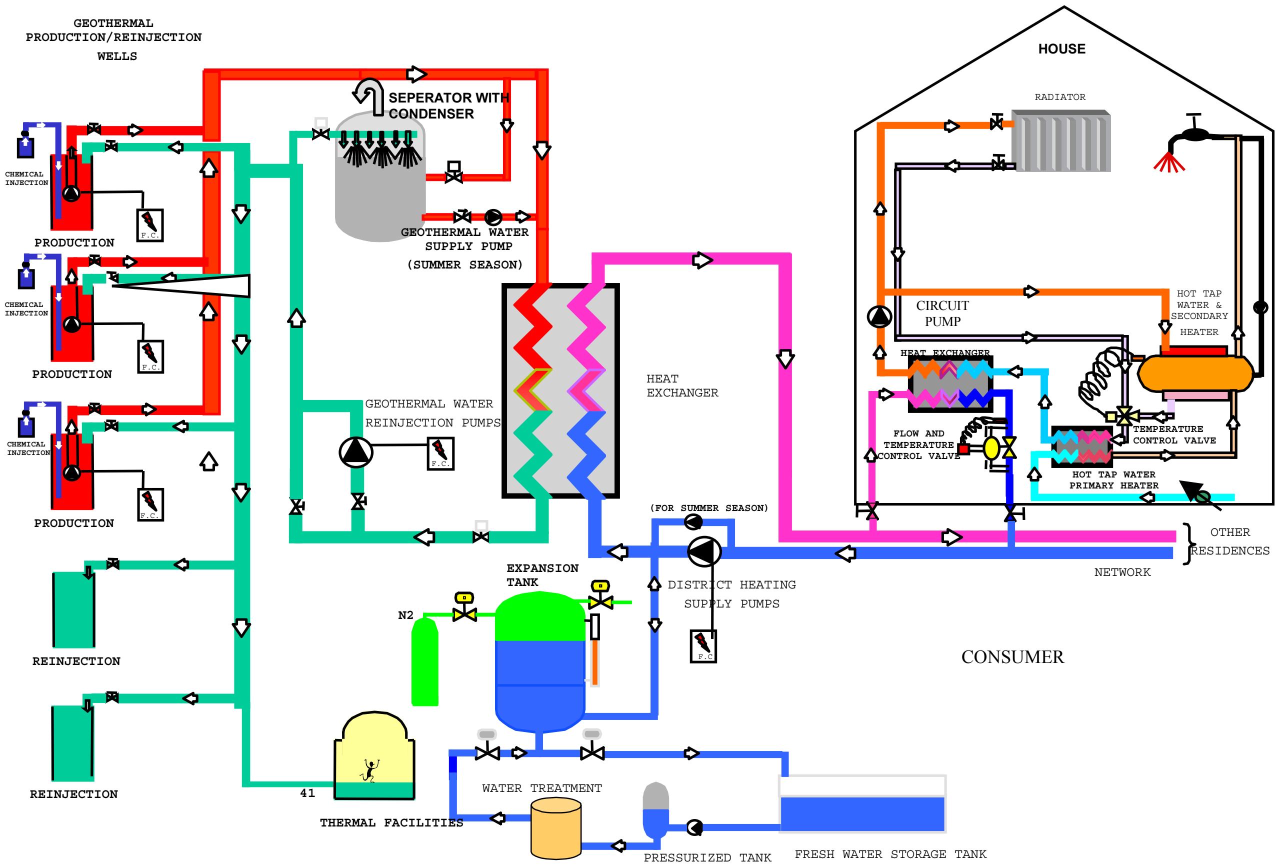


Figure 2 : Izmir Geothermal District Heating System Flow Chart