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EXPLOITATION AND DEVELOPMENT OF GEOTHERMAL DISTRICT HEATING SYSTEMS IN TURKEY

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ABSTRACT

The widespread use of thermal springs in Turkey started with the Romans for bathing purposes. 170 geothermal fields have been discovered by MTA. With the development of technology, utilization areas are increased and widened and geothermal fluids have been started to be used mainly in district heating, in power production, greenhouse heating, hot tap water supply, liquid CO_2 and dry ice production in Turkey.

1. INTRODUCTION

The first geothermal well was drilled in 1963 in Balcova geothermal field. The first geothermal heating application started in 1983 with the geothermal heating of Balcova Thermal Facilities and Dokuz Eylul Medical Faculty and Campus heating with downhole heat exchanger. Since then many important geothermal fields like Kizildere and Germencik high temperature geothermal fields have been discovered. The first geothermal power production started in 1984 in Kizildere with 20,4 MWe installed capacity. In 1987, the first city based geothermal district heating system started to operate with 1400 residences capacity in Gonen City. Now, the number of the heated residences in Gonen has reached 3400 residences, where, thermal facilities heating and hot water supply for the tanneries are integrated to the system.

Most of the development is achieved in geothermal direct-use applications in Turkey with nearly 57.000 residences equivalence geothermal heating (540 MWt) including district heating, thermal facilities and nearly 500,000 m^2 geothermal greenhouse heating. 195 spas are used for balneological purposes (327 MWt) in Turkey. Engineering design of nearly 300,000 residences equivalence geothermal district heating has been completed. Total direct use installed capacity is 867 MWt.

Today, 40-45 °C temperatured geothermal fluids are used for space heating in Turkey without heat-pump.

2. DEVELOPMENT

The people in Turkey are living usually in apartment houses. 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 as fuel types in these heating systems. The prices of these fuels are determined in international market conditions and reflected to the consumers.

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.

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

1- As the geothermal heat selling price iheld 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 in original had been set larger than necessary

The rapid development of geothermal district heating systems in Turkey is depending on the following factors:

1. Development and realisation of suitable geothermal district heating systems according to Turkey's conditions.
2. The participation of the consumers to the geothermal district heating investments by about 60 % without any direct financing refund. No foreign credit has been obtained in geothermal district heating investments in Turkey yet.
3. The geothermal district heating investments are supported by the consumers and the people are applying pressure on Municipalities to realize and organise geothermal district heating systems in Turkey.
4. The well introduction of environment friendly, cheap and comfortable geothermal district heating to the Turkish people.
5. The transition from 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.

Because of the high temperature, long mean time between the failures, low repair cost and availability of spare parts (most of them) as locally LSP system (line shaft pump) has been used in geothermal wells. In LSP system, filtered geothermal water has been used as a lubricant which is supplied to the line shaft bearings through the enclosing tube.

Water lubrication system has been selected instead of oil lubrication system, because of the fact that, some of the geothermal brine is being used for balneological purposes after heating the supply water by means of heat exchangers (40-50°C).

16 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:

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

2. 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.

3. 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.

4. 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.

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 63% annually.

In order to prevent corrosion and scaling in the well, geothermal water transportation line and close circulation networks, corrosion and scale inhibitors are used with water treatment plant and pH control system.

Heating has been done mostly by coal and other fossil fuels in Turkey. This resulted in serious air-pollution in big cities like Kirsehir (was the third mostly air polluted city of Turkey). With the use of geothermal district heating, air pollution has been reduced in important amounts.

Due to geothermal district heating systems, the areas used for storing the fuels have been emptied, these areas could be used for more useful purposes.

The last two big earthquakes happened in 1999 in Turkey have proven, how safe the geothermal energy is, by preventing fire and similar harmful events during and after the earthquake.

Due to these advantages the worth of geothermaly heated residences are increased incredibly.

Geothermal heating fee including hot tap water varies from 13 –26 $/month for the existing geothermal district heating systems in Turkey. As this fee remains the same for the whole year in Turkish Lira basis, this brings a big economical advantage to the consumers if compared with other fuel types.

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.

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.

3. SOME GEOTHERMAL HEATING APPLICATIONS IN TURKEY

3.1. Gonen Geothermal District Heating System

Start up Year : 1987
Capacity : 3400 residences equivalence, thermal hotels and Tanneries, 32 MWt
Geoth. Water Temp. : 80 °C

3.2. Simav Geothermal District Heating System

Start up Year : 1991
Capacity : 3200 residences equivalence, thermal complex and hotels, 25 MWt
Target Capacity : 6500 residences heating
Geoth. Water Temp. : 137 °C

3.3. Kirsehir Geothermal District Heating System

Start up Year : 1994
Capacity : 1800 residences equivalence 18 MWt

Target Capacity : 8400
residences heating
Geoth. Water Temp. : 57 °C

3.4. Kizilcahamam Geothermal District Heating System

Start up Year : 1995
Capacity : 2500
residences equivalence 25 MWt
Geoth. Water Temp. : 80 °C

3.5. Balcova Geothermal District Heating System

Start up Year : 1996
Capacity : 11.500
residences equivalence 100 MWt
Target Capacity : 15.000
residences heating
Geoth. Water Temp. : 137 °C

Dokuz Eylul University Medical Faculty and Campus are heated from Balcova geothermal field since 1983 with 1100 residences equivalence capacity.

3.6. Narlidere Geothermal District Heating System

Start up Year : 1998
Capacity : 1500
residences equivalence 12 MWt
Target Capacity : 5000
residences heating
Geoth. Water Temp. : 137 °C

3.7. Sandikli Geothermal District Heating System

Start up Year : 1998
Capacity : 2000
residences equivalence 45 MWt
Geoth. Water Temp. : 70 °C

3.8. Salihli Manisa Geothermal District Heating System

Start up Year : 2002
Capacity : 1500
residences equivalence
Target Capacity : 20.000/24.000
residences heating and 2000 residences
cooling (air-conditioning) 120 MWt
Geoth. Water Temp. : 94 °C

3.9. Thermal Facilities Heating and Balneological Utilization

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Some of the spa & thermal curing centre applications in Turkey are as follows :

- Balcova Thermal Facilities are heated with 70 °C geothermal water. Capacity is 7 MWt.
- Balcova Thermal Princess Hotel is heated with 125 °C geothermal water. Capacity is 5 MWt.
- Gediz spa & motel facilities are heated by 78°C geothermal water. Capacity is 200.000 kcal/h.
- Floor heating system was applied in Havza spa. Heated area is 1000 m^2 and geothermal water is 54°C. Total capacity is 600.000 kcal/h.
- Rize Ayder thermal curing center is heated with a geothermal water of 54°C. Altitude of this facility is 1700 m above sea level.
- Two mosques in Haymana are heated by 43°C geothermal water. In this system operation cost is zero. Since geothermal is producing in artesian mode, electricity cost does not exist. Due to the characteristics of geothermal fluid, scale inhibitor is not used. Floor heating system is fed by geothermal water directly and plastic pipes were used. If all these benefits are added up, with a small investment cost fully free of charge heating system has been obtained.
- Sivas Sicak Çermik Spa is heated by 46°C geothermal water. Area of heated space is 2100 m^2. In addition, geothermal water is used in sanitary hot tap water production and in greenhouses.
- Afyon Gazligöl Spa facilities uses 68°C geothermal water for heating and curing purposes. System capacity is 550.000 kcal/h.
- Orucoglu Thermal Resort uses 48 °C geothermal water for heating and curing purposes.
- Cankiri-Cavundur Thermal Facility uses 56 °C geothermal water for heating and balneological purposes.
- Bolu-Karacasu Thermal Facilities uses 44 °C geothermal water for balneological purposes.

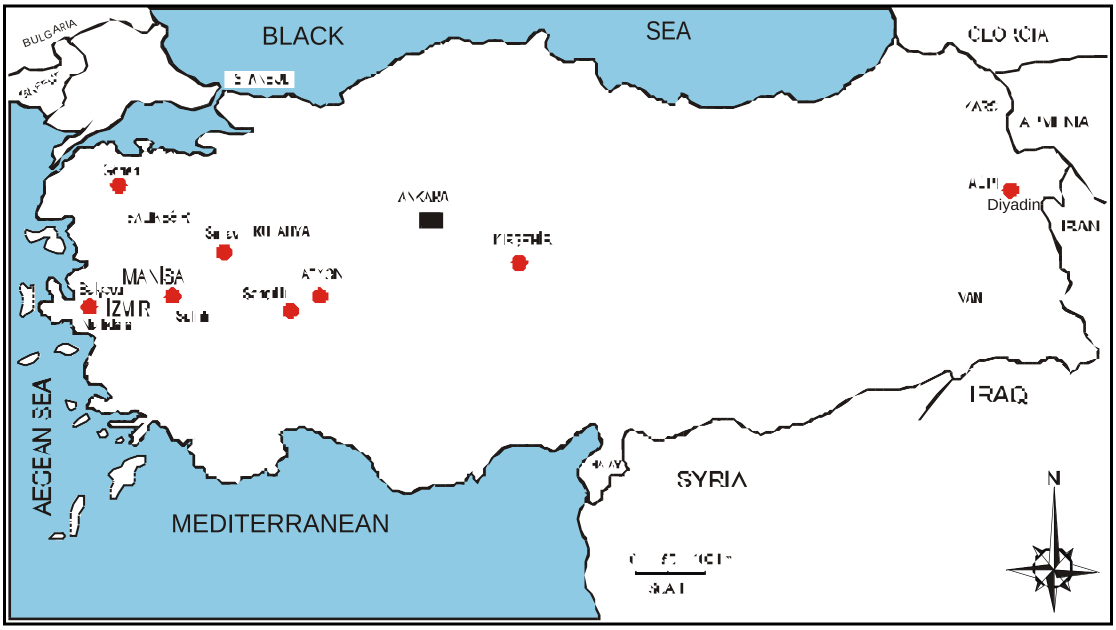

Figure 1: City based geothermal district heating systems in Turkey

3.9. Greenhouse Heating

The total area of greenhouses heated by geothermal energy is 500.000 m^2 in Turkey. In Sanliurfa city nearly 250.000 m^2 geothermal greenhouses exist, where the yield obtained from the greenhouses is exported to Europe.

4. GEOTHERMAL POTENTIAL AND FUTURE PROJECTIONS

With the existing geothermal wells and springs, the proven geothermal capacity calculated by MTA is 3132 MWt (exhaust temperature is assumed to be 40 °C). The geothermal potential is estimated as 31,500 MWt. Up to now nearly 420 geothermal explanatory and production wells and 200 gradient wells have been drilled in Turkey.

As it will be considered, the number of geothermal production wells is too few if compared to the high geothermal potential of Turkey. Most of these wells have been drilled by MTA and financed by the Governorships, Municipalities and their companies, which constitutes 66.2 % and followed by MTA with 16.5 % and 11.7 % Private.

Until 2010, nearly 1 million residences are planned to be heated geothermaly. With the total geothermal potential, it is possible to meet 5 % of the electricity needs and 30 % of the heat energy demand of Turkey. By taking the weighted mean of these values, 14 % of Turkey's energy demand for electricity and heating could be met by geothermal energy.

Turkey's total geothermal power production capacity has been estimated as 2000 MWe and 2010 geothermal electricity production target is 500 MWe.

RESULTS

Geothermal space heating capacity is nearly 57.000 residences equivalence (540 MWt) today. It was started with total 1850 residences equivalence heating in 1983. This means an important development in 19 years. This development is depending on the following facts :

- 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 - 60 % 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 with punlic open meetings and conferences.
- 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 1/4 - 1/7 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 3500 MWt (500.000 residences) space heating is targeted for the year 2010.
- With the existing geothermal wells 3132 MWt geothermal heat capacity is proven.
- 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.
- 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 57.000 residences equivalence geothermally in Turkey 565.000 tons of CO_2 emission has not been discharged to the atmosphere. It is equal to cancel 340.000 cars from the traffic (As peak emission amount in January).

2. GEOTHERMAL POTENTIAL OF TURKEY

Turkey is located on the Mediterranean Sector of Alpine-Himalayan Tectonic Belt. At the same time, this young belt is an important geothermal potential. Geothermal fields are caused from the graben systems of Western Anatolia, widespread volcanism and tectonism of Central and Eastern Anatolia and right lateral and strike slip North Anatolian Fault Zone. Distribution of thermal and mineral water resources has developed through the zones subjected above. The first geothermal researches and investigations in Turkey started by MTA in 1960's. Approximately 170 geothermal fields which can be useful at the economic scale and about 1000 hot and mineral water resources (spring discharge and reservoir temperature) which have the temperatures ranged from 20-242 ^{o}C, have been determined (Figure 1). As a result of the researches and the drillings carried out by General Directorate of Mineral Research and Exploration (MTA), the temperatures and the flow rates of thermal sources in geothermal fields have been increased very seriously (Simsek, 1995, Batik et. al., 2000).

Upon this, 170 geothermal fields have been discovered by MTA, where 95% of them are low-medium enthalpy fields, which are suitable mostly for direct-use applications. The portion of the wells drilled by MTA in the total number of wells is 305. Moreover, the first geothermal well was drilled in 1963 and the number of the wells drilled increase after 1982.

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

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.