ANALYSIS OF GEOTHERMAL CIRCUIT OF BALÇOVA – NARLIDERE GEOTHERMAL DISTRICT HEATING SYSTEM

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ABSTRACT

The aim of this study is to determine the performance of the Balçova – Narlıdere District Heating System and to reveal the critical points. During this study, with the help of Balçova Jeotermal Company's database, Balçova – Narlıdere Geothermal District Heating System is simulated in Pipelab Geothermal District Heating System simulation program and the pressure and temperature distributions of the system are determined. In the light of these analyses, the critical points of the Balçova – Narlıdere Geothermal District Heating System are pointed out with the possible reasons and solution alternatives are discussed. Meanwhile, with the flow meters which are assembled to two apartment buildings chosen in the system, the amount of the fluid and the energy consumed by the users are observed. The observed values are compared with the calculated values according to the outdoor temperatures.

ÖZ

Bu çalışmanın amacı Balçova – Narlıdere Jeotermal Bölge Isıtma Sistemi'nin performansının belirlenmesi ve kritik noktalarının açığa çıkarılmasıdır. Çalışma esnasında Balçova – Narlıdere Jeotermal Bölge Isıtma Sistemi, Balçova Jeotermal Şirketi veri tabanından yararlanılarak PIPELAB bölge ısıtma sistemi simülasyon programında modellendi ve Sistem'deki basınç ve sıcaklık dağılımları bulundu. Bu analizler doğrultusunda Balçova – Narlıdere Jeotermal Bölge Isıtma Sistemi'nin kritik noktaları tespit edildi ve bu kritik noktaların muhtemel sebepleri incelenip çözüm alternatifleri üretildi. Aynı sırada Sistem üzerinde seçilen iki apartmana takılan debimetrelerle tüketicilere gönderilen akışkan miktarı ve verilen enerji gözlendi. Gözlenen değerlerin dış hava sıcaklığı ve hesaplanan değerlerle karşılaştırması yapıldı.

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Nomenclature

D	:	Diameter	[m]
A	:	Area	[m^2]
ν	:	Velocity	[m/s]
$\lvert \nu \rvert$	:	Absolute velocity	[m/s]
h_l	:	Head loss	[m]
g	:	Gravitational acceleration	[m/s^2]
ρ	:	Density	[kg/m^3]
υ	:	Viscosity	[m^2/s]
Re	:	Reynold's Number	
ε	:	Pipe inner surface roughness value	
f	:	Friction factor	
R	:	Resistance	[m.s/kg]
ΔP	:	Power loss	[W/m]
ΔT	:	Temperature loss	[$^0C/m$]
Q_r	:	Energy consumption by building	[kcal/h]
Q_t	:	Theoretical energy should be supplied	[kcal/h]
Q_p	:	Peak heating load of building	[kcal/h]
$Q_{t,it}$	:	Energy amount according to indoor temperature	[kcal/h]
T_o	:	Outdoor temperature	[^0C]
$T_{d,o}$	:	Outdoor design temperature	[^0C]
T_i	:	Indoor temperature	[^0C]
$T_{d,i}$	:	Indoor design temperature	[^0C]

CHAPTER 1

INTRODUCTION

Recently, conventional energy sources of the world are consumed rapidly. So, the alternative energy sources are become more popular day by day. The geothermal energy which comes from the earth, takes an important act in these alternative energy sources because of its huge potential, cleanness, sustainability. The geothermal energy being renewable makes it an infinite energy source.

There are many alternative usages of geothermal energy. This variety depends on the temperature characteristics of the geothermal sources. Using geothermal energy as a heat source for district heating systems is one of the most common usages. Geothermal district heating systems supply clean and cheap heat to people.

District heating is a system may be defined as heating of two or more structures from a central heat source. The main goal of a district heating system is to supply sufficient heat to its consumers. It must provide significant benefits to both to community in which it is operated and the consumer who buys energy from the system. In addition, societal benefits should be noted.

Turkey having a great potential of geothermal resources, is one of the biggest country in the geothermal industry. There is only one electricity generating site, but there are many applications of district heating systems.

Balçova – Narlıdere Geothermal District Heating System is the leading district heating system of Turkey with a 90,000,000 kcal/h heating capacity. It is also leading the educational purpose to develop the geothermal district heating technology.

Balçova – Narlıdere Geothermal District Heating System serves to different types of users like commercial buildings, multi family apartments, residences, spas, greenhouses. The system consists of mainly two parts: the geothermal circuit and city distribution network.

1.1 Formation of The Study

This study was formed in the meetings which were organized at Balçova Jeotermal Company at nearly all Saturdays of the first half of year 2004. The first topics discussed were the fluctuation of the pressure distribution of the main pipeline between 2003 and 2004 and the increasing electricity consumptions of wells as shown in Figure 1.1. The decision taken was, modeling recent situation of Geothermal Circuit of Balçova – Narlıdere Geothermal District Heating System to see the distributions of pressure and velocity.

In this study, geothermal circuit of the Balçova – Narlıdere Geothermal District Heating System will be studied. After the last expansions, the question coming up to minds is the constructed system's capability of serving. For this aim, the geothermal circuit of the system will be analyzed. The critical points of the system are going to be pointed out using the Pipelab Geothermal District Heating System Simulation Program.

Before this study, consumption side of Balçova – Narlıdere GDHS was analyzed in Pipelab by C. Şener but main distribution line has never been analyzed.

Additionally, a study will be done for revealing the end user's energy usage. The way of this study is measuring the flow rates and indoor temperatures of the buildings and calculating the consumed energy from this data. By this way, it will be possible to see the response of the system to the changing outdoor temperature. With the results obtained from this study, making a comparison between these results and the average heat load value used in the system designs.

If any problem regarding to the results of this study are faced, these will be discussed and solution alternatives for these problems will be tried out.

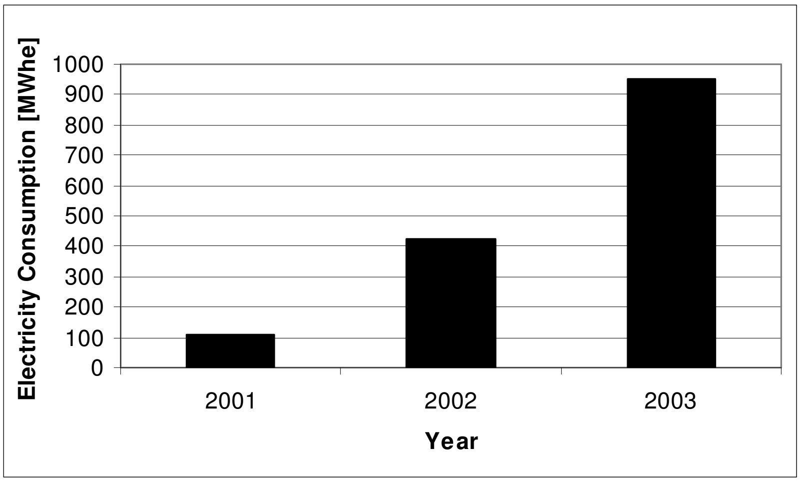

Figure 1.1. Electricity consumptions of wells at 2001, 2002, and 2003

CHAPTER 2

GEOTHERMAL ENERGY

2.1 Geothermal Systems

Geothermal systems can therefore be found in regions with a normal or slightly above normal geothermal gradient, and especially in regions around plate margins where the geothermal gradients may be significantly higher than the average value. In the first case the systems will be characterized by low temperatures, usually no higher than 100 °C at economic depths; in the second case the temperatures could cover a wide range from low to very high, and even above 400 °C. (Dickson and Fanelli 2004)

A geothermal system can be described schematically as '*convecting water in the upper crust of the Earth, which, in a confined space, transfers heat from a heat source to a heat sink, usually the free surface*' (Hochstein 1990). A geothermal system is made up of three main elements: a *heat source*, a *reservoir* and a *fluid*, which is the carrier that transfers the heat. The heat source can be either a very high temperature (> 600 °C) magmatic intrusion that has reached relatively shallow depths (5-10 km) or, as in certain low-temperature systems, the Earth's normal temperature increases with depth. The reservoir is a volume of hot permeable rocks from which the circulating fluids extract heat. The reservoir is generally overlain by a cover of impermeable rocks and connected to a superficial recharge area through which the meteoric waters can replace or partly replace the fluids that escape from the reservoir through springs or are extracted by boreholes. The geothermal fluid is water, in the majority of cases meteoric water, in the liquid or vapor phase, depending on its temperature and pressure. This water often carries with it chemicals and gases such as CO_2, H_2S, etc. Figure 2.2 shows simplified representation of an ideal geothermal system. (Dickson and Fanelli 2004)

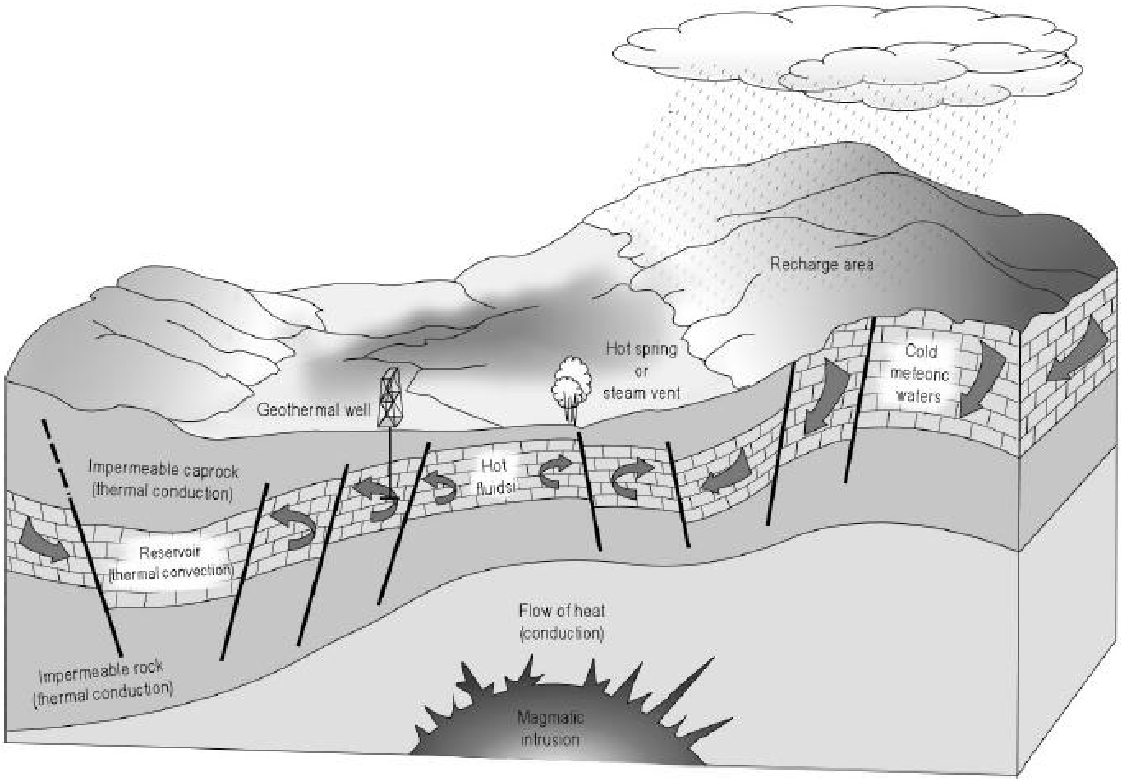

Figure 2.1. Schematic representation of an ideal geothermal system (Dickson and Fanelli 2004)

The mechanism underlying geothermal systems is by and large governed by *fluid convection*. Figure 2.3 describes schematically the mechanism in the case of an intermediate-temperature hydrothermal system. Convection occurs because of the heating and consequent thermal expansion of fluids in a gravity field; heat, which is supplied at the base of the circulation system, is the energy that drives the system. Heated fluid of lower density tends to rise and to be replaced by colder fluid of high density, coming from the margins of the system. (Dickson and Fanelli 2004)

Convection, by its nature, tends to increase temperatures in the upper part of a system as temperatures in the lower part decrease. (White 1973)

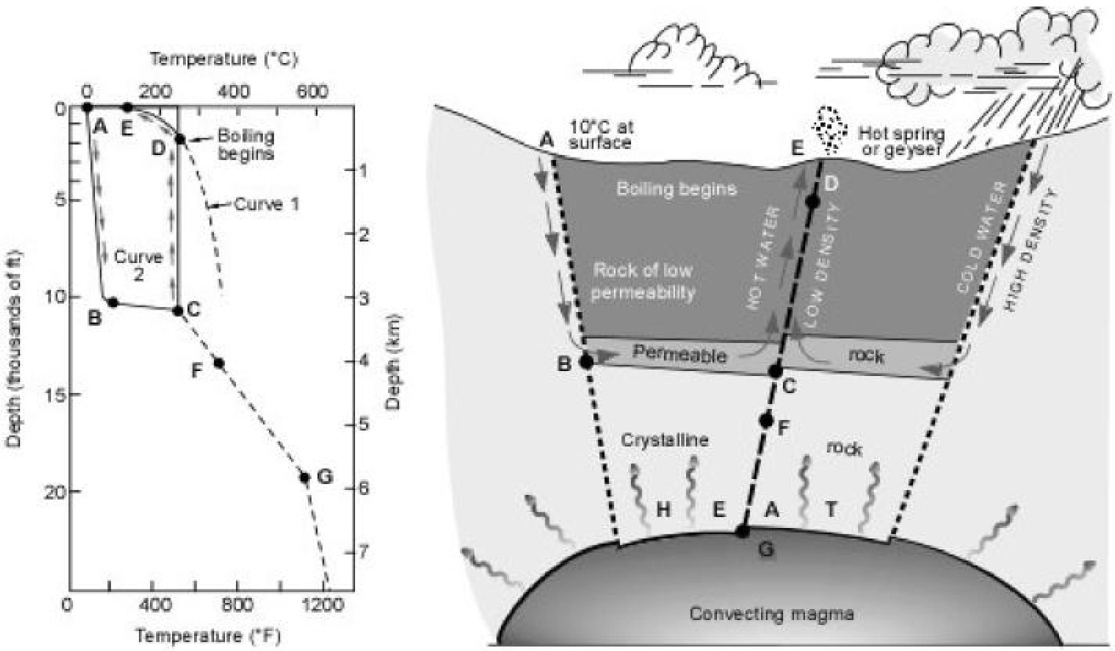

Figure 2.2. Model of a geothermal system. Curve 1 is the reference curve for the boiling point of pure water. Curve 2 shows the temperature profile along a typical circulation route from recharge at point A to discharge at point E (White 1973).

The most important criteria about the classification for the assessment of the viability of the resources is classify geothermal areas according to their thermal gradient. A necessary condition for any potential resource is accessibility through drilling. Useful temperatures can be obtained through relatively shallow drilling in areas with high thermal gradients. But only high thermal gradient is not enough for exploitable resources.

Geothermal systems can be divided into five groups. These are: (Anderson and Lund 1979)

1. Hydrothermal convection systems related to young igneous intrusions,
2. Fault-controlled systems,
3. Radiogenic heat sources,
4. Geo-pressured geothermal reservoirs,
5. Deep regional aquifers.

The most common criterion for classifying geothermal resources is based on the enthalpy of the geothermal fluids that act as the carrier transporting heat from the deep hot rocks to the surface. *Enthalpy* is used to express the heat (thermal energy) content of the fluids, and gives a rough idea of their 'value'. The resources are divided into low, medium and high enthalpy (or temperature) resources, according to criteria that are generally based on the energy content of the fluids and their potential forms of utilization. Table 2.1 reports the classifications proposed by a number of authors. A standard method of classification, as with terminology, would avoid confusion and ambiguity but, until such a method exists, the temperature values or ranges involved case by case, since terms such as low, intermediate and high are meaningless at best, and frequently misleading(Anderson and Lund 1979)

Table 2.1. Classification of geothermal resources according to several criterions (Anderson and Lund 1979)

	Muffler and Cataldi, 1978	Hochstein, 1990	Benderitter and Cormy, 1990	Nicholson, 1993	Axelsson and Gunnlaugsson, 2000
Low enthalpy resources	<90°C	<125°C	<100°C	≤150°C	≤190°C
Intermediate enthalpy resources	90 – 150°C	125 – 225°C	100 – 200°C	-	-
High enthalpy resources	>150°C	>225°C	>200°C	>150°C	>190°C

Frequently a distinction is made between water-dominated or liquid-dominated geothermal systems and vapor-dominated (or dry steam) geothermal systems (White, 1973). In *water-dominated systems* liquid water is the continuous, pressure-controlling fluid phase. Some vapor may be present, generally as discrete bubbles. These geothermal systems, whose temperatures may range from < 125 to > 225 °C, are the most widely distributed in the world. Depending on temperature and pressure conditions, they can produce hot water, water and steam mixtures, and wet steam and, in some cases, dry steam. In *vapor-dominated systems* liquid water and vapor normally co-exist in the reservoir, with vapor as the continuous, pressure-controlling phase. Geothermal systems of this type, the best-known of which are Larderello in Italy and The Geysers in California, are somewhat rare, and are high-temperature systems. They normally produce dry-to-superheated steam. (Anderson and Lund 1979)

Another division between geothermal systems is that based on the *reservoir equilibrium state* (Nicholson, 1993), considering the circulation of the reservoir fluid and the mechanism of heat transfer. In the *dynamic systems* the reservoir is continually recharged by water that is heated and then discharged from the reservoir either to the surface or into underground permeable formations. Heat is transferred through the system by convection and circulation of the fluid. This category includes high temperature (>150°C) and low-temperature (<150°C) systems. In the *static systems* (also known as stagnant or storage systems) there is only minor or no recharge to the reservoir and heat is transferred only by conduction. This category includes low-temperature and geo-pressured systems. The *geo-pressured systems* are characteristically found in large sedimentary basins at depths of 3 - 7 km. The geo-pressured reservoirs consist of permeable sedimentary rocks, included within impermeable low-conductivity strata, containing pressurized hot water that remained trapped at the moment of deposition of the sediments. The hot water pressure approaches litho-static pressure, greatly exceeding the hydrostatic pressure. The geo-pressured reservoirs can also contain significant amounts of methane. The geo-pressured systems could produce thermal and hydraulic energy (pressurized hot water) and methane gas. These resources have been investigated extensively, but so far there has been no industrial exploitation. *Geothermal field* is a geographical definition, usually indicating an area of geothermal activity at the Earth's surface. In cases without surface activity this term may be used to indicate the area at the surface corresponding to the geothermal reservoir below (Axelsson and Gunnlaugsson, 2000). (Anderson and Lund 1979)

As geothermal energy is usually described as *renewable* and *sustainable*, it is important to define these terms. Renewable describes a property of the energy source, whereas sustainable describes how the resource is utilized. (Anderson and Lund 1979)

The most critical factor for the classification of geothermal energy as a renewable energy source is the rate of energy recharge. In the exploitation of natural geothermal systems, energy recharge takes place by advection of thermal water on the same time scale as production from the resource. This justifies classification of geothermal energy as a renewable energy resource. In the case of hot, dry rocks, and some of the hot water aquifers in sedimentary basins, energy recharge is only by thermal conduction; due to the slow rate of the latter process, however, hot dry rocks and some sedimentary reservoirs should be considered as finite energy resources (Stefansson 2000) (Anderson and Lund 1979).

2.2 Geothermal Energy Resources in Turkey

Geologically, Turkey is composed of the Aegean and Anatolian plates that cover the western and central parts of the country. These plates are bordered in the north by the North Anatolian Fault Zone and in the south and east by the Ecemiş Fault Zone, the Aegean Trench, and the Dead Sea – Eastern Anatolian Fault Zone.

Turkey is located in the Mediterranean sector of Alpine – Himalayan Tectonic Belt. This belt is an important geothermal energy zone that is the scene of geologically recent volcanic activities and is characterized by acidic volcanism. Although Turkey has a place among the first seven countries in the world in the abundance of geothermal resources, only 2 – 3 % of its potential is in use. Turkey has extensive geothermal resources. Estimated power generation potential is 4.000 – 4.500 MW_e and low enthalpy direct use resources potential is 32.000 MW_t that is enough to heat nearly five million homes.

Turkey can be separated into four main geothermal regions:

1. Western Anatolia,
2. The North Anatolian Fault Zone,
3. Eastern Anatolia, and
4. Central Anatolia.

Systematic geothermal exploration began in Turkey in 1961 – 1962 when the MTA (The General Directorate of Mineral Research and Exploitation) began an inventory of Turkey's hot springs. The inventory was followed by the development and implementation of geological and hydro-geological studies, magnetic maps, gravity studies, hydro-chemical analysis, gradient drillings, and resistivity and seismic reflection methods.

95 % of Turkey's geothermal areas have incrusting geothermal fluids. Operators have to overcome the effects of scaling and corrosion in both high and low temperature wells.

2.3 Geothermal Energy Utilization

Type of geothermal utilization depends on the type of geothermal fluid especially on temperature of geothermal fluid. Variety of types of geothermal utilization increases with the increasing temperature of geothermal fluid. High temperature fluids are suitable for both direct use and generating electricity. It is important to find suitable type of geothermal utilization while geothermal fluid's temperature decreasing. For various applications, approximate temperature requirements of geothermal fluids are shown in Figure 2.5 which is derived from classical Lindal Diagram (Lindal 1973).

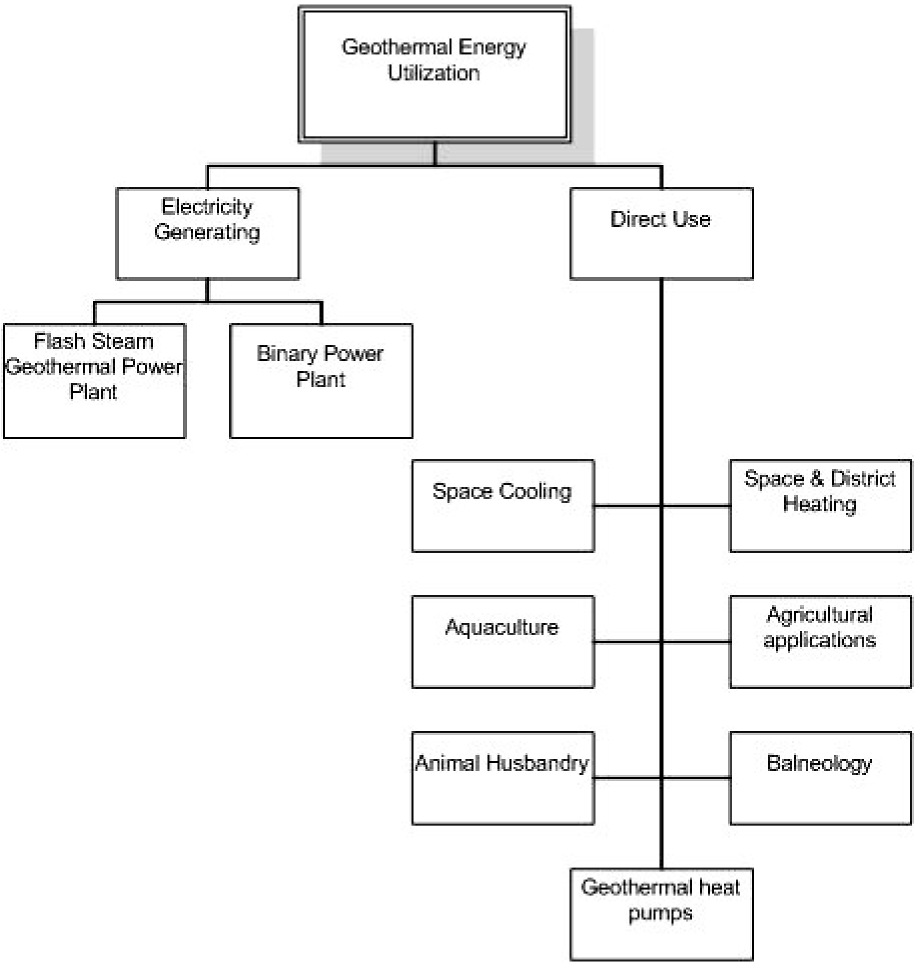

Figure 2.3. Geothermal Energy Utilization types

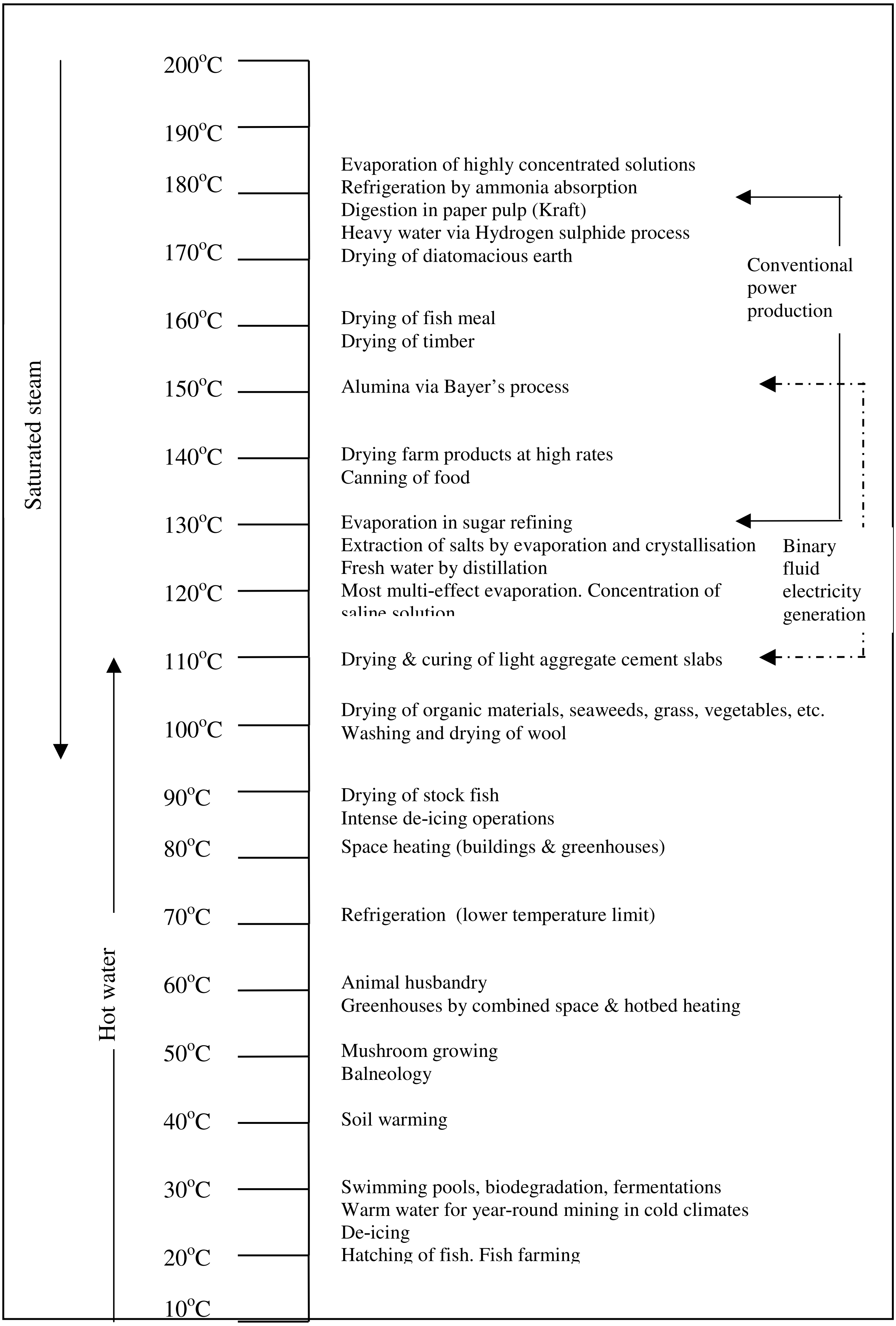

Figure 2.4. Approximate temperatures of geothermal fluids for various applications. Derived from Classical Lindal Diagram (Lindal 1973)

2.3.1 Direct Use of Geothermal Energy

Direct heat use is one of the oldest, most versatile and also the most common form of utilization of geothermal energy. Bathing, space and district heating, agricultural applications, aquaculture, some industrial uses and heat pumps are the best known forms of utilization. There are many other types of utilization, on a much smaller scale, some of which are unusual.

2.3.1.1 Space and District Heating

District heating involves the distribution of heat of hot water or steam from a central location, through a network of pipes to individual houses or blocks of buildings. The distinction between district heating and space heating systems, is that space heating usually involves one geothermal well per structure. (Lienau 1990)

An important consideration in district heating projects is the thermal load density, or the heat demand divided by the ground area of the district. A high heat density is required to make district heating economically feasible, since the distribution network which transports the hot water to the consumer is expensive. (Lienau 1990)

Geothermal district heating systems are capital intensive. The principal costs are initial investment costs for production and injection wells, downhole and circulation pumps, heat exchangers, pipelines and distribution network, flowmeters, valves and control equipment, etc. Operating expenses, however, are in comparison lower and consist of pumping power, system maintenance, control and management. (Lienau 1990)

2.3.1.2 Geothermal Heating of Greenhouses

A number of commercial crops can be raised in greenhouses, making geothermal resources in cold climates particularly attractive. Crops include vegetables, flowers (potted and cut), house plants and tree seedlings. (Lienau 1990)

Greenhouse heating can be accomplished by several methods: finned pipe, unit heaters, finned coils, soil heating, plastic tubing, cascading, and a combination of these methods. The use of geothermal energy for heating can reduce operating costs and allow operation in colder climates where commercial greenhouses would not normally be economical. (Lienau 1990)

Greenhouses are one of the fastest growing applications in the direct use industry. Many of the existing greenhouse systems are expanding rapidly. (Lienau 1990)

2.3.1.3 Spas and Pools

Geothermal energy used for swimming pools and spas is the earliest use of the resource. Mankind has used geothermal water and mineral waters for bathing and being healthy for many thousands of years. Balneology, the practice of using natural mineral water for the treatment and cure of disease, also has a long history. Due to the archaeologists, mineral waters has been used for bathing since the Bronze Age. The Romans, Greeks, and Turks were famous for their spa development and use from Persia to England.

CHAPTER 3

GEOTHERMAL DISTRICT HEATING SYSTEMS

3.1 District Heating Systems

District heating is defined as the groping together of several buildings and using a boiler plant or any other heat source to heat a number of dwellings or blocks of buildings. (Karlsson 1982)

District heating is a system composed of many elements, building a chain from the resource over to the interior of the buildings that are heated. All elements in this chain are equally important, from the geothermal well over to the building radiators and they all have to be designed with utmost care. (Valdimarsson 2003)

The most fundamental classification criterion for district heating systems is the type of heat generation. The most common method of heat generation for district heating in Western Europe is firing of fossil fuel, either in boilers dedicated to the district heat production, or in the boilers of a power station, where the steam plant reject heat is used for the district heat system. The heat is distributed to the consumers through a closed loop network, where the hot water is piped to each consumer in the supply network, cooled down by the heat consumer, piped back to the boiler in the return network, and re-heated. (Valdimarsson 2003)

Difficulties to overcome about district heating systems are heat distribution cost, heat loss in distribution, the high initial investment, and low load density. Load density, the number of buildings in the area heated, is an important economic factor. District heating system will become more economic with increasing load density.

Heat for the district heating system may come from low or high temperature steam. Low temperature (< 120°C) water in the main lines may permit direct connections at the consumer buildings. The direct connection provides better efficiency and allows the use of small pipes (thus, less circulating hot water), which reduces heat losses. The design of the system is simplified because recirculation is eliminated. In turn, internal pumps in space heating installations are also eliminated, leading to lower installation and operating costs.

High temperature (> 150°C) water systems usually require heat exchangers and re-circulating pumps. So, the distribution network loses more heat than using low temperature water. According to low and high temperature water, steam is least efficient heat carrier, because it cannot be transported as far as other two.

Basic components of a geothermal district heating system are generally similar with the components of a conventional heating system. Just the geothermal production field that includes the wells, pumps, and collection mains replaces the boilers. All other components like piping, valves, controls, and metering are same with a conventional system.

The most desirable network for distribution from an economical standpoint would be the single open-ended (just supply) system with heat exchangers installed in each building. The geothermal fluid would be disposed of at the end of the customer connection. This system would cost 30 % less than a closed network (supply and return), that requires central heat exchanger, pumping and control equipment. If re-injection of geothermal fluid is inevitable, two-pipe system might be most desirable.

The main difference between conventional district heating systems and geothermal district heating systems is that the geothermal district heating systems distribute water rather than energy because all cost is directly related to water usage rather than energy usage. (Valdimarsson 2003)

Geothermal district heating systems are operated according to constant temperature difference (ΔT) – variable flow rate principle. So, in the design of direct use systems one of the major goals is capturing the most possible heat from each liter of fluid pumped. This arises from the fact that owning and operating costs for the systems are composed primarily of well pumping and well capitalization components. Maximizing system's ΔT (minimizing flow requirements) minimizes well capital cost and pump operating cost.

While operating a geothermal district heating system, the minimum operational demands are: (Valdimarsson 2003)

- Sufficient pressure difference between supply and return pipe at every consumer connection.
- Maximum line pressure does not exceed the design value.
- Water inlet temperature by every consumer is sufficiently high.

- Water temperature in the secondary and tap water system must not exceed a safety limit set for inhabitants and equipment.
- Sufficient reliability.

3.2 Components of Geothermal District Heating Systems

Typically, a line-shaft multistage centrifugal pump is used for producing the geothermal fluid. When the geothermal fluid reaches the surface, it is delivered to the application site through the transmission and distribution system.

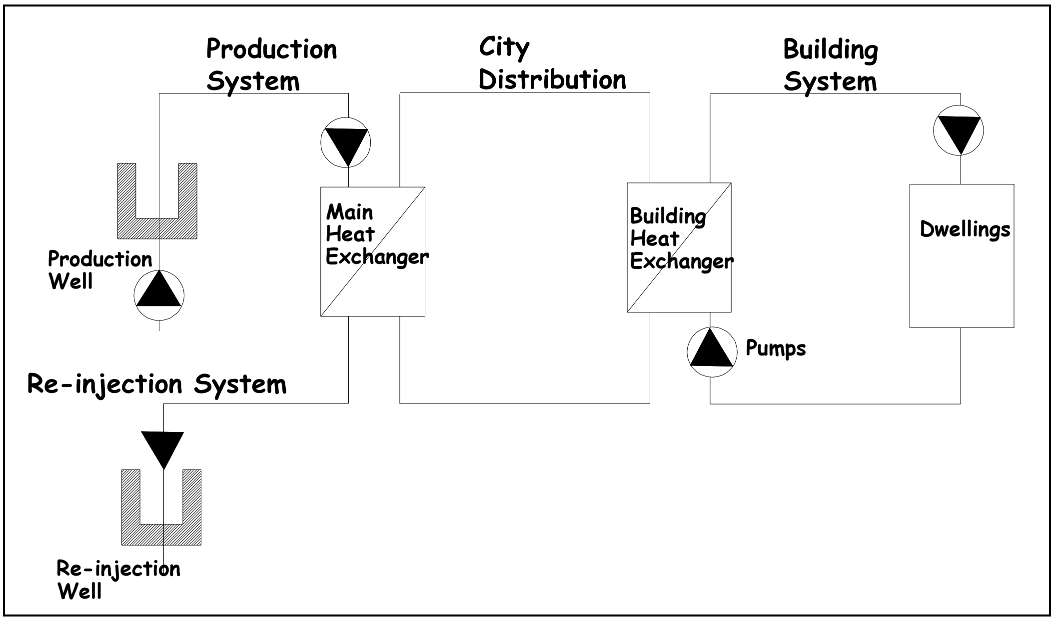

Figure 3.1. Typical Geothermal District Heating System scheme

District heating systems can be divided into five sub systems: (ASHRAE 2002)

1. The production system including the production well bore and associated wellhead equipment.
2. The transmission and distribution system which transports the geothermal energy from the resource site to the consumer site and then distributes it to the individual user loads.
3. The user system.
4. The disposal system that can be either surface disposal or injection back into a formation.
5. An optional peaking / backup system.

3.2.1 Geothermal Well Pumps

In geothermal district heating systems, geothermal well pumps are important equipments of production system. To bring geothermal fluid, geothermal well pumps are used. Generally two main types of well pumps are shown in district heating systems: line-shaft turbine pumps and submersible pumps.

The difference between these two types is the location of the driver. In a line-shaft pump, the driver usually a vertical shaft electric motor is mounted above the wellhead and drives the pump. In a submersible pump, electric motor is usually located below the pump itself and drives the pump through a relatively short shaft with a seal section to protect the motor from the fluid.

Using line-shaft pumps for geothermal direct use applications is common all around the world. There is no specific application of submersible pumps in Turkish geothermal district heating systems. Line-shaft pumps are preferred.

3.2.2 Circulating and Booster Pumps

Circulation pumps are used to deliver hot water to the customers and collect cooled water from the consumers in geothermal district heating systems. Booster pumps are used to increase the pressure of the fluid, for instance the head of the well pumps may not be sufficient to transmit geothermal fluid until heat exchangers. Booster pumps are installed into the geothermal pipeline system to increase the pressure of the fluid. Sometimes the circulation of hot water in the city distribution system cannot be provided by the circulation pumps then booster pumps are installed into critical places where fluid pressure becomes insufficient. These pumps may be centrifugal or vertical turbine pumps. Both types are commonly used in industry.

Circulating pumps are generally operated in parallel combinations in district heating systems. The use of variable speed drives in control of pumps became common in recent applications. Variable speed drives provide efficient operation at partial loads.

3.2.3 Piping in Geothermal District Heating Systems

Because of the distance between production system and consumers, transmission pipeline system is a requirement to transport the geothermal fluid. Even in the absence of transmission line requirements, it is frequently advisable to employ other than standard piping materials for in-building or aboveground piping. Geothermal fluid for direct use applications is usually transported in the liquid phase and has some of the same design considerations as water distribution systems. Several factors including pipe material, dissolved chemical components, size, installation method, head loss, and pumping requirements, temperature, insulation, pipe expansion and service taps should be considered before final specification. (Rafferty 1998)

According to their cost and durability there are many types of piping materials for geothermal district heating systems. Some of the materials which can be used in geothermal applications include: asbestos cement (AC), ductile iron (DI), slip-joint steel (STL-S), welded steel (STL-W), gasketed polyvinyl chloride (PVC-G), solvent welded PVC (PVC-S), chlorinated polyvinyl chloride (CPVC), polyethylene (PE), cross-linked polyethylene (PEX), mechanical joint fiberglass reinforced plastic (FRPM), FRP epoxy adhesive joint-military (FRP-EM), FRP epoxy adhesive joint (FRP-E), FRP gasketed joint (FRP-S), and threaded joint FRP (FRP-T). The temperature and chemical quality of the geothermal fluids, in addition to cost, usually determines the type of pipeline material used. Figure 3.2 shows the temperature limitations of the materials covered in this chapter. Generally, the various pipe materials are more expensive the higher the temperature rating. (Rafferty 1998)

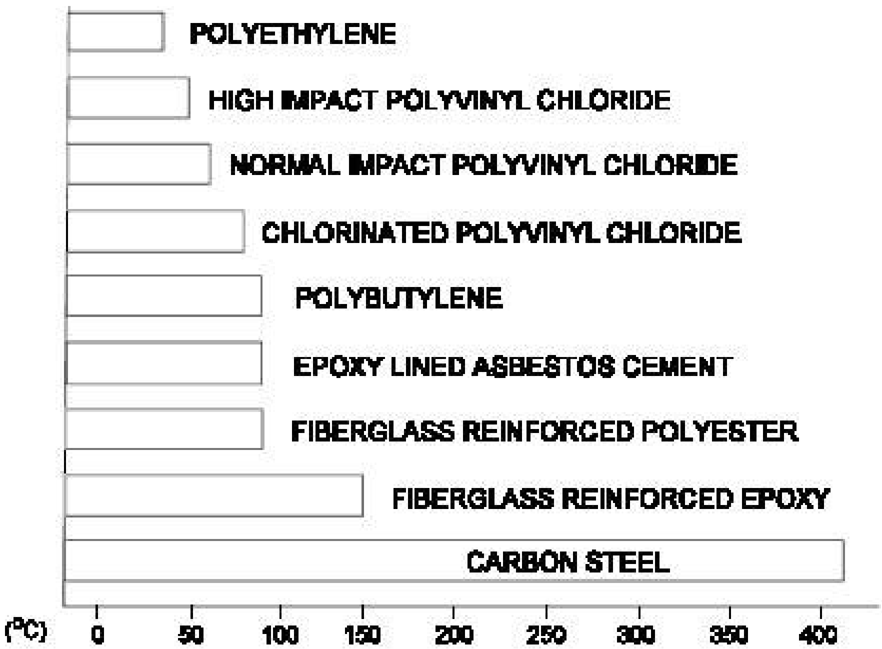

Figure 3.2. Pipe materials according to their usage temperature

Both metallic and nonmetallic piping can be considered for geothermal applications. Carbon steel is the most widely used metallic pipe and has an acceptable service life if properly applied. Ductile iron has seen limited application. (Rafferty 1998)

The attractiveness of metallic piping is primarily related to its ability to handle high temperature fluids. In addition, its properties and installation requirements are familiar to most installation crews. The advantage of nonmetallic materials is that they are virtually impervious to most chemicals found in geothermal fluids. However, the installation procedures, particularly for fiberglass and polyethylene are, in many cases, outside the experience of typical laborers and local code officials. This is particularly true in rural areas. (Rafferty 1998)

In Balçova – Narlıdere GDHS, mostly carbon steel pipes are used. But in recent days, in a small scale system is utilized with fiberglass pipes. Now, it is still tested.

3.2.4 Heat Exchangers

The fundamental principle of geothermal district heating systems is transferring the heat of the geothermal fluid for our heating demand. The task of heat transfer from the geothermal fluid to a closed process loop is mostly handled by a plate heat exchanger.

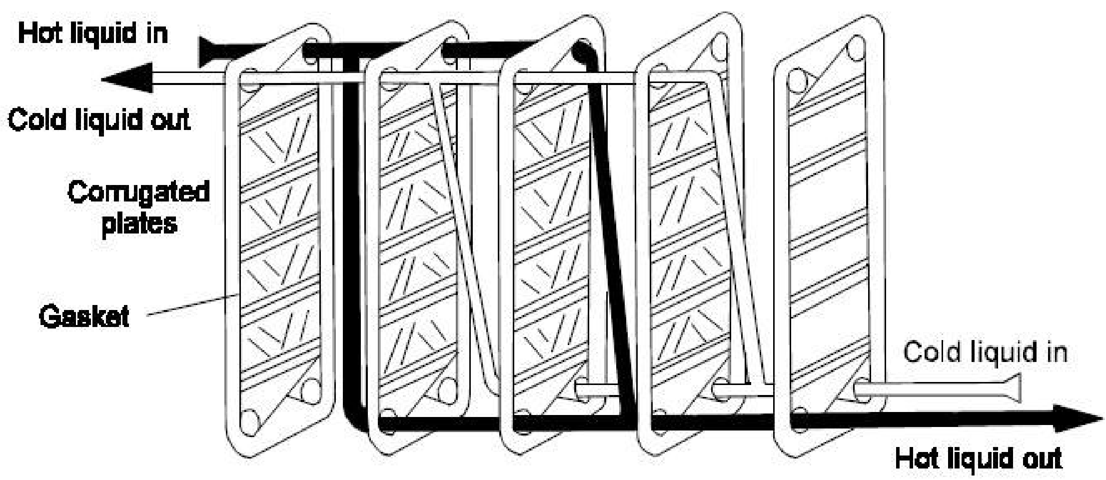

Figure 3.3. Plate heat exchanger

The plate heat exchanger is the most widely used configuration in geothermal systems of recent design. A number of characteristics particularly attractive to geothermal applications are responsible for this. Among these are: (Rafferty 1998)

1. Superior thermal performance: Plate heat exchangers are capable of nominal approach temperatures of 10°C compared to a nominal 20°C for shell and tube units. In addition, overall heat transfer coefficients (U) for plate type exchangers are three to four times those of shell and tube units.

2. Availability of a wide variety of corrosion resistant alloys: Since the heat transfer area is constructed of thin plates, stainless steel or other high alloy construction is significantly less costly than for a shell and tube exchanger of similar material.

3. Ease of maintenance: The construction of the heat exchanger is such that, upon disassembly, all heat transfer areas are available for inspection and cleaning. Disassembly consists only of loosening a small number of tie bolts.

4. Expandability and multiplex capability: The nature of the plate heat exchanger construction permits expansion of the unit should heat transfer requirements increase after installation. In addition, two or more heat exchangers can be housed in a single frame, thus reducing space requirements and capital costs.

5. Compact design: The superior thermal performance of the plate heat exchanger and the space efficient design of the plate arrangement results in a very compact piece of equipment. Space requirements for the plate heat exchanger generally run 10% to 50% that of a shell and tube unit for equivalent duty. In addition, tube cleaning and replacing clearances are eliminated.

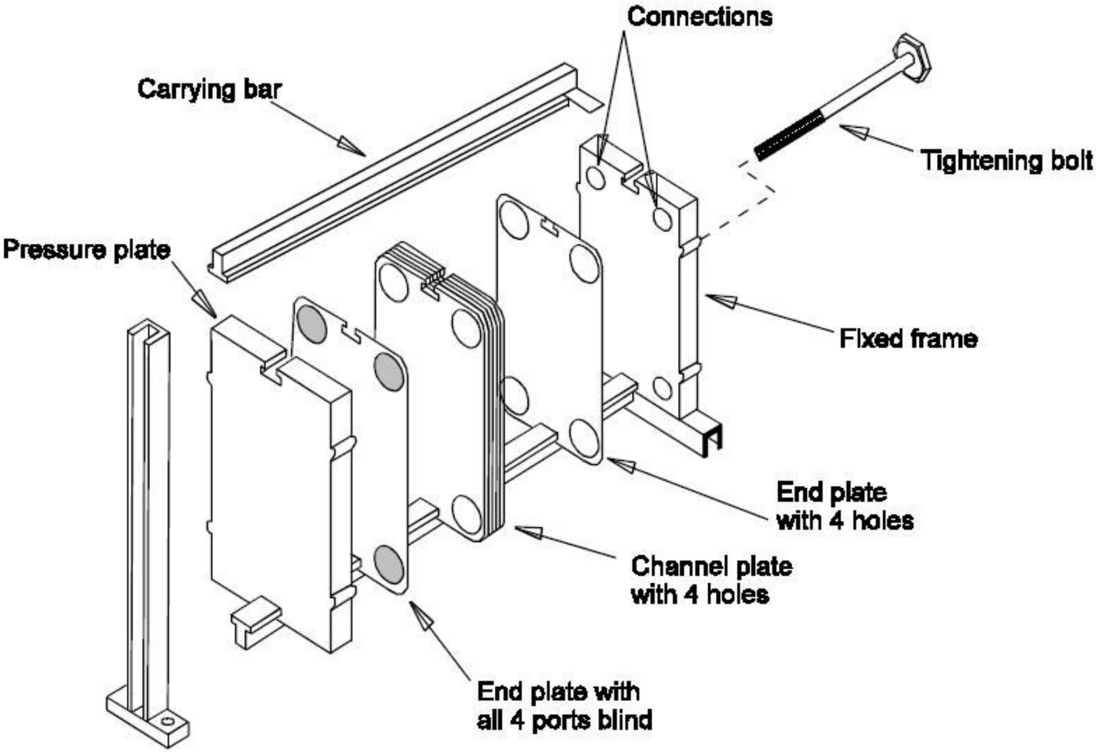

Figure 3.4. A sample plate type heat exchanger utilization

As shown in Figure 3.4, the plate heat exchanger is basically a series of individual plates pressed between two heavy end covers. The entire assembly is held together by the tie bolts. Individual plates are hung from the top carrying bar and are guided by the bottom carrying bar. For single-pass circuiting, hot and cold side fluid connections are usually located on the fixed end cover. Multi-pass circuiting results in fluid connections on both fixed and moveable end covers. (Rafferty 1998)

Figure 3.3 shows the nature of fluid flow through the plate heat exchanger. The primary and secondary fluids flow in opposite directions on either side of the plates. Water flow and circuiting are controlled by the placement of the plate gaskets. By varying the position of the gasket, water can be channeled over a plate or past it. Gaskets are installed in such a way that a gasket failure cannot result in a mixing of the fluids. In addition, the outer circumference of all gaskets is exposed to the atmosphere. As a result, should a leak occur, a visual indication is provided.

3.2.5 Controllers and Regulators

For geothermal district heating operators, controllers and regulators are useful tools to provide proper operation and control of the system. Their function is controlling and regulating system according to their set points by considering feedback information.

Sometimes controllers and regulators can be connected to the automatic control system, or controlled manually. Desired case is connecting them to the automatic control system, and controlling them from central control center. But, because of increasing costs through automatic control systems, manual controlled and self-actuating types are used in Turkish geothermal district heating systems. There are many types of controller and regulator alternatives depending on the type of system design. Among these variable frequency drivers and self-operated regulators are the most commons that are used in Turkish geothermal district heating systems as well as other geothermal district heating systems.

CHAPTER 4

BALÇOVA – NARLIDERE
GEOTHERMAL DISTRICT HEATING SYSTEM

4.1 A Brief History

Balçova Geothermal Field or so called Agamemnon Spas have been attractive place for settlers over the ages. Agamemnon Spas were known in antiquity for the therapeutic qualities of the water. According to a legend, Agamemnon was advised by an oracle to bring soldiers who had been wounded during campaign against Troy to the sulphur-rich waters of these natural hot springs. The periods that Ionians passed to Aegean Coasts, a part of Alexander the Great's army's injured soldiers were cured in these hot springs. It had a wide usage in that period, constructions were brought and progressed. Today, the ancient ruins are not seen in the area. Only information about the springs is available from the historical sources in 1763. After that period, Agamemnon Spas are reconstructed by a Frenchman named Elfont Meil with adding the staying units and they endured to our century. Today there is a modern spa complex with a total capacity of a thousands persons per day providing hot spring pools, baths, and therapy pool. (Şener 2003) (Gökçen 2001)

The reconnaissance and exploration studies started in Balçova in 1963. The first well was 40 m deep and producing two phase fluid at 124°C. Then three exploration wells were drilled after the first evaluation of geological, geophysical, and geochemical data. Because of high calcite precipitation problem, the field could not be developed until 1981. Turkey's first down-hole heat exchanger application was conducted at the well B-1 in 1982. This well was 100 m deep and had a bottom temperature of 115°C. The clean water temperature circulating in the loop was 50 – 95°C depending on flow velocity and outer effects.

After this down-hole heat exchanger application, 10 gradient wells were drilled. These were shallow wells at maximum 200 m with the maximum temperature of 130°C. The reservoir temperature was calculated as approximately 200°C. BD-2 production well is located in the 1st zone that has the highest temperature.

4.2 Progress in Geothermal Utilization in Balçova

Geothermal utilization in Balçova – Narlıdere has a continuous improvement since 1963. This improvement has been accelerated in last ten years with the help of local governments. Inhabitants and governors have understood the benefits of geothermal energy in the region and they strongly support the geothermal energy projects. Table 4.1 represents a chronological representation of the improvement of Balçova – Narlıdere District Heating System.

Table 4.1. Chronological improvement of Balçova – Narlıdere District Heating System (updated from 9)

Year	Improvement
1963	The first geothermal well was drilled in the field
1983	A down hole heat exchanger was used to heat Balçova Thermal Facilities
1983	A down hole heat exchanger was used to heat Dokuz Eylül University Medical Faculty
1992	Plate type heat exchanger usage was started in Dokuz Eylül University Medical Faculty
1994	Geothermal heating of Princess Hotel was started
1995	Adjudication of the first stage geothermal heating and cooling works with 2500 and 500 dwellings, respectively
1996	Increasing the capacities from 2500 to 5000 dwellings for heating and 500 to 1000 dwellings for cooling
1996	Balçova Geothermal District Heating System was commissioned
1996	Re-injection was started
1997	Capacity was increased to 7680 dwellings
1998	Narlıdere Geothermal District Heating System was commissioned for 1500 dwellings
2001	Modernization and enlargement of Dokuz Eylül University Medical Faculty geothermal heating center
2001	İzmir University of Economics was connected to the Balçova Geothermal District Heating System
2001	Geothermal reservoir was modeled by İTÜ Petroleum and Natural Gas Engineering Department
2002	Energy economy and automation studies were started
2002	Feasibility studies for the geothermal heating of 5000 dwellings were started
2002	Re-injection to the shallow wells was stopped and re-injection to the deep wells was started
2003	Dokuz Eylül University Fine Arts Faculty has been connected to the system
2003	Özdilek Hotel and Shopping Center was connected to the system
2003	İnciraltı Dormitory of YURTKUR was connected to the system
2004	Salih İşgören housing estate was connected to the system

In addition, Sahil Evleri district, Yeniköy Houses in Narlıdere, and Balçova Geothermal District Heating System 2 were connected to system and will be heated in 2004 – 2005 heating season.

Number of facilities and dwellings connected to the system has been increasing continuously. This increase is directly related to the geothermal reservoir studies done in the field.

4.3 Recent Situation in Balçova – Narlıdere Geothermal District Heating System

In accordance to increasing heat demand of the Balçova – Narlıdere Geothermal District Heating System, the extracted heat from the reservoir increases rapidly. In 2002 – 2003 heating season, recorded maximum heat extraction was 50 MW_t. The last season (2003 – 2004), approximately 70 MW_t heat was extracted from field. Figure 4.1 represents the heat production of Balçova – Narlıdere Geothermal District Heating System in 2003 – 2004 heating season. Detailed data is given in Appendix A.

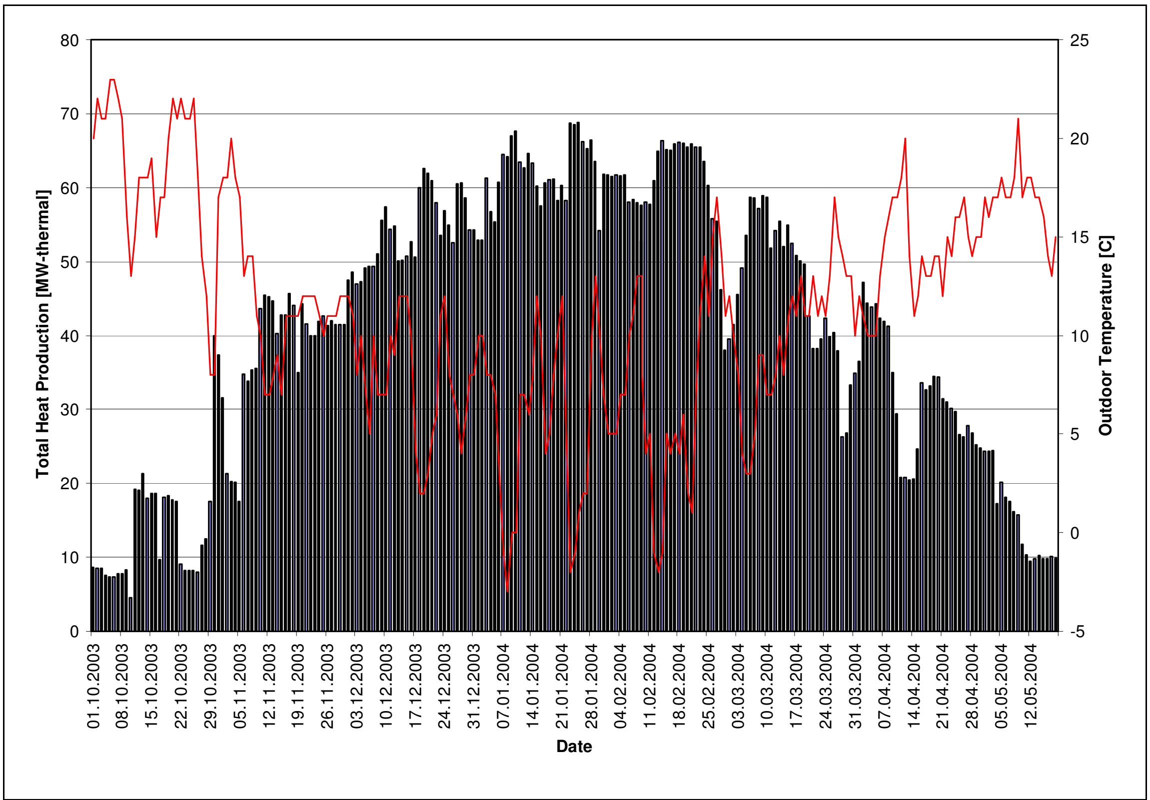

Figure 4.1. Heat production in Balçova – Narlıdere Geothermal District Heating System in 2003 – 2004 heating season

During the years 2001 and 2002, Balçova Jeotermal Company made the field more productive by re-activating unused wells and changing the re-injection strategy. The total production capacity has been increased from 620 m^3/h to 1250 m^3/h. Also, BD-6 well, which was cleaned and prepared to use again, and BD-9 well, which was drilled in 2003, will be ready for use until 2004 – 2005 heating season. Those two wells can produce 500 m^3/h geothermal fluids according to tests.

In the year 2002, the re-injection strategy has been completely changed. It has been found that the re-injection to shallow wells causes decrease in the geothermal fluid temperature. After stopping re-injection to the shallow wells, geothermal fluid temperatures have been started to increase. After this event, all re-injection has been directed to the BD-8 well. The effects of re-injection to BD-8 to the reservoir are still being observed and until now, there is not any negative effect detected. Next season, BD-10 will be used for re-injection. BD-10 was drilled at 2004 summer.

Table 4.2 represents the recent situation of the wells in Balçova – Narlıdere Geothermal District Heating System.

Table 4.2. Recent situation of the wells in Balçova – Narlıdere Geothermal District Heating System (updated from Şener 2003)

Well	Date	Length [m]	Temperature [°C]	Flow Rate [m^3/h]	Role
BD-1	1994	677	120	70	Production
BD-2	1995	564	135	165	Production
BD-3	1996	750	131	115	Production
BD-4	1998	624	137	195	Production
BD-5	1999	1100	121	90	Production
BD-6	1999	605	135	200	No production
BD-7	1999	1100	120	85	Production
BD-8	2002	630		2500	Re-injection
BD-9	2004	776	139	300	New drilled
BD-10	2004	750			New drilled
B-1	1982	104	103	100	Production
B-2	1989	150	95	-	No production
B-3	1983	160	110	-	No production
B-4	1983	125	100	60	Production
B-5	1983	109	106	125	Production
B-6	1983	150	-	-	Closed
B-7	1983	120	95	80	Production
B-8	1983	250	95	-	No production
B-9	1983	48	95	-	No production
B-10	1989	125	100	180	Production
B-11	1989	125	109	-	No production
B-12	1998	160	95	-	No production
ND-1	1996	800	115	-	No production
N-1	1997	150	95	-	No production
BTF-2					Closed
BTF-3			100	30	No production
BH-1			80	15	No production

4.4 Balçova – Narlıdere Geothermal District Heating System

There are several sub systems in the Balçova – Narlıdere Geothermal District Heating System. These are; Balçova GDHS, Narlıdere GDHS, Dokuz Eylül University Medical Faculty, Balçova Thermal Facility, Princess Hotel, İnciraltı Dormitory of YURTKUR, Salih İşgören housing estate, and Özdilek Hotel and Shopping Center. In addition, Sahil Evleri housing estate, Yeniköy housing estate, and Balçova Geothermal District System 2 are going to be heat in 2004 – 2005 heating season.

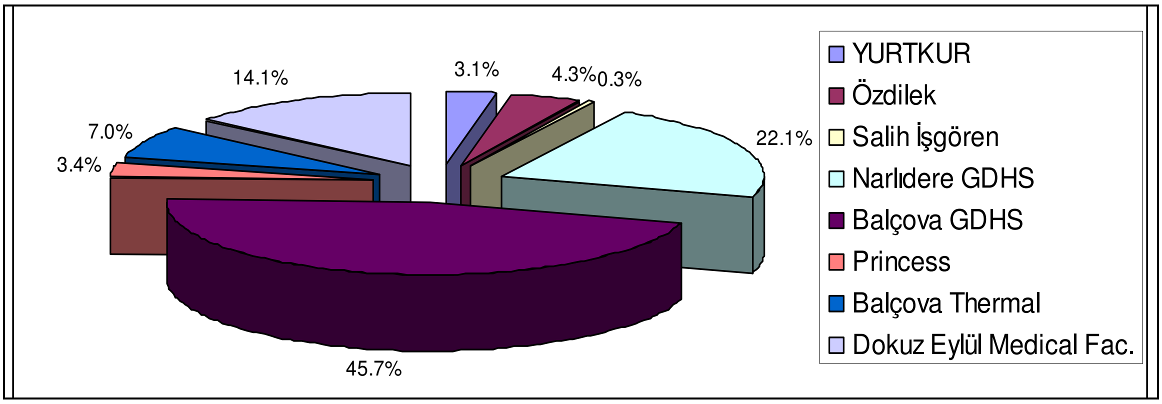

Figure 4.2. Recent load distribution of Balçova – Narlıdere District Heating System

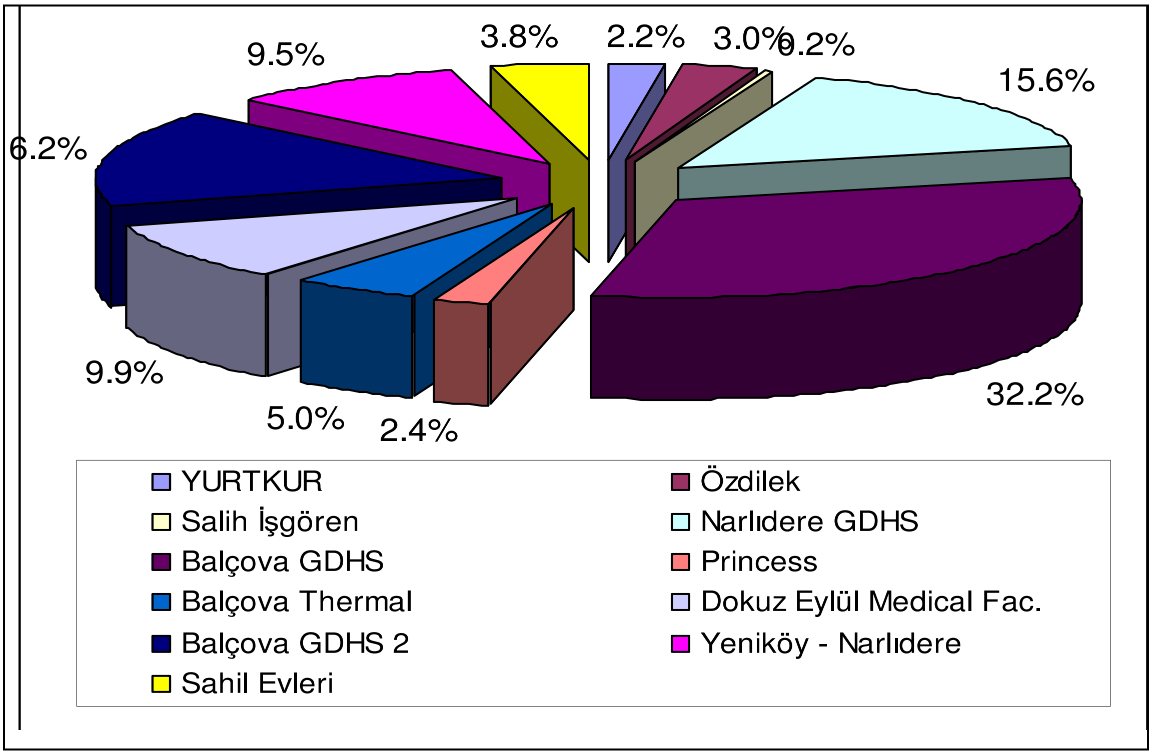

Figure 4.3. Projected load distribution of Balçova – Narlıdere GDHS in 2004 – 2005 heating season

Figure 4.2 shows the recent load distribution of Balçova – Narlıdere Geothermal District Heating System. As can be seen easily from the figure, the main consumer of the extracted heat from reservoir is Balçova Geothermal District Heating System which is the nearly consumes a half of all system.

Figure 4.3 shows the projected load distribution of Balçova – Narlıdere Geothermal District Heating System in 2004 – 2005 heating season.

Balçova Geothermal District Heating System, Narlıdere Geothermal District Heating System, and geothermal pipeline system are operated by Balçova Jeotermal Company. Other facilities have separate heating systems and their own operators. Also Sahil Evleri, Yeniköy, and Balçova GDHS 2 will be operated by Balçova Jeotermal Company.

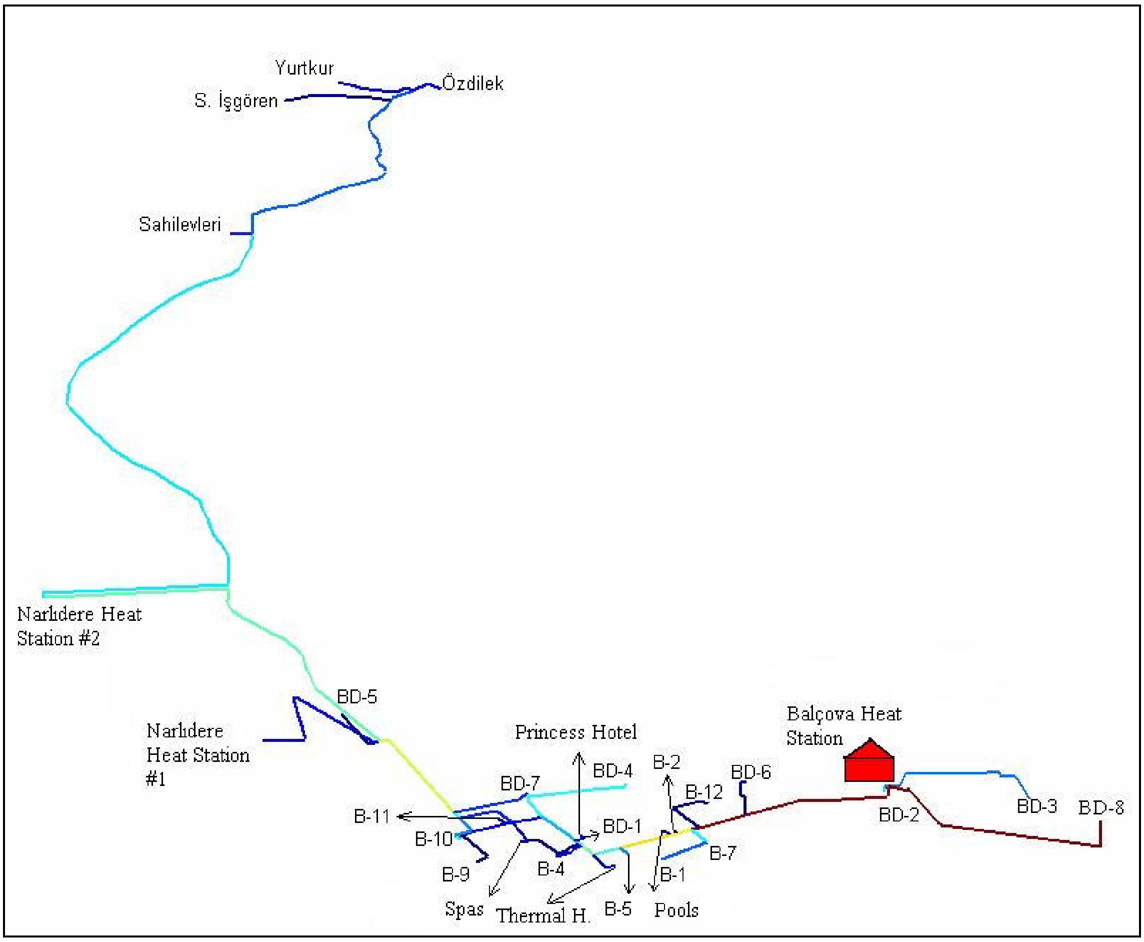

Figure 4.4. Balçova – Narlıdere Geothermal District Heating System, geothermal pipeline

4.4.1 Geothermal Pipeline System

Geothermal pipeline system of Balçova – Narlıdere Geothermal District Heating System collects the geothermal fluid from the 11 production wells and distributes it to the 10 heat stations of each sub systems. After transferring its heat to the consumers, geothermal fluid is directed to re-injection well. Well head temperatures, maximum and average flows of wells that were in production in 2002 – 2003 heating season are shown in Table 4.3.

Table 4.3. Production wells in 2003 – 2004 heating season

Well	Temperature [°C]	Average Flow [m^3/h]	Maximum Flow [m^3/h]
BD-1	120	55	70
BD-2	135	108	165
BD-3	131	81	115
BD-4	137	141	195
BD-5	121	77	90
BD-7	120	65	85
BD-8	63	-310	-510
B-1	103	77	100
B-4	100	41	60
B-5	106	95	125
B-7	95	65	80
B-10	100	95	180

Table 4.4. Facilities directly connected to geothermal pipeline system

Facility	Maximum Static Heat Load [kW]
Balçova GDHS	50365
Narlıdere GDHS	24000
Balçova Thermal Hotel	5175
Princess Hotel	3200
Özdilek Hotel & Supermarket Complex	4650
İnciraltı Dormitory of YURTKUR	3375
Salih İşgören housing estate	400
Dokuz Eylül University Medical Faculty	15700

Facilities directly connected to the geothermal pipeline system and their maximum static heat loads are shown in Table 4.4. In the 2004 – 2005 heating season, three new facilities will be connected to the geothermal pipeline. Number of facilities and dwellings are directly related to the productions of the wells and their characteristics.

Figure 4.4 represents the recent situation of geothermal pipeline. Geothermal pipeline system consists of two parallel pipeline systems; supply and return. Supply part of the system collects the geothermal fluid from the wells and distributes it to the consumers. Return part collects the geothermal fluid from the consumers and transmits it to the re-injection well. Just supply part of geothermal pipeline system is represented in the Figure 4.4.

Most of the pipes of main geothermal pipeline are 300 mm steel pipes, and some parts of 200 mm and some part of 250 mm steel pipes are used. Well branches are mostly 150 mm steel pipes. All pipes in the system have polyurethane foam insulation wrapped with insulating coat (fiberglass) to provide seal.

Geothermal fluids pumped from the wells which are connected different points of geothermal pipeline and mixed in the geothermal pipeline system. Because of the difference of geothermal fluids from each well, the temperature of the geothermal pipeline system is not constant and it changes according to the operation of wells.

Because the geothermal pipeline system is quite complex network as shown in Figure 4.4, it is important to monitor and control the temperatures and pressures along the system. For the proper operation of system, thermodynamic and hydraulic balance of the pipeline system is very important.

The geothermal fluids temperature changes according to operations of wells. Heat exchanger inlet temperatures vary between 105 – 115°C and re-injection temperature is about 60°C in the system.

Geothermal well pumps of the system are operated according to constant well head pressure strategy. Well head pressures are kept constant at 3 bars with the help of valves in the system. Pressure monitoring is available only at the well heads.

To increase the inlet pressure of the heat exchangers at the Balçova and Narlıdere Heat Stations, booster pumps are used. The pressure of the geothermal fluid along the pipeline is about 1.5 – 2 bars. There is no monitoring or controlling device for the geothermal pipeline pressure.

Flow rates and flow directions are regulated with the help of valves installed into critical points of the system. There is not an automatic control system, and valves are controlled manually. Data acquisition and monitoring processes have also been done manually. But an automatic control system installation is planned and studies about this project are going on.

CHAPTER 5

ANALYSIS OF BALÇOVA – NARLIDERE GDHS

5.1 Aim of The Study

For the proper operation of pipeline systems, controlling the pressure and the temperature has a great importance. Most of the works and the costs are spent for controlling the pipelines pressure. Because of that reason, monitoring the temperature, pressure, and flow rates is important. But, in Balçova – Narlıdere Geothermal District Heating System, there is not enough monitoring of temperature and pressure. Just at heat stations and well heads, these parameters are controlled. The pressures and temperatures among the pipeline cannot be known.

In the light of these, simulating the pipeline system due to the real conditions is become a necessity. During this study, Balçova – Narlıdere Geothermal Pipeline System was simulated with the real data taken from the Balçova Jeotermal Company's database. These simulations were realized by PIPELAB District Heating Simulation Program.

5.2 PIPELAB District Heating Simulation Program

Pipelab is a district heating simulation software using graph theory to solve network flow and heat distribution problems. Pipelab can be used for design a new pipe network or analyze an existing pipe network. Pipelab uses these data to model the system: (Şener 2003)

1. Nodal coordinates of the system,
2. Start and end nodes of the network elements,
3. Roughness values of pipes [m],
4. Heat loss coefficients of pipes [W/°C.m],
5. Amount of head supply [m],
6. Required load (flow or heat) at the end points of the system [kg/s or W].

It can be determined from Pipelab the nodal heads, nodal temperatures, and head and head loss gradients on the screen and it can be stored on files after entering necessary data. Figure 5.1 shows the user interface of the Pipelab while analyzing the geothermal pipeline.

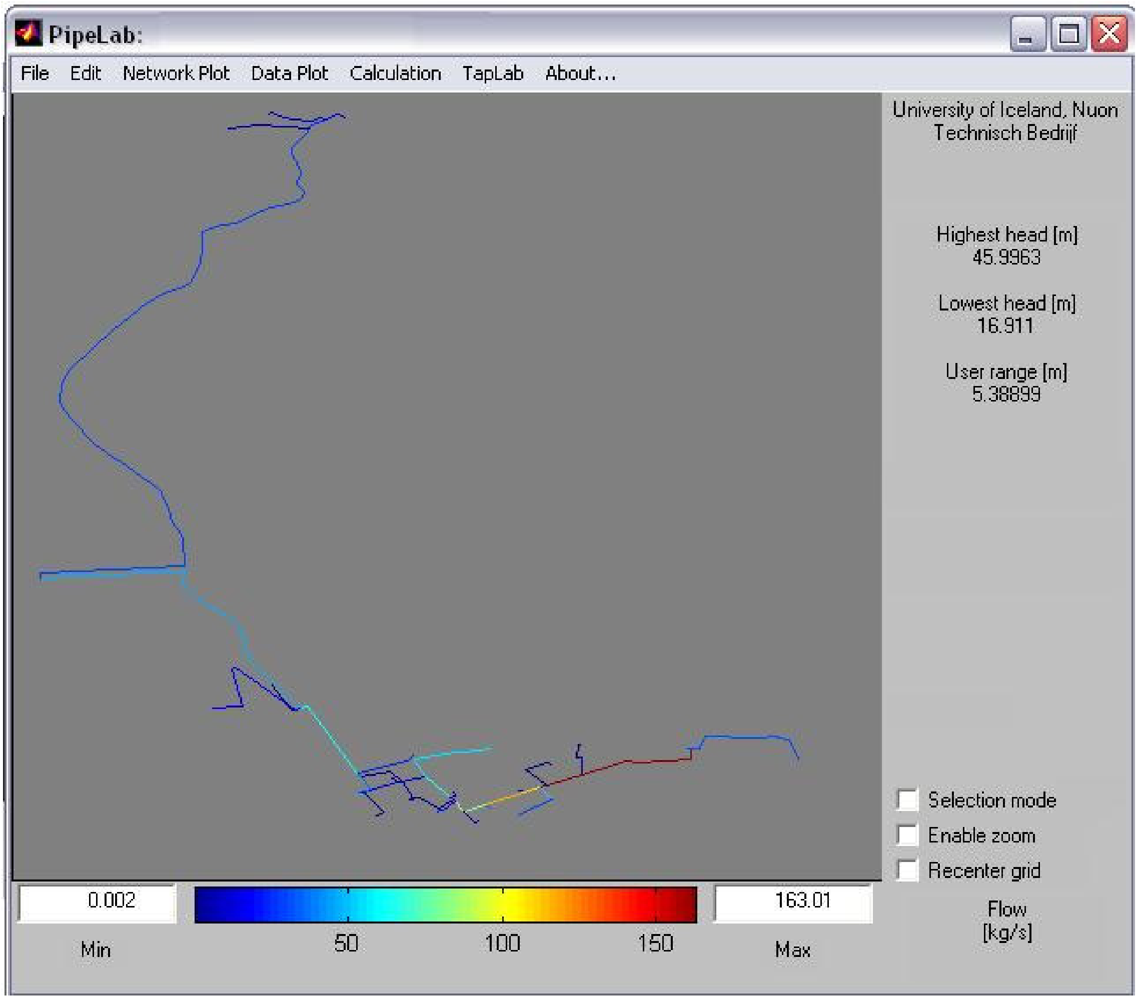

Figure 5.1. Pipelab user interface while analyzing the water flow of Geothermal Pipeline

5.2.1 Calculation of Head and Flow in Pipelab

The most important activity of the Pipelab is the calculation of head and flow in a net. These calculation procedures are the core of the software.

While calculating the head and flow, Pipelab follows these two steps:

1. Sorting the net. The net may contain many loops which will disturb any calculations when left unchecked. By making a tree, loops are prevented by selecting and removing specific pipes. When no loops exist, all nodes are connected to the reference by one and only one route. This net is named the *tree*. The removed pipes are called *co-tree*.

2. Calculation. After the net is sorted (tree and co-tree), an iteration is performed to match the flow through a pipe, the head loss over a pipe and the heads on each nodes. In each iteration a match is made for the tree and the co-tree respectively. The iteration ends when the flows in two successive iterations are the same (barring a small difference epsilon).

The calculation requires a convergent iteration. When an iteration does not converge, this may indicate an unusual configuration in the net. Experiences show that this usually implies an erroneous network.

The first activity in the iteration is the calculation of resistances. The head loss over a resistor is determined from the velocity of the water:

$$\left.\begin{aligned} A &= \frac{\Pi \cdot D^2}{4} \\ v &= \frac{\dot{m}}{A \cdot \rho} \end{aligned}\right\} h_1 = \frac{1}{2g} \cdot c \cdot v^2 \tag{5.1}$$

The head loss over a pipe is determined from the velocity:

$$\left.\begin{aligned} A &= \frac{1}{4} \cdot \Pi \cdot D^2 \\ v &= \frac{\dot{m}}{A \cdot \rho} \\ \mathrm{Re} &= v \cdot \frac{D}{\upsilon} \end{aligned}\right\} f = \frac{1.325}{\left[\log\left(\frac{3.7 \cdot \varepsilon}{D} + 5.74 \cdot \mathrm{Re}^{-0.9}\right)\right]^2} \tag{5.2}$$

$$h_1 = \frac{1}{2g} \cdot f \cdot \frac{L}{D} \cdot v \cdot |v| \tag{5.3}$$

Then the resistance can be calculated by dividing the head loss by the flow.

$$R = \frac{h_1}{\dot{m}} \tag{5.4}$$

5.2.2 Calculation of Temperatures and Heat Flow in Pipelab

The temperature distribution in a net is not uniform. It is in accordance with flow throughout the net, the laying of the pipes and the feed points where water with a known temperature is fed into net.

In a pipe with hot water flow through in it, a power loss occurs as temperature flows from the water to the environment. The power loss of pipe depends on the length of the pipe and the temperature of the water inside. The power loss results in a loss of temperature.

$$\Delta P = \xi(D,T) \cdot L \tag{5.5}$$

$$\Delta T = \frac{\Delta P}{c_p \cdot \dot{m}} \tag{5.6}$$

$$T_{n+1} = T_n - T \tag{5.7}$$

The factor ζ is dependent on the diameter of the pipe and the average temperature of the water in the pipe. Actually, the temperature of a node in the net can be calculated from the temperature of the previous node and the temperature loss over the connecting pipe.

Equations (5.4), (5.5), and (5.6) are applied to every pipes, equation (5.7) is applied to every node. Certainly, Pipelab needs a point to start to the calculations. This point needs to a fixed temperature and a fixed pressure; hence the source of flow is used. There is a handicap about the software. The method can not calculate the temperature while the flow is zero. This implies indefinite temperature loss. In reality, the zero flow means, the temperature on the end node would equal to the temperature of the environment.

5.2.3 Other Features of Pipelab

Pipelab calculates the steady state solution of head and flow as well as the temperature in a district heating net. It can also be used for calculations in a net for domestic hot water. Pipelab is rather extensive software; its code is separated in more than a hundred procedures. Also Pipelab is developed continuously.

5.3 Analysis of Balçova – Narlıdere Geothermal Pipeline

First of all, the nodal coordinates of Balçova – Narlıdere Geothermal District Heating Systems Geothermal Circuit were obtained from the real data from Balçova region. After completing the data collection, geothermal circuit was simulated in Pipelab. The most critical point to analyze is pressure distribution along the pipe line. Figure 5.2 represents the pressure distribution named H-L plot for the real operating conditions at maximum loads in 2003 – 2004 heating season.

In the H-L plot, horizontal axis stands for the length from the source. Here, Balçova Heat Station was assigned to *source*. On the other hand, the vertical axis represents the heads of the nodes. The nodes are assigned to the critical points (points where direction changes such as elbows). In the H-L plots, it is desired the slope of the line to be smaller. Being the slope high, means that in a very short distance there is a high pressure drop undesired.

In analyze of the geothermal circuit, there is a big problem about the BD-4 well branch as shown in red line. As a result of the observations and analysis the BD-4 well branch which connects the well to the main pipeline has a design error. The diameter of this branch was chosen smaller than it should be.

During this study, Balçova Jeotermal Company has tried to improve the BD-6 production well. Formerly BD-6 was a proper working well, but because of some technical reasons it was stopped. During the 2004 summer, the improvement studies about the BD-6 well are finished and the results of the tests showed that it can produce about 200 m^3/h geothermal water.

Balçova Jeotermal Company's operating strategies for 2004 – 2005 heating season includes BD-6 as a production well. So a new analysis including BD-6 well branch is needed to be carried out. Figure 5.3 shows the H-L plot of the new situation which will be faced in 2004 – 2005 heating season at maximum loads.

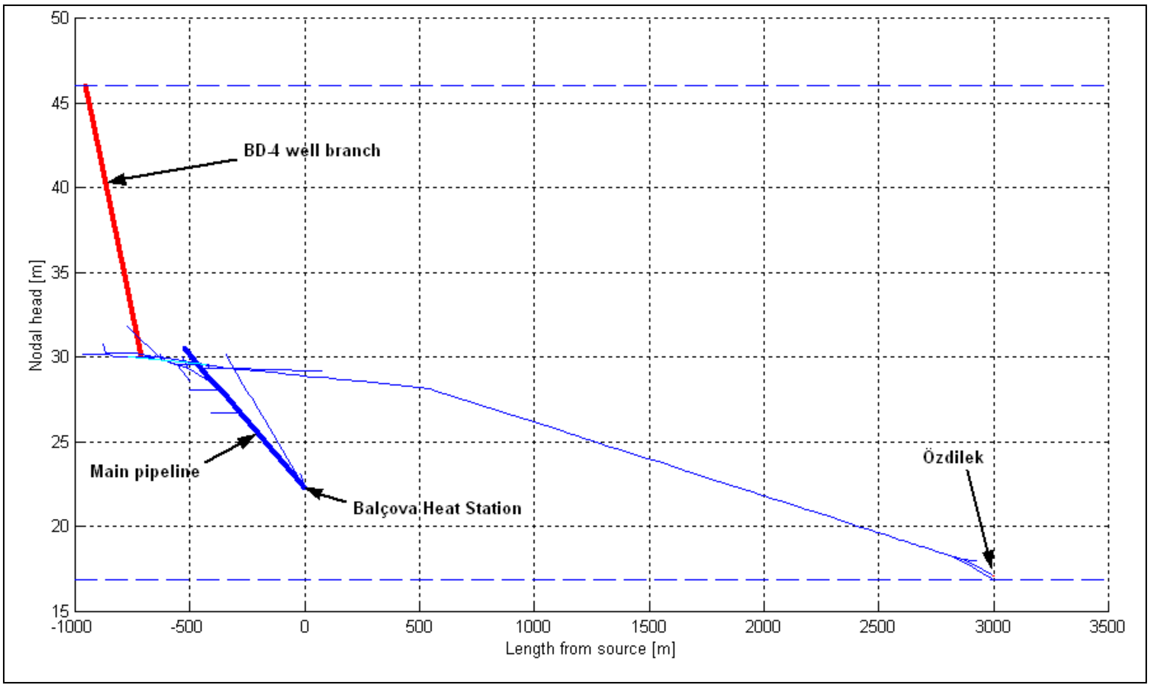

Figure 5.2. Recent H-L plot of geothermal pipeline system

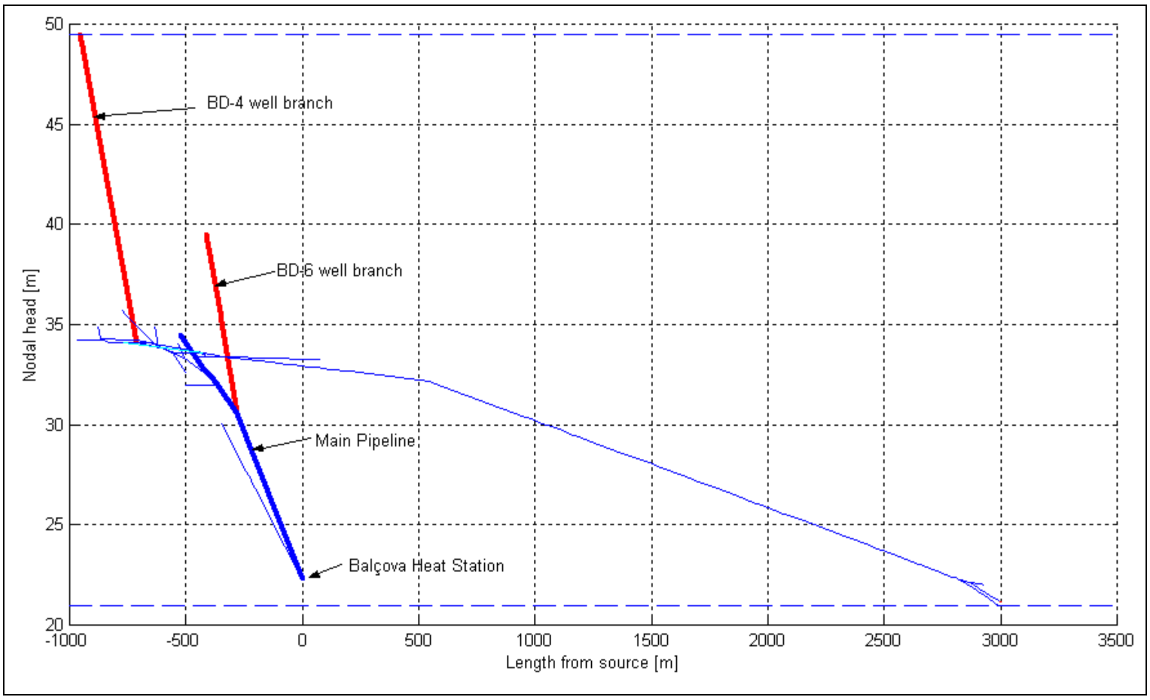

Figure 5.3. H-L plot of geothermal pipeline system if BD-6 starts to produce

While BD-6 well will work, the problem encountered in the BD-4 well branch will be last increasingly. The head of BD-4 well was 45.4 m in the last heating season, while it will be 49.5 m in the coming heating season.

In addition to this problem BD-6 well branch is seemed to be problematic. Again the source of problem is the diameter of the branch connected the BD-6 to the main pipeline. The slopes of these two lines are very similar as seen easily in the Figure 5.3.

Another result of these analyses is the high velocities of the geothermal fluids at these pipelines. For the recent situation, the velocity of the geothermal fluid can reach to 3.25 m/s in the BD-4 well branch. In the projected situation, the velocity of the geothermal fluid can reach to 3.3 m/s in the BD-6 well branch and to 3 m/s in the main pipeline. Figure 5.4 represents the recent velocity distribution of the pipeline system and Figure 5.5 represents the projected velocity distribution while BD-6 well is in operation.

The high speeds and more pressure drops cause an increase in the electricity consumptions. In geothermal district heating systems, the huge amount of operating costs come from electricity consumption. Designers should keep this fact in mind all the time. If anything causes increase in the electricity consumption, this problem should be instantaneously solved.

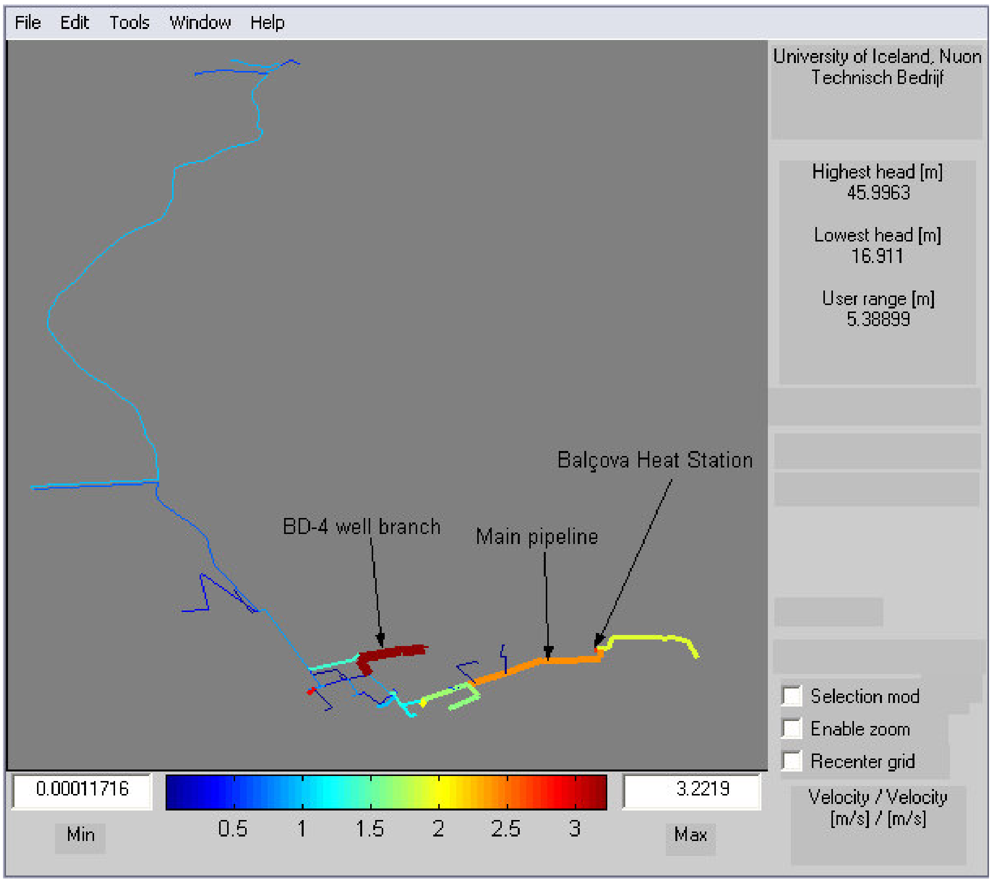

Figure 5.4. Recent velocity distribution of geothermal pipeline system

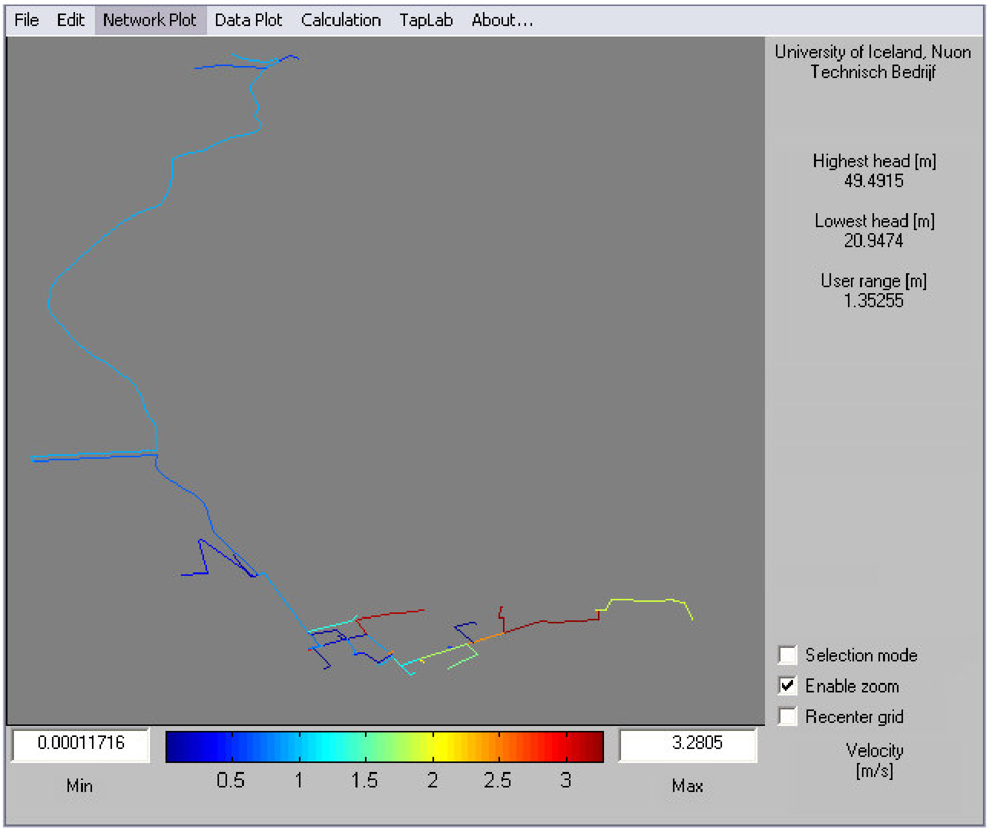

Figure 5.5. Velocity distribution of geothermal pipeline system while BD-6 well working

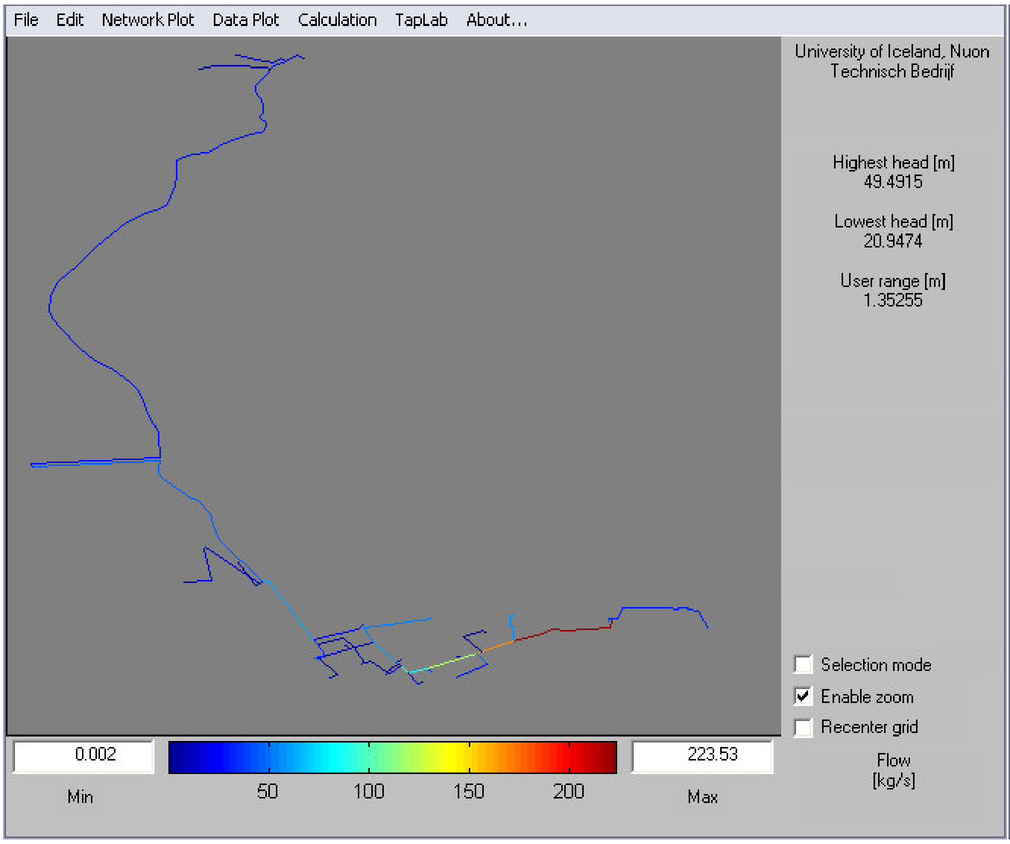

Figure 5.6. Water flow of geothermal pipeline system while BD-6 well working

5.3.1 Solution Alternatives

The results of the analysis show that the diameters of the BD-4 and BD-6 well branches are smaller than they should be. This problem creates a high pressure drop in a short distance which causes an increase in the electricity consumption. To prevent this, some alternatives which are defined below are introduced:

- Changing the diameters of BD-4 and BD-6 branches to one larger standard diameter.
- Making a new connection between BD-4 and B-12 well branches.

a. Changing the diameters of BD-4 and BD-6 branches to one larger standard diameter:

The first solution method coming to ones mind is changing the diameters. For this solution alternative, the velocity distribution is shown in Figure 5.7 and H-L plot is shown in Figure 5.8. Pressure drop is reduced to acceptable limit. Also velocities of the geothermal fluids in the BD-4 and BD-6 branches are reduced to acceptable limits.

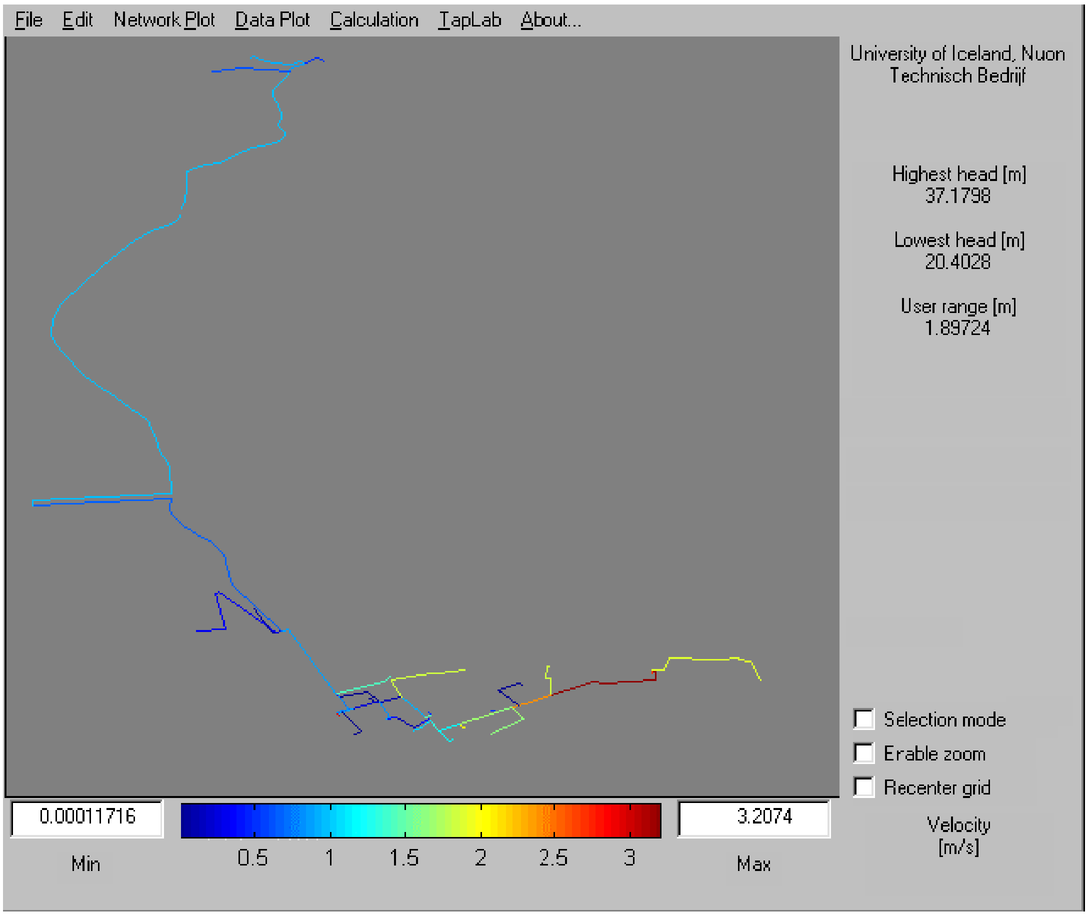

Figure 5.7. Velocity distribution of geothermal pipeline system, diameters of BD-4 and BD-6 branches are increased to one larger standard diameter

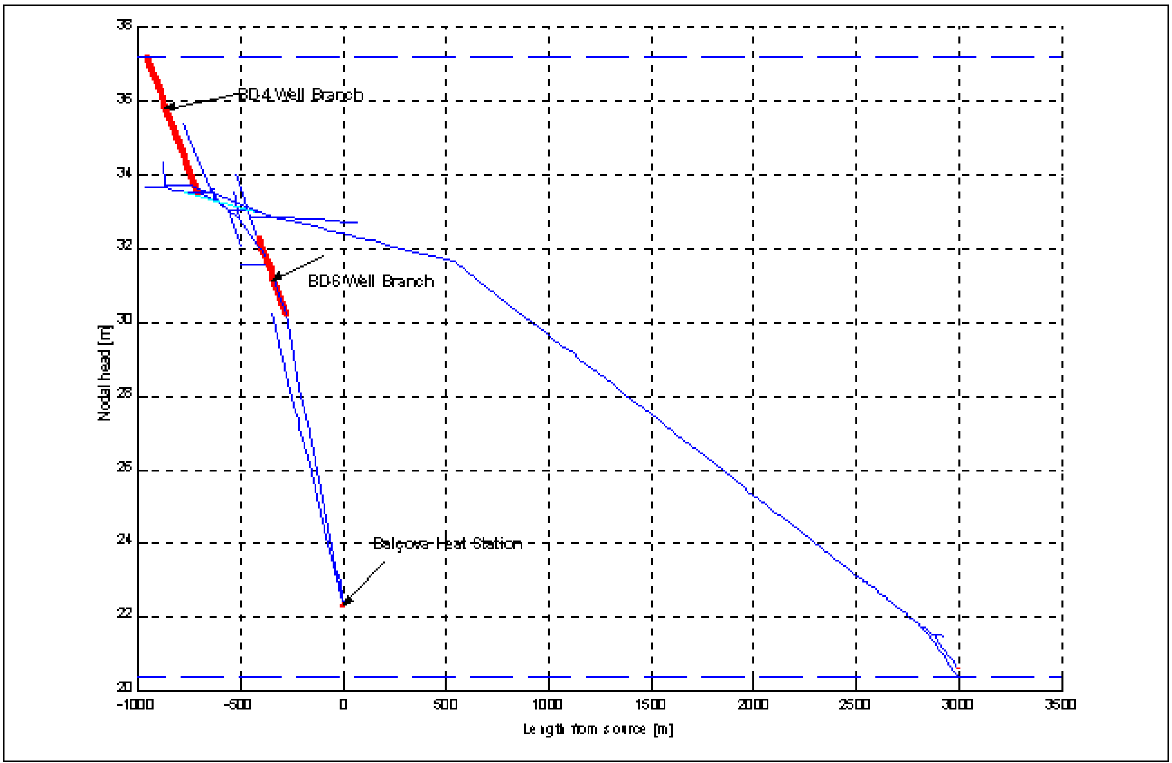

Figure 5.8. H-L plot of geothermal pipeline system, diameters of BD-4 and BD-6 branches are increased to one larger standard diameter

b. Making a new connection between BD-4 and B-12 well branches:

Another solution for the problem with the BD-4 well branch is making a new connection to the main pipeline. For this connection, there are two alternative routes; through B-12 and through BD-6. Distance between BD-4 and BD-6 is nearly one and half bigger than the distance between BD-4 and B-12 (B-12 and BD-6 branches are included). Keeping in mind that BD-6 well will soon be taken into operation, connection to this well is not suggested. In addition to this, B-12 well is not working and it won't be taken into operation in the near future.

Because of these reasons explained above, the connection alternative to the BD-6 well is not taken into consideration in the analysis.

In Figure 5.9, H-L plot of geothermal pipeline system for the connection alternative to the B-12 well branch is represented. As easily seen from the Figure 5.9, the pressure drop problem is overcome. The velocity distribution of geothermal pipeline system is represented in Figure 5.10. Velocities are reduced to acceptable limits among all system.

When BD-6 works, this connection alternative will be work properly. Just the velocity of the geothermal fluid in the main pipeline will reach 3.3 m/s. Figure 5.11 and 5.12 show the H-L plot and the velocity distribution of this situation.

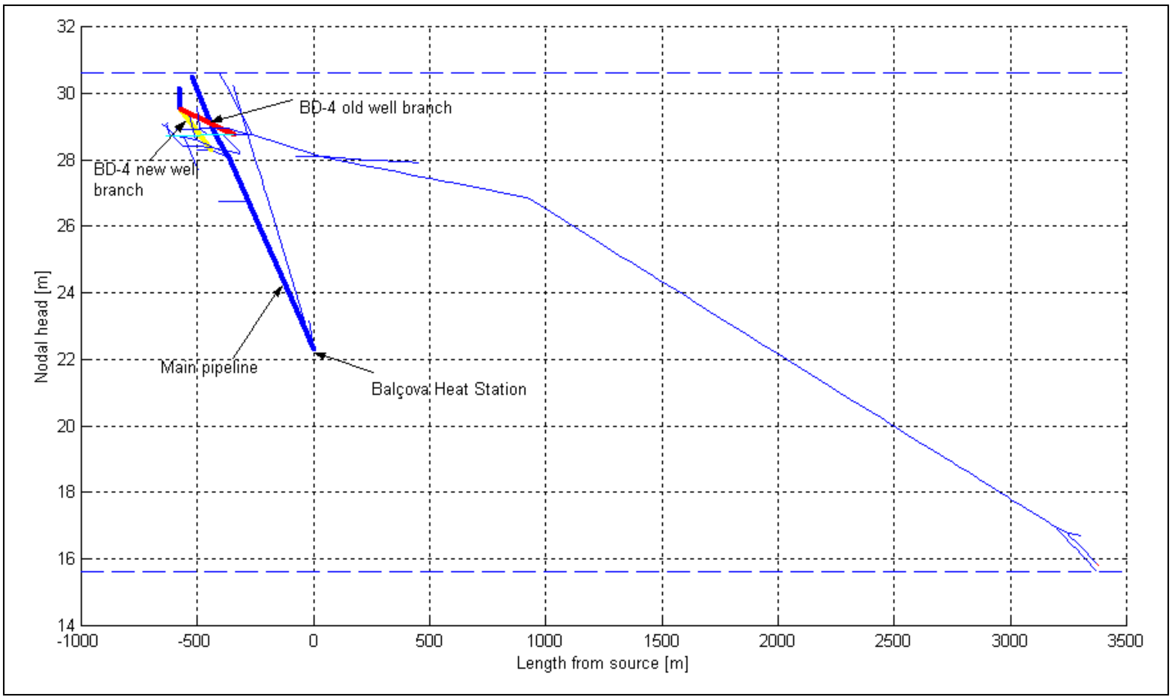

Figure 5.9. H-L plot of geothermal pipeline system, if BD-4 is connected to B-12 well branch

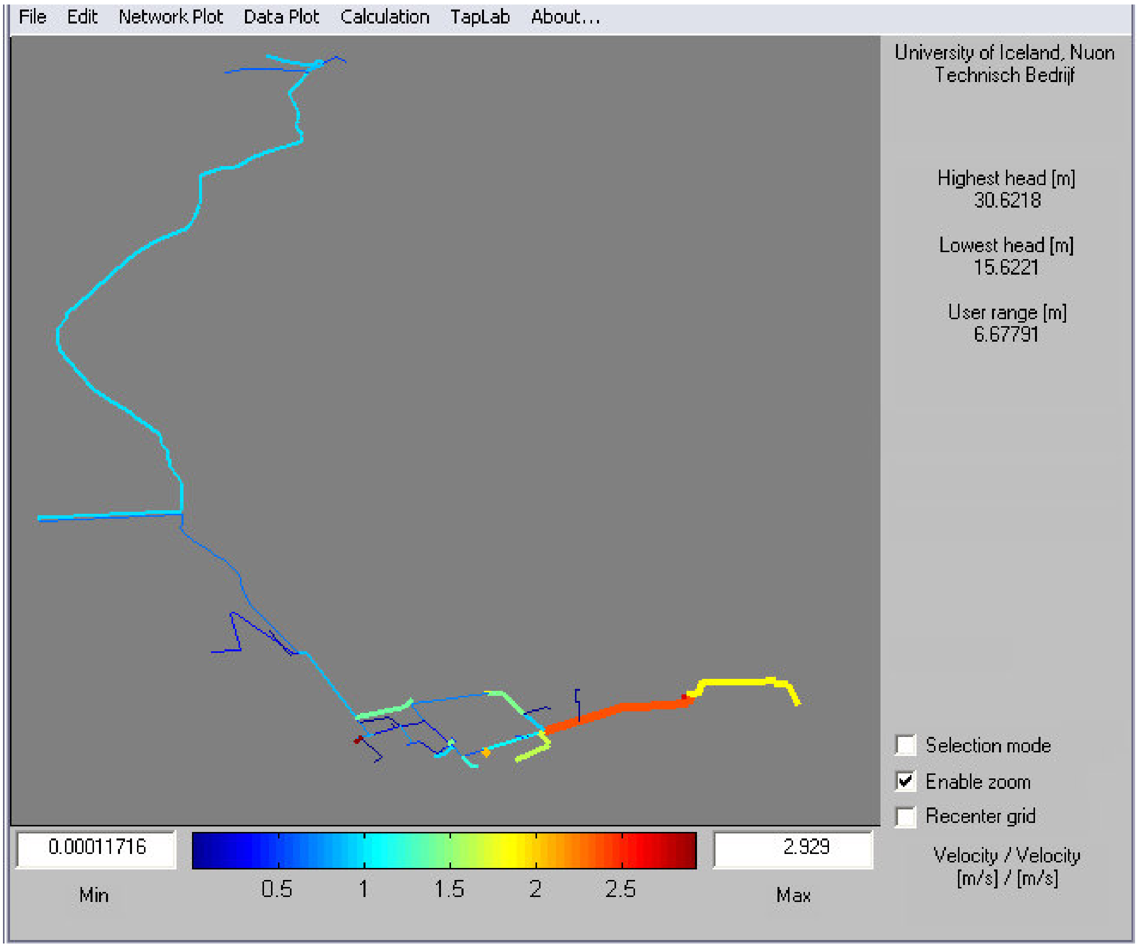

Figure 5.10. Velocity distribution of geothermal pipeline system, if BD-4 is connected to B-12 well branch

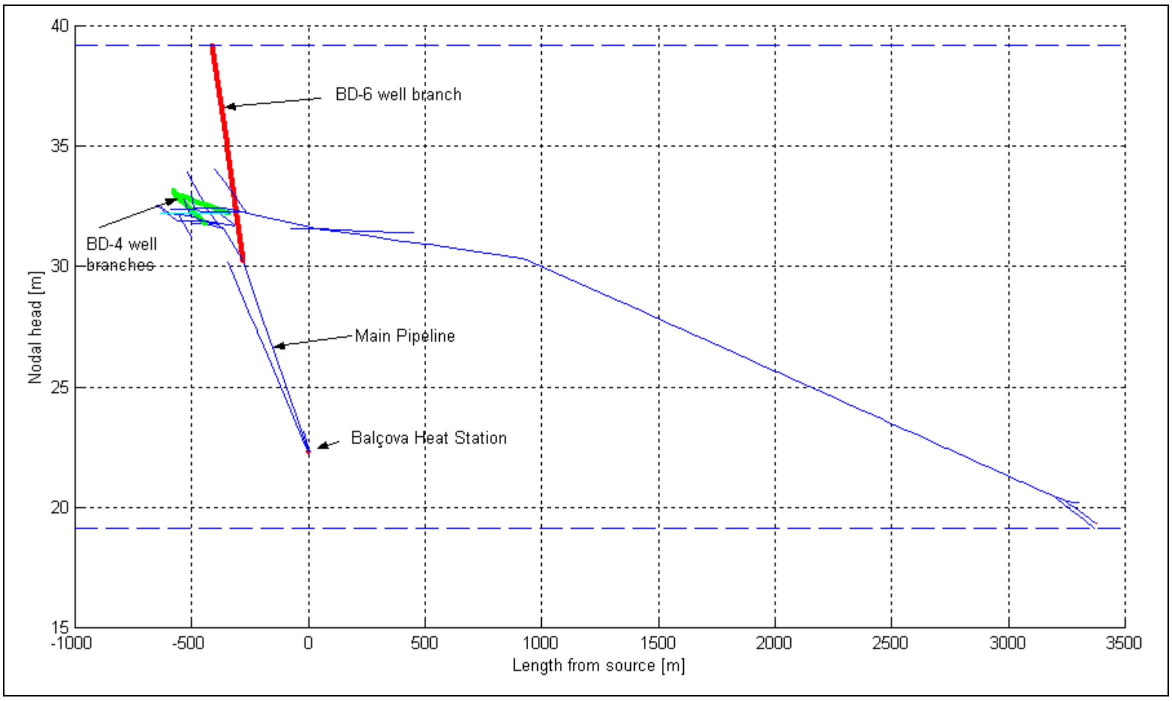

Figure 5.11. H-L plot of geothermal pipeline system, if BD-4 is connected to B-12 well branch while BD-6 works

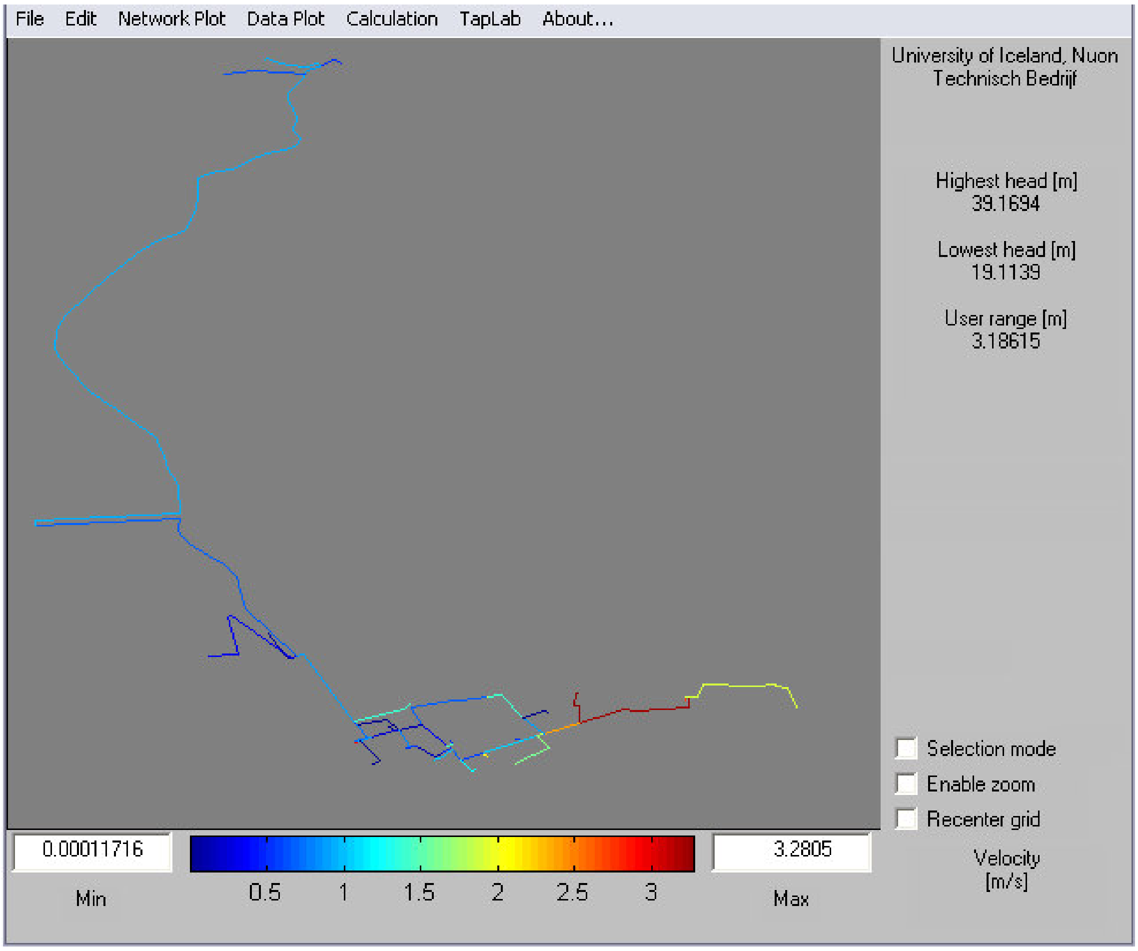

Figure 5.12. Velocity distribution of geothermal pipeline system, if BD-4 is connected to B-12 well branch while BD-6 works

If the diameter of the geothermal pipeline system is to be renewed using Pipelab District Heating Design Software, for either BD-6 is working or recent situation, resulting H-L plots are shown in Figure 5.16 and Figure 5.14. According velocity distributions of both situations are shown in Figure 5.15 and Figure 5.13.

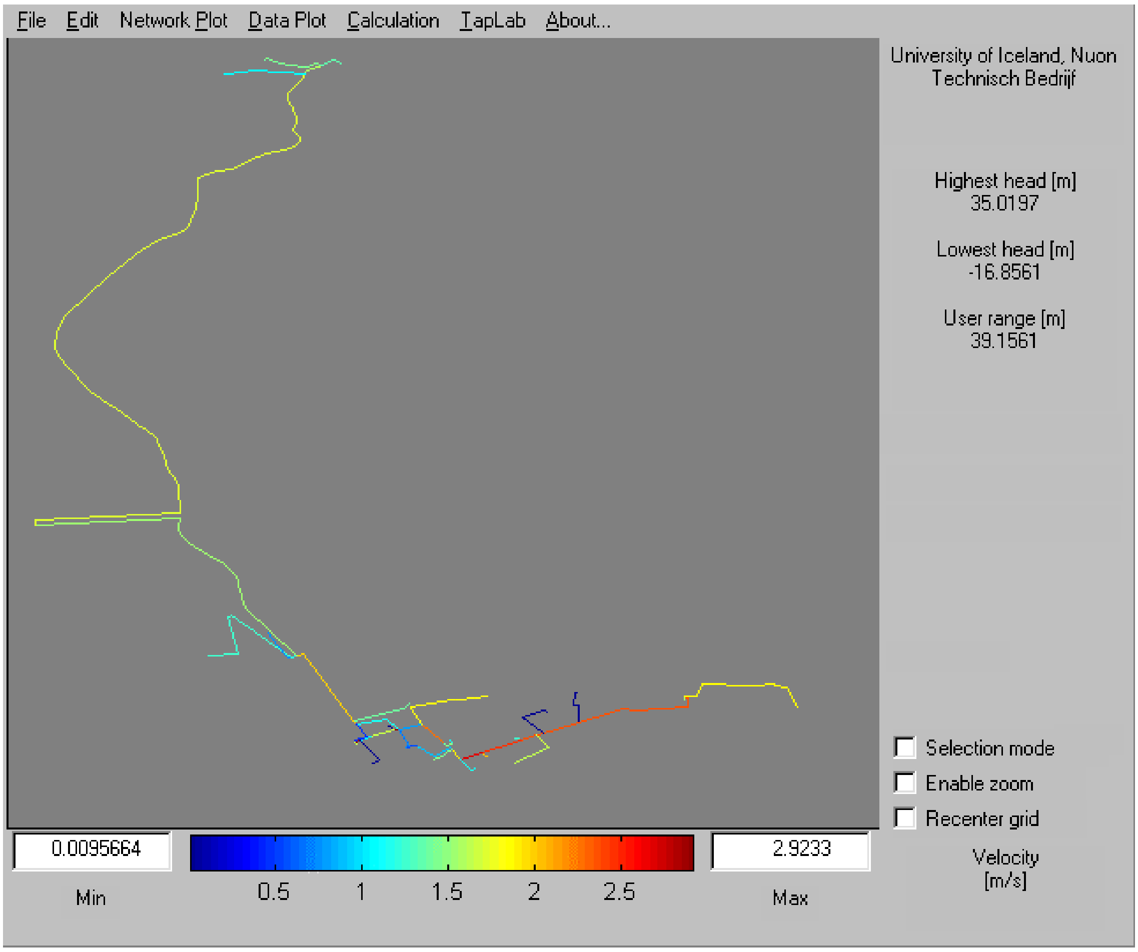

Figure 5.13. Velocity distribution of the geothermal pipeline for recent situation, diameters selected by Pipelab

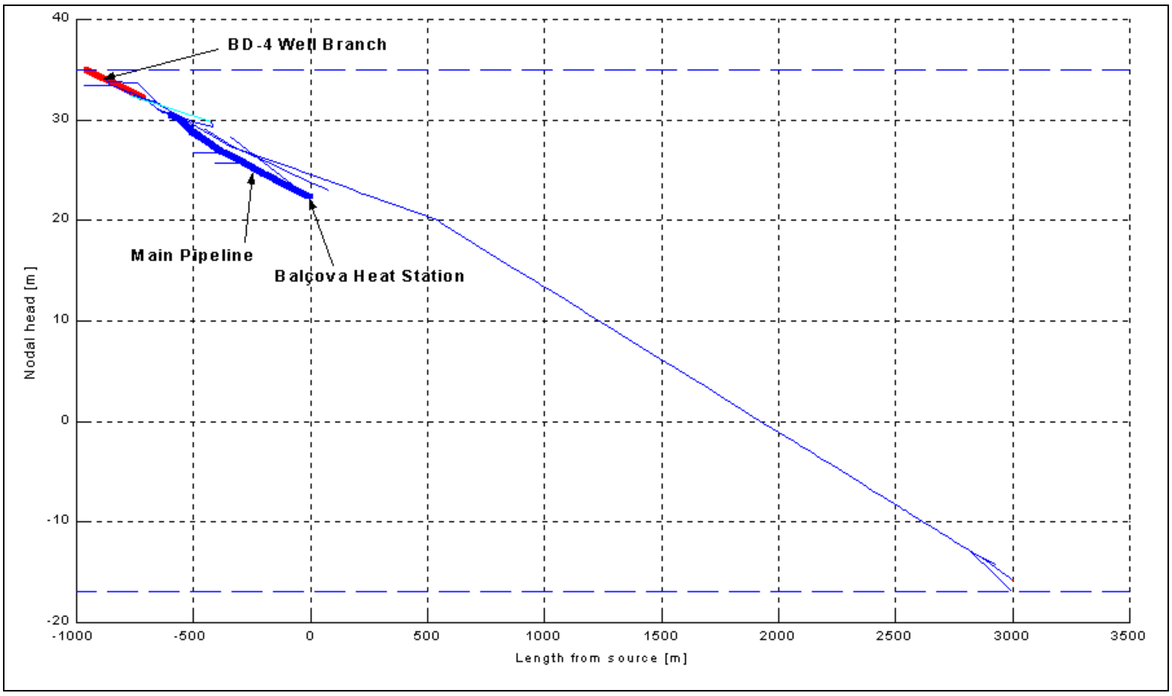

Figure 5.14. H-L plot of geothermal pipeline system, recent situation, diameters selected by Pipelab

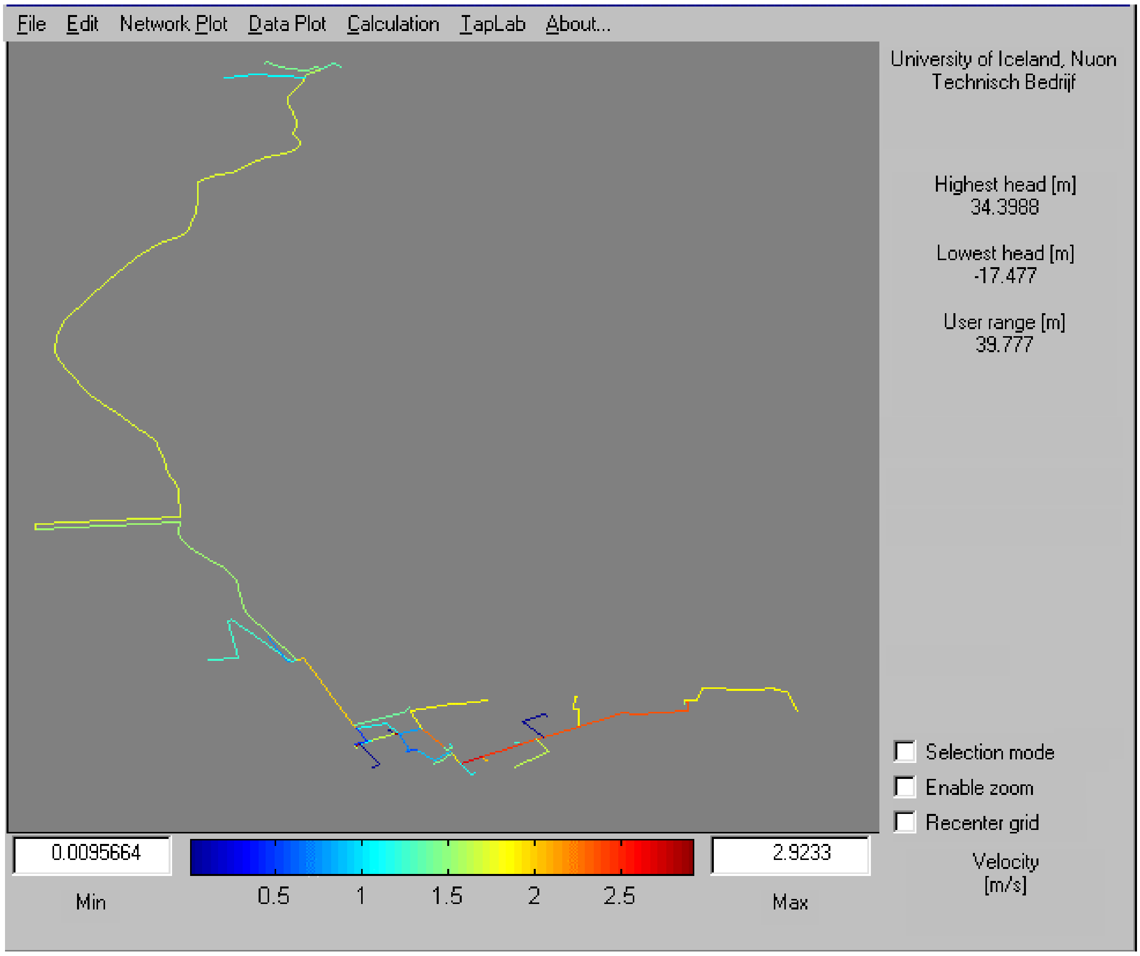

Figure 5.15. Velocity distribution of the geothermal pipeline while BD-6 works, diameters selected by Pipelab

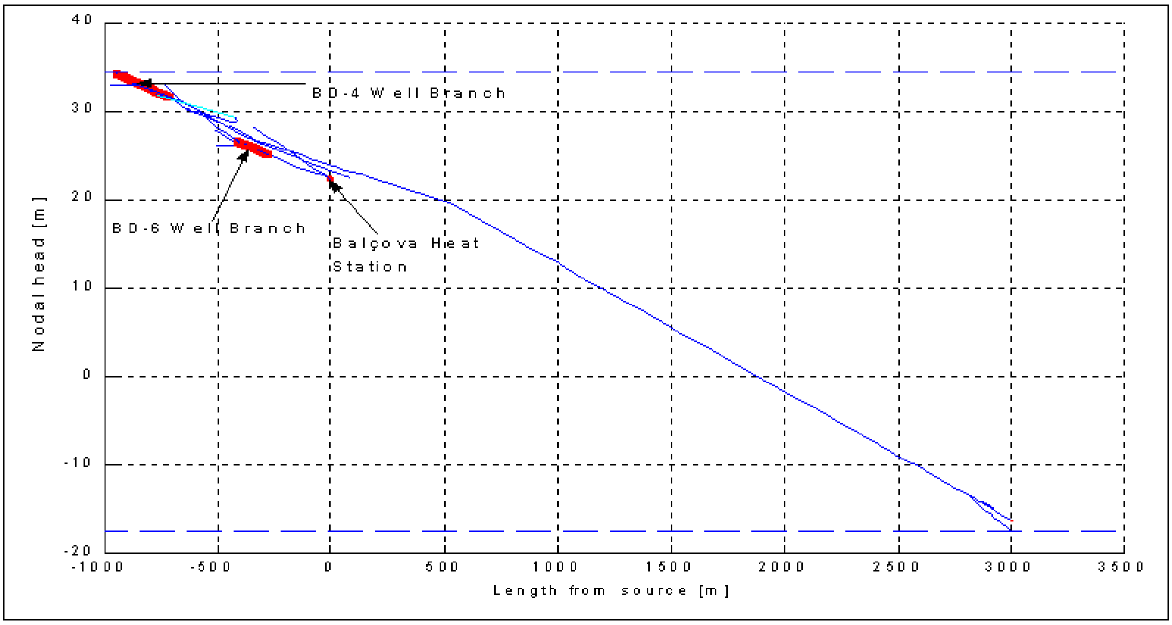

Figure 5.16. H-L plot of geothermal pipeline system, if BD-6 works, diameters selected by Pipelab

CHAPTER 6

ANALYSIS OF ENERGY USAGE OF CONSUMERS

6.1 Aim of The Study

The aim of this study is to form an opinion about the energy consumed by the end users of the Balçova – Narlıdere Geothermal District Heating System. In Balçova – Narlıdere District Heating System, there is not any monitoring system about end users energy consumptions, except Özdilek Hotel and Supermarket Complex. According to the protocol between Özdilek and Balçova Jeotermal Company, Özdilek pays for their own usage measured with a calorimeter.

For achieving proper operation conditions, it is important to monitor how much energy was consumed by end users. Knowledge of amount of energy consumed helps the operators about the working regime of system, and gives the operators doing the correct interference ability.

In the light of these explanations, a study was carried out to show the energy usage of end users in the Balçova – Narlıdere Geothermal District Heating System.

Another aim of this study is making a comparison with the "Average Heat Load in Balçova Geothermal District Heating System" which is used in the design of new systems. (Toksoy and Çanakçı 2001)

6.2 The Path of The Study

Firstly, two flow meters were assembled to two separate apartment buildings placed on the Narlıdere district at the west side of the Balçova – Narlıdere Geothermal District Heating System. Used flow meter is shown in Figure 6.5. These flow meters are the products of Danfoss. They measure the cumulative amount of the water passed through the heat exchanger. Figure 6.3 and 6.4 show the building connection equipments.

One of these apartment buildings named Ardıç has a total heating area of 1875 m^2, is on the Ardıç Street. The other one named Doğan, has a total heating area of 825 m^2, is on the Tur Street. In Table 6.1, the calculated peak heating loads, total heating areas, and peak heating loads per unit area of these apartment buildings are given. General views from the front sides of the two apartment buildings are shown in Figure 6.1 and Figure 6.2.

Peak heating loads were calculated by the procedure explained in the related publication of Turkish Chamber of Mechanical Engineers.

One of the parameters of consideration about the apartment building selection is the subscription status. Buildings with full subscriptions were chosen because of the monitoring the energy usage in these buildings is more proper.

Another parameter is the thermostatic radiator valves. While selecting the building to monitor its energy usage, this preferred the radiators of the buildings have thermostatic valves. Usage of the thermostatic radiator valves in the heating systems is preferred. According to energy management strategies, thermostatic radiator valves are most critical equipments because of their energy savings about 20 to 40%.

For creating a variety, one of the buildings was chosen as a middle height, and the other was chosen as a height building. Ardıç apartment building has 9 floors and 15 flats. Doğan apartment building has 4 floors and 8 flats.

First flow meter was assembled to Ardıç Apartment in 22.02.2004. In 26.03.2004, the second one was assembled to Doğan Apartment. Since these dates, the amount of the fluid passed through the flow meters has been measured in a daily period.

The indoor and outdoor temperatures were recorded hourly. In Figure 6.6, these temperatures are shown graphically.

Additionally, two thermometers were installed to two flats of Ardıç Apartment building. One of them was installed to Flat 7 and the other one was installed to Flat 15. Thermometers are Testo products with data recorder.

Table 6.1. Load details of the two apartment buildings

Name of Block	Ardıç	Doğan
Total heating area [m^2]	1875	825
Peak heating load [kcal/h]	141860	64896
Peak heating load per unit area [kcal/h.m^2]	75,66	78,66

Figure 6.1. Front view of Ardıç Apartment Building

Figure 6.2. Front view of Doğan Apartment Building

Figure 6.3. Heat exchanger and the flow meter at the Ardıç apartment building

Figure 6.4. Heat exchanger and the flow meter at the Doğan apartment building

Figure 6.5. Flow meter assembled to the heat exchanger inlet

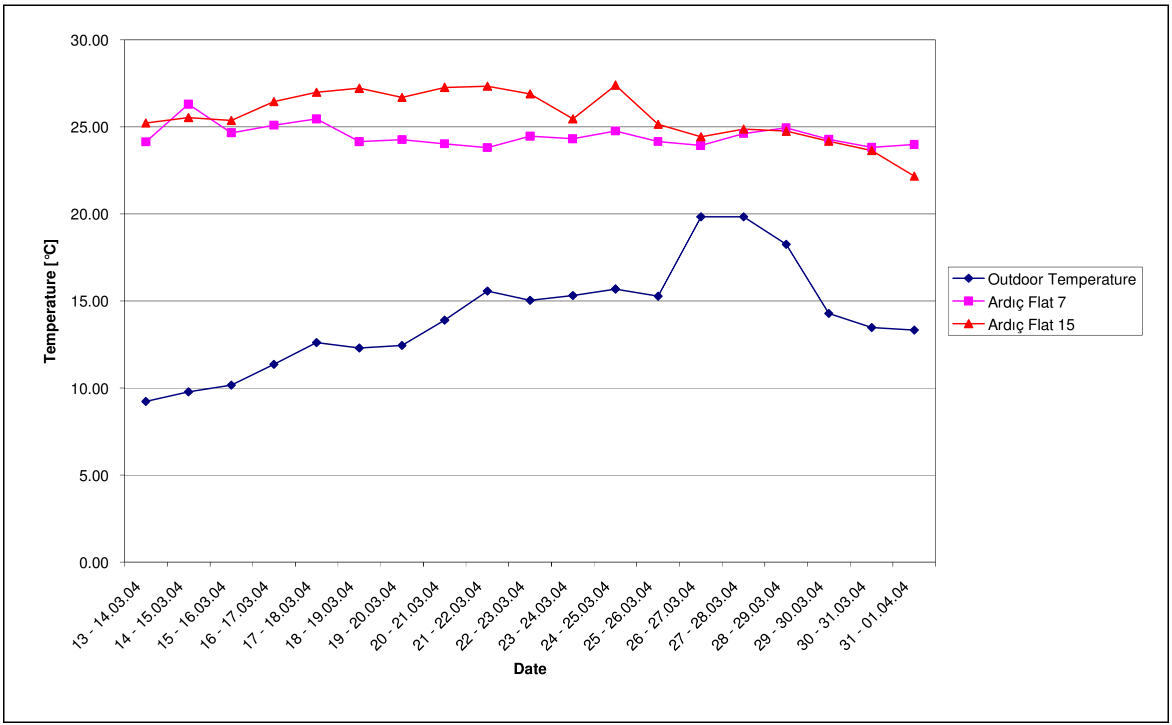

Figure 6.6. Recorded indoor and outdoor temperatures

6.3 Calculation Details

The consumed energy is calculated from Equation 6.1. The flow rate was measured at the heat exchanger inlet. The temperature difference ΔT is calculated from the measured temperatures from the inlet and the outlet of the heat exchangers of the buildings. The specific heat of the water was taken for average temperature.

$$Q_r = \dot{m} \times c_p \times \Delta T \tag{6.1}$$

The energy amount which should be supplied to achieve the thermal comfort conditions in the apartment buildings was calculated from Equation 6.2. The design parameters according to Turkish Chamber of Mechanical Engineers are 0°C outdoor temperature and 22°C average indoor temperature. According to hourly changing outdoor temperature, the theoretical energy should be supplied was calculated from Equation 6.2.

$$Q_t = Q_p \times \frac{(T_{d,i} - T_o)}{(T_{d,i} - T_{d,o})} \tag{6.2}$$

Another amount of energy which is according to the indoor temperature is calculated from Equation 6.3. This energy amount was calculated just for Ardıç Apartment Building because of having the only indoor temperature measurement.

$$Q_{t,it} = Q_p \times \frac{(T_i - T_o)}{(T_{d,i} - T_{d,o})} \tag{6.3}$$

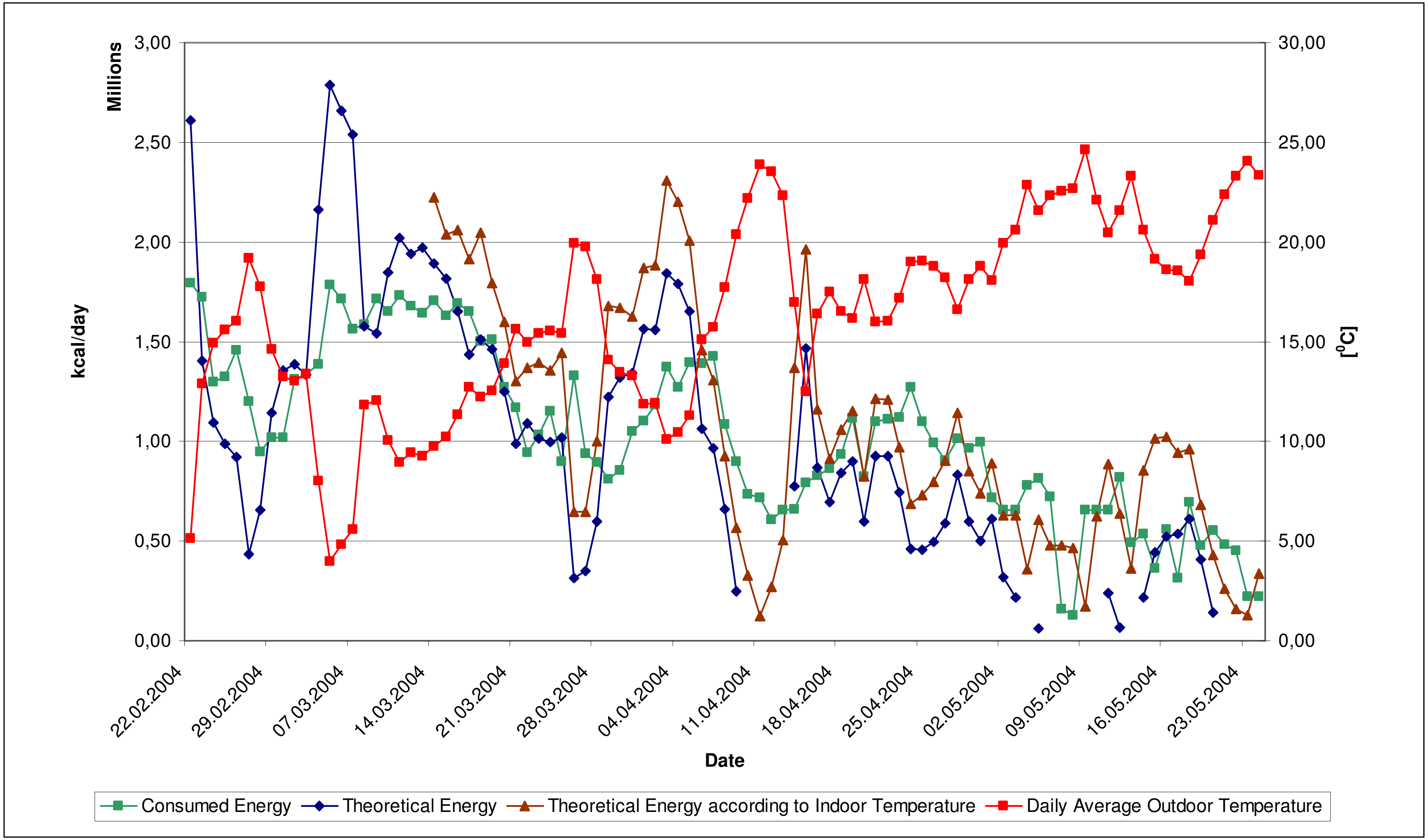

Figure 6.7. Comparison between the consumed and theoretical energy – Ardıç Apartment

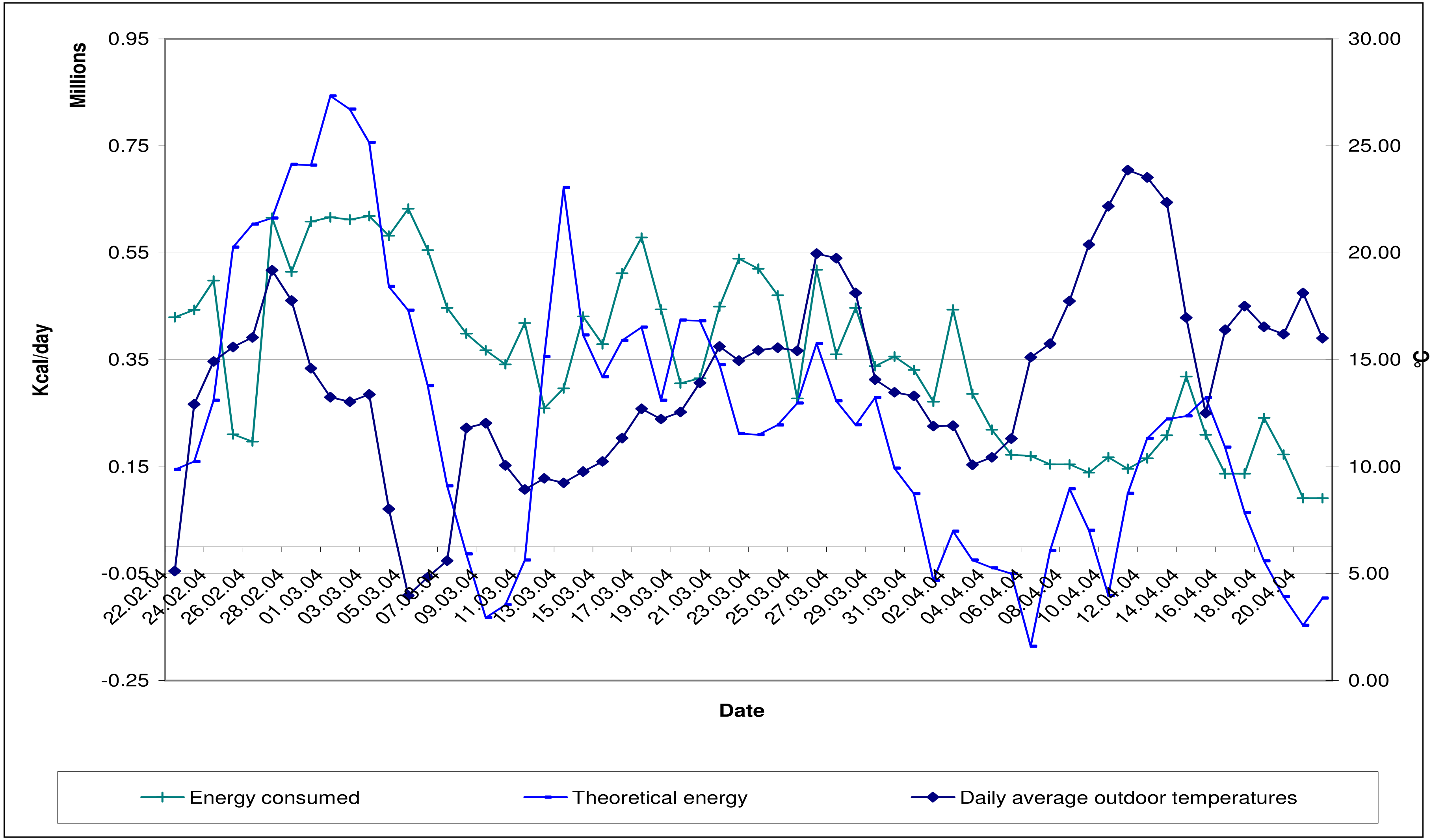

Figure 6.8. Comparison between the consumed and theoretical energy – Doğan Apartment

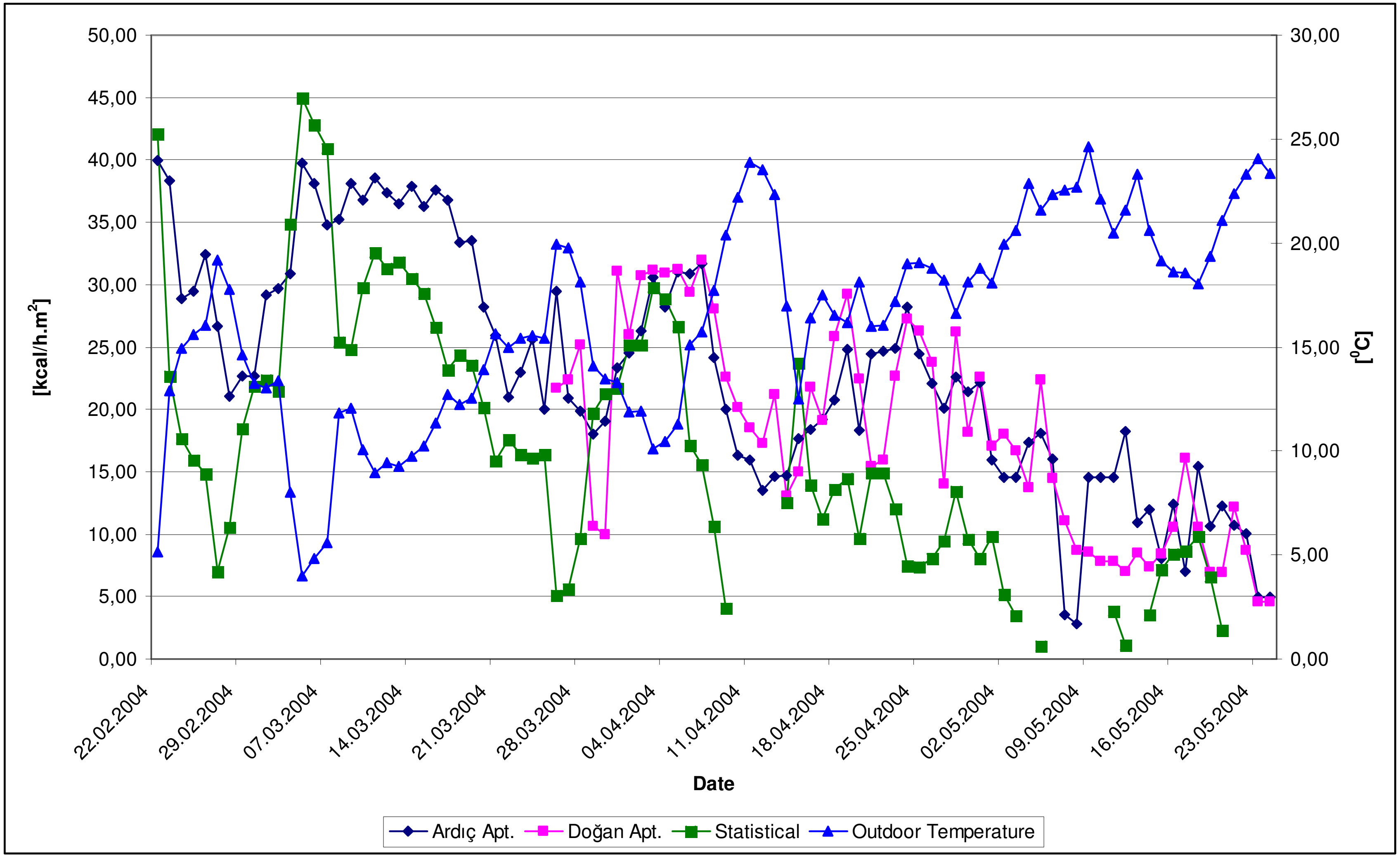

Figure 6.9. Comparison between the consumed energy and calculated energy from statistical average peak load [54,9 kcal/h.m^2]

6.4 Analysis Results

In Figure 6.7 and 6.8, comparisons between the consumed (Q_r) and theoretical energy (Q_t) are represented graphically. In the systems which are controlled automatically, these curves should be same accept special situations like breakdowns. However, in Balçova – Narlıdere Geothermal District Heating System, these two curves are just similar due to lack of control and user behaviors.

Specially, in Figure 6.7, there is an additional data line represented. These data calculated from the peak heating load of Ardıç Apartment according to the indoor temperatures measured from the Flat 7. As easily seen from the Figure 6.7, theoretical energy Q_t and theoretical energy according to indoor temperature $Q_{t,i}$ are parallel each other. Also, $Q_{t,i}$ is always more than Q_t. This situation shows the excess of the energy distributed than the energy needed.

In Figure 6.9, the consumed energy of both buildings is compared with the 54.9 kcal/h.m^2 value which is determined from statistical data of 40 buildings in Balçova – Narlıdere Geothermal District Heating System. It should be noted that, 54.9 kcal/h.m^2 value is used as design peak heat load value to determine the system capacity. These curves are almost parallel.

As easily seen from these three graphs, consumed energy by end users is mostly more than the theoretical and the statistical energy values. This can also be seen from the indoor temperatures shown in Figure 6.6. Indoor temperatures are almost 25°C instead of the design value 22°C.

CHAPTER 7

CONCLUSION

Being national, renewable, sustainable, and clean, gives geothermal energy a significant role through the energy sources of the new decade. Because of the Turkey's dependency of conventional energy sources, usage of alternative energy sources has to develop rapidly. Turkey is one of the richest countries in the name of geothermal potential.

According to the temperature regimes of geothermal sources, there are various utilization alternatives of geothermal energy. One of the common ways is the district heating system.

The western side of İzmir has a great geothermal potential. Balçova – Narlıdere Geothermal District Heating System is the biggest one and can be accepted as a huge laboratory.

Main goal of this study was analyzing the geothermal circuit of the Balçova – Narlıdere Geothermal District Heating System. For this aim, Pipelab District Heating Simulation Program was selected as analyzing tool.

The nodal network including all production wells and energy consumers as blocks was created. The real data of 2003 – 2004 heating season obtained from Balçova Jeotermal Company's database was used in the analysis. This data includes well productions, heat loads, and temperatures.

The main geothermal pipeline is the oldest part of the system and not yet renewed although the system has been expanded rapidly. One of the aims of this study is to reveal the characteristic of the main pipeline at peak load including the new loads.

A series of analysis were done in the Pipelab simulation program. The results showed that the critical points of the geothermal circuit of the system are BD-4 and BD-6 well branches and main pipeline. In the BD-6 and BD-4 well branches, the high pressure drop and the high velocities are the sources of the problem. Also in the main pipeline, high velocities are observed.

As discussed in the Chapter 5, some alternatives were introduced. Among these alternatives for BD-4 well branch, adding a new connection to B-12 well branch is suggested to be the best. Thus, having two connections (old one still can be used), the production of the BD-4 well will be shared by the two districts, Balçova and Narlıdere, according to demand. On the other hand making a new connection for BD-6 well branch is not suggested due to high investment cost. Instead, changing the BD-6 well branch with next larger diameter solves the problem.

If the system were at design stage, it would be possible to reduce the velocity of the geothermal fluid in the main pipeline significantly. But at this stage the only alternative which can be applied is to revise the diameters of the main pipeline. Unfortunately, it seems to be impossible because of the high investment cost. In the future, at the end of the operational life of the main pipeline, it will be an obligation to change this pipe. At that time, it will be logical to select next larger diameter.

Because of the system extensions, heat load has been increasing which makes the amount of the geothermal fluid passing through the main pipeline increases. Thus, at peak loads the required amount of the geothermal fluid was studied. The total peak load of the system was calculated from the Table 4.4 as nearly 90,000,000 kcal/h. On the other hand the energy extracted from the production wells at realized maximum flow rates was nearly 70,000,000 kcal/h. It shows the amount of the geothermal fluid doesn't meet the demand at peak loads. In 2003 – 2004 heating season, no problem was encountered due to the lack of the geothermal fluid. But this is a possible risk that can be faced at any time.

Of course, the heating loads may change due to the user's behaviors in the so called blocks. The characteristics of these blocks are much different from each other (university, hospital, dormitory, hotel, shopping center, and houses). These entire block connections should be analyzed one by one. In this study, only two apartment buildings energy analysis were conducted.

The system was designed to keep indoor temperature constant at 22°C. However, the observed indoor temperatures in this study were about 25°C. Actually this is a known fact and to overcome this problem, thermostatic radiator valves are to be favored. Although these two buildings have these valves, the indoor temperatures are still higher than the design value. Thermostatic radiator valves are adjustable between 18 – 25°C. The end users adjust these valves to its maximum possible value. Especially in Balçova district, few buildings have thermostatic radiator valves. So the indoor temperatures of those buildings are most likely higher than 25°C. These arguments imply that the energy consumed by many buildings is at higher values than their design requirement, which reveals the possibility of far branches not to be heated as desired.

Actually all these problems are because of the lack of the control. For example, thermostatic radiator valves should have the maximum adjustable value of nearly the design temperature. Recently, system is controlled by the operator’s experiences. So, system does not respond to the changing outdoor temperatures.

An automatic control system is seriously recommended for the Balçova – Narlıdere District Heating System. If this can not be setup due to any reason, at least according to the changing outdoor temperature, an operational control strategy should be developed and applied in the earliest heating season.

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APPENDIX A

Data of Figure 4.1

Date	Total Heat Production [MW_{th}]	Average Outdoor Temperature [^0C]
01.10.03	9	20
02.10.03	9	22
03.10.03	8	21
04.10.03	8	21
05.10.03	7	23
06.10.03	7	23
07.10.03	8	22
08.10.03	8	21
09.10.03	8	16
10.10.03	5	13
11.10.03	19	15
12.10.03	19	18
13.10.03	21	18
14.10.03	18	18
15.10.03	19	19
16.10.03	19	15
17.10.03	10	17
18.10.03	18	17
19.10.03	18	20
20.10.03	18	22
21.10.03	18	21
22.10.03	9	22
23.10.03	8	21
24.10.03	8	21
25.10.03	8	22
26.10.03	8	18
27.10.03	12	14
28.10.03	13	12
29.10.03	18	8
30.10.03	40	8
31.10.03	37	17
01.11.03	32	18
02.11.03	21	18
03.11.03	20	20
04.11.03	20	18
05.11.03	18	17
06.11.03	35	13
07.11.03	34	14
08.11.03	35	14
09.11.03	36	11
10.11.03	44	10
11.11.03	45	7
12.11.03	45	7
13.11.03	45	8
14.11.03	40	9
15.11.03	43	7
16.11.03	43	11
17.11.03	46	11
18.11.03	44	11
19.11.03	35	11
20.11.03	44	12
21.11.03	42	12
22.11.03	40	12
23.11.03	40	12
24.11.03	42	11
25.11.03	43	10
26.11.03	41	11
27.11.03	42	11
28.11.03	42	11
29.11.03	41	12
30.11.03	41	12
01.12.03	47	12
02.12.03	49	11
03.12.03	47	8
04.12.03	47	10
05.12.03	49	7
06.12.03	49	5
07.12.03	49	10
08.12.03	51	7
09.12.03	56	7
10.12.03	57	7
11.12.03	54	10
12.12.03	55	9
13.12.03	50	12
14.12.03	50	12
15.12.03	51	12
16.12.03	53	10
17.12.03	51	4
18.12.03	60	2
19.12.03	63	2
20.12.03	62	3
21.12.03	61	5
22.12.03	58	6
23.12.03	54	11
24.12.03	57	12
25.12.03	55	8
26.12.03	53	7
27.12.03	61	6
28.12.03	61	4
29.12.03	59	6
30.12.03	54	8

31.12.03	54	8
01.01.04	53	10
02.01.04	53	10
03.01.04	61	8
04.01.04	57	8
05.01.04	55	7
06.01.04	61	3
07.01.04	64	-1
08.01.04	64	-3
09.01.04	67	0
10.01.04	68	0
11.01.04	63	7
12.01.04	63	7
13.01.04	65	6
14.01.04	63	8
15.01.04	60	12
16.01.04	57	10
17.01.04	61	4
18.01.04	61	5
19.01.04	61	8
20.01.04	58	10
21.01.04	60	12
22.01.04	58	5
23.01.04	69	-2
24.01.04	69	-1
25.01.04	69	1
26.01.04	66	2
27.01.04	65	2
28.01.04	66	10
29.01.04	64	13
30.01.04	54	10
31.01.04	62	7
01.02.04	62	5
02.02.04	62	5
03.02.04	62	5
04.02.04	62	7
05.02.04	62	7
06.02.04	58	10
07.02.04	58	11
08.02.04	58	13
09.02.04	53	13
09.02.04	58	8
10.02.04	58	4
11.02.04	58	5
12.02.04	61	-1
13.02.04	65	-2
14.02.04	66	-1
15.02.04	65	5
16.02.04	65	4
17.02.04	66	5
18.02.04	66	4
19.02.04	66	6

20.02.04	65	2
21.02.04	66	1
22.02.04	65	7
23.02.04	65	11
24.02.04	63	14
25.02.04	60	11
26.02.04	56	15
27.02.04	55	17
28.02.04	46	14
29.02.04	38	11
01.03.04	40	12
02.03.04	41	10
03.03.04	46	8
04.03.04	49	4
05.03.04	54	3
06.03.04	59	3
07.03.04	59	5
08.03.04	57	9
09.03.04	59	9
10.03.04	59	7
11.03.04	52	7
12.03.04	54	8
13.03.04	55	10
14.03.04	52	8
15.03.04	55	11
16.03.04	52	12
17.03.04	51	11
18.03.04	50	13
19.03.04	50	11
20.03.04	43	11
21.03.04	38	13
22.03.04	38	11
23.03.04	39	12
24.03.04	42	11
25.03.04	40	13
26.03.04	40	17
27.03.04	38	15
28.03.04	26	14
29.03.04	27	13
30.03.04	33	13
31.03.04	35	10
01.04.04	36	12
02.04.04	47	11
03.04.04	44	10
04.04.04	44	10
05.04.04	44	10
06.04.04	42	13
07.04.04	42	15
08.04.04	41	16
09.04.04	35	17
10.04.04	29	17
11.04.04	21	18

12.04.04	21	20
13.04.04	20	14
14.04.04	21	11
15.04.04	25	12
16.04.04	34	14
17.04.04	33	13
18.04.04	33	13
19.04.04	34	14
20.04.04	34	14
21.04.04	31	12
22.04.04	31	15
23.04.04	30	14
24.04.04	30	16
25.04.04	27	16
26.04.04	26	17
27.04.04	28	15
28.04.04	27	14
29.04.04	25	15
30.04.04	25	15
01.05.04	24	17
02.05.04	24	16
03.05.04	24	17
04.05.04	17	17
05.05.04	20	18
06.05.04	18	17
07.05.04	18	17
08.05.04	16	18
09.05.04	16	21
10.05.04	12	17
11.05.04	10	18
12.05.04	9	18
13.05.04	10	17
14.05.04	10	17
15.05.04	10	16
16.05.04	10	14
17.05.04	10	13
18.05.04	10	15

APPENDIX B

Data of Figure 6.7

Date	Consumed Energy	Theoretical Energy	Theoretical Energy According to Indoor Temperature	Daily Average Outdoor Temperature
	[kcal/day]	[kcal/day]	[kcal/day]	[^{0}C]
22.02.2004	1.796.506	2.611.512		5,13
23.02.2004	1.725.316	1.405.703		12,92
24.02.2004	1.299.536	1.096.190		14,92
25.02.2004	1.324.527	989.795		15,60
26.02.2004	1.458.303	922.089		16,04
27.02.2004	1.199.572	436.131		19,18
28.02.2004	946.375	654.490		17,77
29.02.2004	1.020.627	1.144.552		14,60
01.03.2004	1.020.627	1.354.117		13,25
02.03.2004	1.313.257	1.386.358		13,04
03.03.2004	1.336.778	1.334.773		13,38
04.03.2004	1.387.740	2.163.364		8,02
05.03.2004	1.787.597	2.788.977		3,98
06.03.2004	1.715.074	2.656.649		4,83
07.03.2004	1.566.107	2.537.358		5,60
08.03.2004	1.584.728	1.576.580		11,81
09.03.2004	1.715.074	1.541.115		12,04
10.03.2004	1.653.821	1.847.403		10,06
11.03.2004	1.734.675	2.021.504		8,94
12.03.2004	1.680.143	1.940.902		9,46
13.03.2004	1.643.067	1.973.143		9,25
14.03.2004	1.705.273	1.892.540	2.222.727	9,77
15.03.2004	1.630.182	1.818.386	2.037.017	10,25
16.03.2004	1.691.532	1.650.734	2.060.875	11,33
17.03.2004	1.655.024	1.437.944	1.916.433	12,71
18.03.2004	1.503.412	1.512.098	2.045.399	12,23
19.03.2004	1.510.245	1.460.512	1.792.626	12,56
20.03.2004	1.270.135	1.250.947	1.599.822	13,92
21.03.2004	1.167.965	986.571	1.300.621	15,63
22.03.2004	945.496	1.089.742	1.368.973	14,96
23.03.2004	1.033.454	1.015.588	1.396.701	15,44
24.03.2004	1.152.530	996.244	1.354.142	15,56
25.03.2004	901.639	1.018.812	1.445.708	15,42
26.03.2004	1.327.403	315.961	648.699	19,96
27.03.2004	940.244	348.202	645.474	19,75
28.03.2004	893.798	599.681	1.002.710	18,13
29.03.2004	809.515	1.225.154	1.679.136	14,08
30.03.2004	856.523	1.318.652	1.670.753	13,48
31.03.2004	1.051.512	1.344.445	1.624.326	13,31
01.04.2004	1.101.964	1.563.683	1.870.006	11,90
02.04.2004	1.182.911	1.560.459	1.885.482	11,92
03.04.2004	1.375.545	1.844.179	2.307.845	10,08
04.04.2004	1.270.239	1.789.369	2.201.448	10,44

05.04.2004	1.397.263	1.653.078	2.008.410	11,32
06.04.2004	1.389.549	1.063.949	1.456.670	15,13
07.04.2004	1.425.810	967.227	1.306.425	15,75
08.04.2004	1.085.813	659.396	925.723	17,74
09.04.2004	899.335	249.629	568.179	20,39
10.04.2004	734.004		329.508	22,18
11.04.2004	718.933		123.162	23,87
12.04.2004	608.328		268.894	23,53
13.04.2004	657.608		504.257	22,35
14.04.2004	662.429	777.650	1.368.973	16,98
15.04.2004	793.133	1.468.895	1.960.927	12,51
16.04.2004	827.013	866.635	1.159.404	16,40
17.04.2004	865.446	695.114	914.368	17,51
18.04.2004	935.046	844.067	1.060.745	16,55
19.04.2004	1.117.796	898.231	1.151.666	16,20
20.04.2004	825.045	599.681	824.737	18,13
21.04.2004	1.100.305	926.603	1.212.924	16,01
22.04.2004	1.110.737	924.669	1.209.055	16,03
23.04.2004	1.121.168	744.765	970.468	17,19
24.04.2004	1.270.135	462.979	685.454	19,01
25.04.2004	1.098.972	458.465	733.171	19,04
26.04.2004	994.308	497.799	797.654	18,78
27.04.2004	905.109	587.429	904.051	18,20
28.04.2004	1.016.763	831.815	1.145.217	16,63
29.04.2004	964.725	597.101	849.241	18,14
30.04.2004	996.827	499.089	742.199	18,78
01.05.2004	717.391	609.998	889.865	18,06
02.05.2004	654.646	321.119	628.064	19,93
03.05.2004	654.646	217.304	627.419	20,60
04.05.2004	782.119		357.236	22,88
05.05.2004	813.155	63.837	606.140	21,59
06.05.2004	720.415		478.464	22,35
07.05.2004	159.565		479.753	22,55
08.05.2004	127.652		464.277	22,70
09.05.2004	655.648		173.459	24,63
10.05.2004	655.648		622.905	22,10
11.05.2004	655.648	237.293	884.706	20,47
12.05.2004	819.560	67.706	639.026	21,56
13.05.2004	490.535		363.684	23,29
14.05.2004	538.084	218.593	855.689	20,59
15.05.2004	361.578	443.635	1.016.896	19,13
16.05.2004	558.970	522.947	1.022.700	18,62
17.05.2004	316.122	534.554	942.096	18,55
18.05.2004	694.916	610.642	959.506	18,05
19.05.2004	478.662	407.525	681.585	19,37
20.05.2004	552.302	140.570	432.036	21,09
21.05.2004	482.139		262.446	22,37
22.05.2004	451.219		158.628	23,31
23.05.2004	221.490		127.031	24,07
24.05.2004	221.490		337.246	23,35

APPENDIX C

Data of Figure 6.8

Date	Consumed Energy	Theoretical Energy	Daily Average Outdoor Temperature
	[kcal/day]	[kcal/day]	[^{0}C]
26.03.2004	429.514	144.541	19,96
27.03.2004	443.320	159.290	19,75
28.03.2004	498.092	274.333	18,13
29.03.2004	210.709	560.465	14,08
30.03.2004	196.899	603.238	13,48
31.03.2004	615.823	615.037	13,31
01.04.2004	514.522	715.331	11,90
02.04.2004	608.606	713.856	11,92
03.04.2004	616.702	843.648	10,08
04.04.2004	612.271	818.575	10,44
05.04.2004	618.912	756.226	11,32
06.04.2004	582.331	486.720	15,13
07.04.2004	632.634	442.473	15,75
08.04.2004	555.517	301.651	17,74
09.04.2004	447.283	114.196	20,39
10.04.2004	398.913		22,18
11.04.2004	367.646		23,87
12.04.2004	341.545		23,53
13.04.2004	418.968		22,35
14.04.2004	259.211	355.748	16,98
15.04.2004	296.326	671.969	12,51
16.04.2004	430.846	396.456	16,40
17.04.2004	379.113	317.990	17,51
18.04.2004	511.589	386.131	16,55
19.04.2004	578.376	410.910	16,20
20.04.2004	444.103	274.333	18,13
21.04.2004	305.773	423.889	16,01
22.04.2004	315.574	423.004	16,03
23.04.2004	449.251	340.704	17,19
24.04.2004	539.102	211.797	19,01
25.04.2004	520.068	209.732	19,04
26.04.2004	470.537	227.726	18,78
27.04.2004	277.574	268.728	18,20
28.04.2004	518.559	380.527	16,63
29.04.2004	360.136	273.153	18,14
30.04.2004	447.231	228.316	18,78
01.05.2004	338.115	279.053	18,06
02.05.2004	356.159	146.901	19,93
03.05.2004	330.719	99.409	20,60
04.05.2004	271.479		22,88
05.05.2004	443.539	29.203	21,59
06.05.2004	286.553		22,35

07.05.2004	219.098		22,55
08.05.2004	172.149		22,70
09.05.2004	169.792		24,63
10.05.2004	154.357		22,10
11.05.2004	154.357	108.553	20,47
12.05.2004	138.921	30.973	21,56
13.05.2004	167.772		23,29
14.05.2004	145.841	99.999	20,59
15.05.2004	166.031	202.947	19,13
16.05.2004	208.645	239.230	18,62
17.05.2004	318.823	244.540	18,55
18.05.2004	209.727	279.348	18,05
19.05.2004	137.108	186.429	19,37
20.05.2004	137.108	64.306	21,09
21.05.2004	241.069		22,37
22.05.2004	172.807		23,31
23.05.2004	91.203		24,07
24.05.2004	91.203		23,35

APPENDIX D

Data of Figure 6.9

Date	Consumed Energy		Statistical Value	Daily Average Outdoor Temperature
	Ardıç	Doğan		
	[kcal/h.m^2]	[kcal/h.m^2]	[kcal/h.m^2]	[^{0}C]
22.02.2004	39,9		42,1	5,13
23.02.2004	38,3		22,7	12,92
24.02.2004	28,9		17,7	14,92
25.02.2004	29,4		16,0	15,60
26.02.2004	32,4		14,9	16,04
27.02.2004	26,7		7,0	19,18
28.02.2004	21,0		10,6	17,77
29.02.2004	22,7		18,5	14,60
01.03.2004	22,7		21,8	13,25
02.03.2004	29,2		22,4	13,04
03.03.2004	29,7		21,5	13,38
04.03.2004	30,8		34,9	8,02
05.03.2004	39,7		45,0	3,98
06.03.2004	38,1		42,8	4,83
07.03.2004	34,8		40,9	5,60
08.03.2004	35,2		25,4	11,81
09.03.2004	38,1		24,9	12,04
10.03.2004	36,8		29,8	10,06
11.03.2004	38,5		32,6	8,94
12.03.2004	37,3		31,3	9,46
13.03.2004	36,5		31,8	9,25
14.03.2004	37,9		30,5	9,77
15.03.2004	36,2		29,3	10,25
16.03.2004	37,6		26,6	11,33
17.03.2004	36,8		23,2	12,71
18.03.2004	33,4		24,4	12,23
19.03.2004	33,6		23,6	12,56
20.03.2004	28,2		20,2	13,92
21.03.2004	26,0		15,9	15,63
22.03.2004	21,0		17,6	14,96
23.03.2004	23,0		16,4	15,44
24.03.2004	25,6		16,1	15,56
25.03.2004	20,0		16,4	15,42
26.03.2004	29,5	21,7	5,1	19,96
27.03.2004	20,9	22,4	5,6	19,75
28.03.2004	19,9	25,2	9,7	18,13
29.03.2004	18,0	10,6	19,8	14,08
30.03.2004	19,0	9,9	21,3	13,48
31.03.2004	23,4	31,1	21,7	13,31
01.04.2004	24,5	26,0	25,2	11,90
02.04.2004	26,3	30,7	25,2	11,92
03.04.2004	30,6	31,1	29,7	10,08
04.04.2004	28,2	30,9	28,9	10,44

05.04.2004	31,1	31,3	26,7	11,32
06.04.2004	30,9	29,4	17,2	15,13
07.04.2004	31,7	32,0	15,6	15,75
08.04.2004	24,1	28,1	10,6	17,74
09.04.2004	20,0	22,6	4,0	20,39
10.04.2004	16,3	20,1		22,18
11.04.2004	16,0	18,6		23,87
12.04.2004	13,5	17,2		23,53
13.04.2004	14,6	21,2		22,35
14.04.2004	14,7	13,1	12,5	16,98
15.04.2004	17,6	15,0	23,7	12,51
16.04.2004	18,4	21,8	14,0	16,40
17.04.2004	19,2	19,1	11,2	17,51
18.04.2004	20,8	25,8	13,6	16,55
19.04.2004	24,8	29,2	14,5	16,20
20.04.2004	18,3	22,4	9,7	18,13
21.04.2004	24,5	15,4	14,9	16,01
22.04.2004	24,7	15,9	14,9	16,03
23.04.2004	24,9	22,7	12,0	17,19
24.04.2004	28,2	27,2	7,5	19,01
25.04.2004	24,4	26,3	7,4	19,04
26.04.2004	22,1	23,8	8,0	18,78
27.04.2004	20,1	14,0	9,5	18,20
28.04.2004	22,6	26,2	13,4	16,63
29.04.2004	21,4	18,2	9,6	18,14
30.04.2004	22,2	22,6	8,0	18,78
01.05.2004	15,9	17,1	9,8	18,06
02.05.2004	14,5	18,0	5,2	19,93
03.05.2004	14,5	16,7	3,5	20,60
04.05.2004	17,4	13,7		22,88
05.05.2004	18,1	22,4	1,0	21,59
06.05.2004	16,0	14,5		22,35
07.05.2004	3,5	11,1		22,55
08.05.2004	2,8	8,7		22,70
09.05.2004	14,6	8,6		24,63
10.05.2004	14,6	7,8		22,10
11.05.2004	14,6	7,8	3,8	20,47
12.05.2004	18,2	7,0	1,1	21,56
13.05.2004	10,9	8,5		23,29
14.05.2004	12,0	7,4	3,5	20,59
15.05.2004	8,0	8,4	7,2	19,13
16.05.2004	12,4	10,5	8,4	18,62
17.05.2004	7,0	16,1	8,6	18,55
18.05.2004	15,4	10,6	9,8	18,05
19.05.2004	10,6	6,9	6,6	19,37
20.05.2004	12,3	6,9	2,3	21,09
21.05.2004	10,7	12,2		22,37
22.05.2004	10,0	8,7		23,31
23.05.2004	4,9	4,6		24,07
24.05.2004	4,9	4,6		23,35

APPENDIX E

Raw Data Used By Pipelab

node	1	0.0000	0.0000	0.0000
node	2	0.2591	-19.6508	0.0000
node	3	6.8756	-6.8281	0.0000
node	4	5.7475	-35.6437	0.0000
node	5	-102.7482	-48.5734	0.0000
node	6	-129.8749	-46.2272	0.0000
node	7	-152.4762	-60.1163	0.0000
node	8	-220.7394	-98.6675	0.0000
node	9	-220.7394	-31.9316	0.0000
node	10	-228.6985	-31.9316	0.0000
node	11	-227.9993	13.5631	0.0000
node	12	-218.0005	17.2775	0.0000
node	13	-293.9102	-139.9843	0.0000
node	14	-336.1120	-74.6968	0.0000
node	15	-290.9789	-49.3378	0.0000
node	16	-281.0909	-60.0797	0.0000
node	17	-306.3872	-147.1266	0.0000
node	18	-282.1255	-191.4875	0.0000
node	19	-354.4941	-249.2380	0.0000
node	20	-329.2805	-160.2316	0.0000
node	21	-334.0109	-151.9681	0.0000
node	22	-341.4765	-167.2281	0.0000
node	23	-345.9273	-158.2521	0.0000
node	24	-353.6567	-158.7911	0.0000
node	25	-420.7970	-211.3631	0.0000
node	26	-406.9684	-234.6824	0.0000
node	27	-463.6955	-235.6742	0.0000
node	28	-443.1495	-278.4307	0.0000
node	29	-428.5709	-269.4664	0.0000
node	30	-482.3416	-202.2072	0.0000
node	31	-494.4346	-214.1089	0.0000
node	32	-498.5276	-224.3369	0.0000
node	33	-522.1555	-241.4456	0.0000
node	34	-487.2285	-195.0587	0.0000
node	35	-502.1686	-209.0900	0.0000
node	36	-552.6711	-182.4223	0.0000
node	37	-579.2471	-191.9010	0.0000
node	38	-568.1143	-186.1897	0.0000
node	39	-492.7392	-184.7258	0.0000
node	40	-478.4444	-177.0616	0.0000
node	41	-500.9378	-171.7956	0.0000
node	42	-507.3851	-219.9158	0.0000
node	43	-517.8179	-228.1354	0.0000
node	44	-544.4837	-103.1181	0.0000
node	45	-567.4984	-46.6364	0.0000
node	46	-566.7235	-35.5334	0.0000
node	47	-481.6233	-14.2952	0.0000
node	48	-464.1349	-12.2496	0.0000
node	49	-410.4979	0.7236	0.0000
node	50	-411.9713	9.9675	0.0000
node	51	-561.1087	-111.8717	0.0000
node	52	-592.3388	-123.9327	0.0000
node	53	-602.0537	-127.6846	0.0000
node	54	-615.4789	-105.4608	0.0000
node	55	-650.0486	-153.1785	0.0000
node	56	-672.9255	-165.1629	0.0000
node	57	-630.5070	-240.6641	0.0000
node	58	-650.2088	-261.5018	0.0000
node	59	-680.5335	-169.3964	0.0000
node	60	-674.5832	-179.5863	0.0000
node	61	-618.0218	-85.3672	0.0000

node	62	-677.6791	-108.0082	0.0000
node	63	-685.3747	-89.3157	0.0000
node	64	-581.4480	-45.6036	0.0000
node	65	-566.9818	-17.2005	0.0000
node	66	-789.1747	162.8098	0.0000
node	67	-804.1383	156.0106	0.0000
node	68	-906.8104	340.4114	0.0000
node	69	-919.2946	404.2152	0.0000
node	70	-924.2904	426.5531	0.0000
node	71	-923.9159	440.7110	0.0000
node	72	-929.9394	461.4626	0.0000
node	73	-953.1759	502.6470	0.0000
node	74	-967.2838	517.2964	0.0000
node	75	-974.7527	526.4178	0.0000
node	76	-984.7112	537.1976	0.0000
node	77	-1013.5928	573.9764	0.0000
node	78	-1023.5513	585.3090	0.0000
node	79	-1040.4255	609.3562	0.0000
node	80	-1046.5112	630.6395	0.0000
node	81	-1045.6813	643.9069	0.0000
node	82	-1043.7449	679.8396	0.0000
node	83	-1339.8215	653.8569	0.0000
node	84	-1342.0890	668.5940	0.0000
node	85	-1043.6154	695.6844	0.0000
node	86	-1045.9648	797.0353	0.0000
node	87	-1050.8475	820.2095	0.0000
node	88	-1068.2307	868.0001	0.0000
node	89	-1077.2636	921.9104	0.0000
node	90	-1085.8082	951.1830	0.0000
node	91	-1092.4532	982.8625	0.0000
node	92	-1110.5190	1014.8184	0.0000
node	93	-1128.8803	1035.9156	0.0000
node	94	-1162.8147	1081.5321	0.0000
node	95	-1194.3077	1111.5365	0.0000
node	96	-1230.3220	1162.2548	0.0000
node	97	-1279.8809	1262.5134	0.0000
node	98	-1296.9830	1304.9843	0.0000
node	99	-1301.6215	1325.4751	0.0000
node	100	-1298.9360	1387.6793	0.0000
node	101	-1285.6824	1429.8702	0.0000
node	102	-1281.2880	1449.1414	0.0000
node	103	-1235.3911	1520.6152	0.0000
node	104	-1190.5979	1597.2812	0.0000
node	105	-1138.8418	1678.7566	0.0000
node	106	-1124.1939	1695.8322	0.0000
node	107	-1104.6633	1715.5912	0.0000
node	108	-1084.7431	1733.8924	0.0000
node	109	-1053.7382	1755.1151	0.0000
node	110	-1036.4048	1768.7756	0.0000
node	111	-1027.6161	1784.8755	0.0000
node	112	-1020.2921	1812.6845	0.0000
node	113	-1009.0689	1859.7555	0.0000
node	114	-1006.1393	1902.4447	0.0000
node	115	-1004.9187	1972.4549	0.0000
node	116	-986.5054	1986.3170	0.0000
node	117	-966.9748	1996.0745	0.0000
node	118	-933.7728	2005.8320	0.0000
node	119	-910.9828	2024.6987	0.0000
node	120	-901.9499	2035.6759	0.0000
node	121	-864.5976	2063.2409	0.0000
node	122	-843.3581	2074.4620	0.0000
node	123	-818.2125	2086.1711	0.0000
node	124	-806.0058	2092.2695	0.0000
node	125	-802.8321	2095.9286	0.0000
node	126	-799.1701	2103.4907	0.0000
node	127	-795.2640	2118.1270	0.0000
node	128	-795.0199	2125.2012	0.0000

node	129	-797.7053	2134.2269	0.0000
node	130	-806.4962	2146.6722	0.0000
node	131	-808.9375	2157.1615	0.0000
node	132	-807.4727	2168.6266	0.0000
node	133	-804.5431	2174.9690	0.0000
node	134	-802.5901	2182.5311	0.0000
node	135	-802.8342	2197.8992	0.0000
node	136	-803.5666	2204.7295	0.0000
node	137	-808.2051	2232.0506	0.0000
node	138	-810.8906	2236.9293	0.0000
node	139	-814.0643	2245.4672	0.0000
node	140	-821.1441	2273.2761	0.0000
node	141	-819.6393	2289.6267	0.0000
node	142	-816.7097	2298.6524	0.0000
node	143	-794.7378	2336.9507	0.0000
node	144	-790.3434	2349.3916	0.0000
node	145	-784.9725	2363.5400	0.0000
node	146	-800.2890	2368.7865	0.0000
node	147	-815.7263	2371.2354	0.0000
node	148	-856.3140	2375.4513	0.0000
node	149	-869.2786	2378.2268	0.0000
node	150	-892.7384	2376.9932	0.0000
node	151	-916.0072	2376.0814	0.0000
node	152	-953.0629	2364.5280	0.0000
node	153	-954.3191	2360.2637	0.0000
node	154	-783.0309	2371.1071	0.0000
node	155	-769.8104	2382.6977	0.0000
node	156	-755.7968	2391.3192	0.0000
node	157	-750.9868	2396.7033	0.0000
node	158	-761.0543	2406.7012	0.0000
node	159	-778.9590	2390.3294	0.0000
node	160	-819.9923	2402.1693	0.0000
node	161	-836.5802	2408.2762	0.0000
node	162	-848.3039	2414.6324	0.0000
node	163	-860.7760	2423.2007	0.0000
node	164	-869.5065	2420.3342	0.0000
node	165	-726.0938	2421.7211	0.0000
node	166	-705.8540	2404.0596	0.0000
node	167	-812.0272	152.4261	0.0000
node	168	-820.2143	147.5839	0.0000
node	169	-823.8909	153.5930	0.0000
node	170	-864.8330	248.3168	0.0000
node	171	-937.1013	310.3842	0.0000
node	172	-942.8030	303.9504	0.0000
node	173	-922.4223	163.8978	0.0000
node	174	-989.0310	156.6228	0.0000
node	175	24.0760	0.0000	0.0000
node	176	34.6132	48.8361	0.0000
node	177	137.2831	45.2543	0.0000
node	178	164.0285	42.0294	0.0000
node	179	165.0644	50.4660	0.0000
node	180	174.9898	49.2473	0.0000
node	181	184.9153	48.0287	0.0000
node	182	183.8794	39.5920	0.0000
node	183	210.6248	36.3671	0.0000
node	184	232.9743	-42.1222	0.0000
node	185	-484.0268	-168.2818	0.0000
node	186	-657.2298	-152.4169	0.0000
node	187	-683.0399	-165.0260	0.0000
node	188	-1041.7444	1902.4068	0.0000

pipe	1	2	19.65	0.15	0.000046	0.006406718
pipe	1	3	9.69	0.3	0.000046	0.005620222
pipe	3	4	28.84	0.3	0.000046	0.016725851
pipe	4	5	109.26	0.3	0.000046	0.063372784
pipe	5	6	27.23	0.3	0.000046	0.015792224
pipe	6	7	26.53	0.3	0.000046	0.015386143

pipe	7	8	78.40	0.3	0.000046	0.045470149
pipe	8	9	66.74	0.15	0.000046	0.021755903
pipe	9	10	7.96	0.15	0.000046	0.002594667
pipe	10	11	45.50	0.15	0.000046	0.014833024
pipe	11	12	10.67	0.15	0.000046	0.003477257
pipe	8	13	84.03	0.3	0.000046	0.04873741
pipe	13	14	77.74	0.15	0.000046	0.025343118
pipe	14	15	51.77	0.15	0.000046	0.01687684
pipe	15	16	14.60	0.15	0.000046	0.004759611
pipe	13	17	14.38	0.3	0.000046	0.008338455
pipe	17	18	50.56	0.2	0.000046	0.020831559
pipe	18	19	92.59	0.15	0.000046	0.03018333
pipe	17	20	26.38	0.3	0.000046	0.015299738
pipe	20	21	9.52	0.1	0.000046	0.002304243
pipe	20	22	14.06	0.3	0.000046	0.008155003
pipe	22	23	10.02	0.1	0.000046	0.002424572
pipe	23	24	7.75	0.1	0.000046	0.001875057
pipe	22	25	90.77	0.3	0.000046	0.052648028
pipe	25	26	27.11	0.15	0.000046	0.008838268
pipe	25	27	49.31	0.3	0.000046	0.028598829
pipe	27	28	47.44	0.1	0.000046	0.011479722
pipe	28	29	17.11	0.1	0.000046	0.004141625
pipe	27	30	38.31	0.3	0.000046	0.022220262
pipe	30	31	16.97	0.15	0.000046	0.005531357
pipe	31	32	11.02	0.15	0.000046	0.003591399
pipe	32	33	29.17	0.15	0.000046	0.009509959
pipe	30	34	8.66	0.3	0.000046	0.005022373
pipe	34	35	45.70	0.05	0.000046	0.008545683
pipe	36	37	28.22	0.05	0.000046	0.005276348
pipe	34	39	11.71	0.3	0.000046	0.00679211
pipe	39	40	16.22	0.1	0.000046	0.003925187
pipe	39	41	15.31	0.3	0.000046	0.008880009
pipe	35	42	12.02	0.1	0.000046	0.002908114
pipe	42	43	47.54	0.1	0.000046	0.011504462
pipe	43	36	58.66	0.1	0.000046	0.01419664
pipe	41	44	81.32	0.3	0.000046	0.047165251
pipe	44	45	60.99	0.15	0.000046	0.019882951
pipe	45	46	11.13	0.15	0.000046	0.003628383
pipe	46	47	87.71	0.15	0.000046	0.028593573
pipe	47	48	17.61	0.15	0.000046	0.005740087
pipe	48	49	55.18	0.15	0.000046	0.017989859
pipe	49	50	9.36	0.15	0.000046	0.003051551
pipe	44	51	18.79	0.3	0.000046	0.01089746
pipe	51	52	33.48	0.3	0.000046	0.01941733
pipe	52	38	66.80	0.1	0.000046	0.016166543
pipe	38	37	12.51	0.1	0.000046	0.003027982
pipe	52	53	10.41	0.3	0.000046	0.006040249
pipe	53	54	25.96	0.15	0.000046	0.008464289
pipe	53	55	54.35	0.3	0.000046	0.031520475
pipe	55	56	25.83	0.15	0.000046	0.008419252
pipe	56	57	86.60	0.15	0.000046	0.028231977
pipe	57	58	28.68	0.15	0.000046	0.009348704
pipe	56	59	8.71	0.15	0.000046	0.002838339
pipe	59	60	11.80	0.15	0.000046	0.003846802
pipe	52	61	46.33	0.3	0.000046	0.026874187
pipe	61	62	63.81	0.3	0.000046	0.03700931
pipe	62	63	20.21	0.3	0.000046	0.011724494
pipe	63	64	112.75	0.15	0.000046	0.036754974
pipe	64	65	31.87	0.15	0.000046	0.010391206
pipe	63	66	272.66	0.3	0.000046	0.158140921
pipe	66	67	16.44	0.3	0.000046	0.009532816
pipe	67	167	8.67	0.3	0.000046	0.005025739
pipe	167	168	9.51	0.15	0.000046	0.003100867
pipe	168	169	7.04	0.15	0.000046	0.002296546
pipe	169	170	103.19	0.15	0.000046	0.033641009
pipe	167	171	201.48	0.25	0.000046	0.099732724
pipe	171	172	8.60	0.25	0.000046	0.004255364

pipe	172	173	141.53	0.25	0.000046	0.070056236
pipe	173	174	67.00	0.25	0.000046	0.033167381
pipe	67	68	211.06	0.3	0.000046	0.104473398
pipe	68	69	65.01	0.3	0.000046	0.032181778
pipe	69	70	22.89	0.3	0.000046	0.011330417
pipe	70	71	14.16	0.3	0.000046	0.007010612
pipe	71	72	21.61	0.3	0.000046	0.010696026
pipe	72	73	47.29	0.3	0.000046	0.023407219
pipe	73	74	20.34	0.3	0.000046	0.010067353
pipe	74	75	11.79	0.3	0.000046	0.005835637
pipe	75	76	14.68	0.3	0.000046	0.007264466
pipe	76	77	46.76	0.3	0.000046	0.023147943
pipe	77	78	15.09	0.3	0.000046	0.007467769
pipe	78	79	29.38	0.3	0.000046	0.014541601
pipe	79	80	22.14	0.3	0.000046	0.010957455
pipe	80	81	13.29	0.3	0.000046	0.006580199
pipe	81	82	35.98	0.3	0.000046	0.017812495
pipe	82	83	297.21	0.3	0.000046	0.147121173
pipe	83	84	14.91	0.2	0.000046	0.006143135
pipe	84	85	299.70	0.2	0.000046	0.123476598
pipe	85	86	101.38	0.2	0.000046	0.04176779
pipe	86	87	23.68	0.2	0.000046	0.009757394
pipe	87	88	50.85	0.2	0.000046	0.020951799
pipe	88	89	54.66	0.2	0.000046	0.022520667
pipe	89	90	30.49	0.2	0.000046	0.012563604
pipe	90	91	32.37	0.2	0.000046	0.013335993
pipe	91	92	36.71	0.2	0.000046	0.015124119
pipe	92	93	27.97	0.2	0.000046	0.011522964
pipe	93	94	56.85	0.2	0.000046	0.023423961
pipe	94	95	43.50	0.2	0.000046	0.017921162
pipe	95	96	62.20	0.2	0.000046	0.025628174
pipe	96	97	111.84	0.2	0.000046	0.046077503
pipe	97	98	45.78	0.2	0.000046	0.018863388
pipe	98	99	21.01	0.2	0.000046	0.008655811
pipe	99	100	62.26	0.2	0.000046	0.025652003
pipe	100	101	44.22	0.2	0.000046	0.018220138
pipe	101	102	19.77	0.2	0.000046	0.008143541
pipe	102	103	84.94	0.2	0.000046	0.034995828
pipe	103	104	88.79	0.2	0.000046	0.036582506
pipe	104	105	96.52	0.2	0.000046	0.039767999
pipe	105	106	22.50	0.2	0.000046	0.009268966
pipe	106	107	27.78	0.2	0.000046	0.011446354
pipe	107	108	27.05	0.2	0.000046	0.011144949
pipe	108	109	37.57	0.2	0.000046	0.015479947
pipe	109	110	22.07	0.2	0.000046	0.009092571
pipe	110	111	18.34	0.2	0.000046	0.007557118
pipe	111	112	28.76	0.2	0.000046	0.011848001
pipe	112	113	48.39	0.2	0.000046	0.019936881
pipe	113	114	42.79	0.2	0.000046	0.017629318
pipe	114	115	70.02	0.2	0.000046	0.028848586
pipe	115	116	23.05	0.2	0.000046	0.00949575
pipe	116	117	21.83	0.2	0.000046	0.008994943
pipe	117	118	34.61	0.2	0.000046	0.01425771
pipe	118	119	29.59	0.2	0.000046	0.012189467
pipe	119	120	14.22	0.2	0.000046	0.005856957
pipe	120	121	46.42	0.2	0.000046	0.019125959
pipe	121	122	24.02	0.2	0.000046	0.009896832
pipe	122	123	27.74	0.2	0.000046	0.011428112
pipe	123	124	13.65	0.2	0.000046	0.005621861
pipe	124	125	4.84	0.2	0.000046	0.001995602
pipe	125	126	8.40	0.2	0.000046	0.003461673
pipe	126	127	15.15	0.2	0.000046	0.006241207
pipe	127	128	7.08	0.2	0.000046	0.002916305
pipe	128	129	9.42	0.2	0.000046	0.003879689
pipe	129	130	15.24	0.2	0.000046	0.006277634
pipe	130	131	10.77	0.2	0.000046	0.004437096
pipe	131	132	11.56	0.2	0.000046	0.004762017

pipe	132	133	6.99	0.2	0.000046	0.002878362
pipe	133	134	7.81	0.2	0.000046	0.003217811
pipe	134	135	15.37	0.2	0.000046	0.006332456
pipe	135	136	6.87	0.2	0.000046	0.002830215
pipe	136	137	27.71	0.2	0.000046	0.011417368
pipe	137	138	5.57	0.2	0.000046	0.002294423
pipe	138	139	9.11	0.2	0.000046	0.003752777
pipe	139	140	28.70	0.2	0.000046	0.011822738
pipe	140	141	16.42	0.2	0.000046	0.006764916
pipe	141	142	9.49	0.2	0.000046	0.00390957
pipe	142	143	44.15	0.2	0.000046	0.018191207
pipe	143	144	13.19	0.2	0.000046	0.005436008
pipe	144	145	15.13	0.2	0.000046	0.006235015
pipe	145	146	16.19	0.065	0.000046	0.004274199
pipe	146	147	15.63	0.065	0.000046	0.004126408
pipe	147	148	40.81	0.065	0.000046	0.010772802
pipe	148	149	13.26	0.065	0.000046	0.003500208
pipe	149	150	23.49	0.065	0.000046	0.006201944
pipe	150	151	23.29	0.065	0.000046	0.006147678
pipe	151	152	38.82	0.065	0.000046	0.010247166
pipe	152	153	4.45	0.065	0.000046	0.001173607
pipe	145	154	7.81	0.2	0.000046	0.003218635
pipe	154	155	17.58	0.2	0.000046	0.007243748
pipe	155	156	16.45	0.2	0.000046	0.006778762
pipe	156	157	7.22	0.2	0.000046	0.002974533
pipe	157	158	14.19	0.125	0.000046	0.005122036
pipe	158	159	24.26	0.125	0.000046	0.008758355
pipe	159	160	42.71	0.125	0.000046	0.015417341
pipe	160	161	17.68	0.125	0.000046	0.006381155
pipe	161	162	13.34	0.125	0.000046	0.004814262
pipe	162	163	15.13	0.125	0.000046	0.005462552
pipe	163	164	9.19	0.125	0.000046	0.003317243
pipe	157	165	35.29	0.2	0.000046	0.014540459
pipe	165	166	26.86	0.2	0.000046	0.011067229
pipe	1	175	24.08	0.15	0.000046	0.007848776
pipe	175	176	49.96	0.15	0.000046	0.016286946
pipe	176	177	102.73	0.15	0.000046	0.033490749
pipe	177	178	26.94	0.15	0.000046	0.008782154
pipe	178	179	8.50	0.15	0.000046	0.002770987
pipe	179	180	10.00	0.15	0.000046	0.00325998
pipe	180	181	10.00	0.15	0.000046	0.003260009
pipe	181	182	8.50	0.15	0.000046	0.002771019
pipe	182	183	26.94	0.15	0.000046	0.008782154
pipe	183	184	81.61	0.15	0.000046	0.026604617
pipe	62	186	55.84	0.25	0.000046	0.0276408
pipe	186	187	28.73	0.25	0.000046	0.01422135
pipe	187	59	5.513	0.25	0.000046	0.002728935
pipe	185	40	5.5	0.15	0.000046	0.00163
pipe	114	188	5.5	0.15	0.000046	0.00163

flow	174	-15	115.000
flow	164	-11	105.000
flow	166	-16	105.000
flow	153	-2	105.000
flow	83	-17	115.000
flow	37	-7	115.000
flow	29	-9	115.000
flow	24	-4	115.000
flow	185	-9	115.000
flow	188	-19	115.000

flow	2	45.64	134.700
flow	12	0.002	100.0
flow	16	0.002	100.0
flow	18	22.4	98.300
flow	19	28	104.300
flow	21	0.002	100.00

flow	170	1.0	122.800
flow	65	22.68	120.100
flow	54	0.002	100.00
flow	26	35	107.800
flow	33	16.24	105.100
flow	58	0.002	100.0
flow	60	50.12	102.400
flow	40	19.04	121.400
flow	50	54.04	137.100
flow	184	31.64	132.100

head	1	22.3	120

APPENDIX F

Pipelab Result File

1. Summary

Summary	General data	Node data	Pipe data	Pipe data (f, v, hl, hg)

Network Name	tam	
Maximum flow	79.00	kg/s
Head loss supply	21.47	m
Number of connections	26	
Total value power connections	213165.38	kW
Maximum power substation (heat exchanger)	213165.38213165.38213165.38	kW
Remark		

2. General data

Summary	General data	Node data	Pipe data	Pipe data (f, v, hl, hg)

Pipelab version	3.18	
File	tam.txt	
Date, time	2005-01-12 23:33	
Calculation by		
Type of substation		
Temperature supply	120.00	°C
Target head loss	62.50	Pa/m
Target velocity	2.00	m/s
Factor special resistance	20	%
Minimal coincidence	55	%
Coincidence step	5	%
Universal coincidence	100	%
Diameter selection	none	

3. Node data

Summary	General data	Node data	Pipe data	Pipe data (f, v, hl, hg)

node	name	head	temp.	load
		[m]	[°C]	[kg/s]
1		22.30	120.00	
2		23.20	134.70	45.640

3		22.41	111.95	
4		22.75	111.95	
5		24.03	111.96	
6		24.35	111.96	
7		24.66	111.97	
8		25.57	111.97	
9		25.57	15.59	
10		25.57	18.35	
11		25.57	68.75	
12		25.57	100.00	0.002
13		26.56	111.98	
14		26.56	14.96	
15		26.56	60.13	
16		26.56	100.00	0.002
17		26.72	111.99	
18		27.37	98.30	22.400
19		28.99	104.30	28.000
20		26.85	119.74	
21		26.85	100.00	0.002
22		26.92	119.74	
23		26.89	119.73	
24		26.86	119.71	-4.000
25		27.40	119.76	
26		28.14	107.80	35.000
27		27.51	126.97	
28		26.78	126.94	
29		26.52	126.92	-9.000
30		27.62	126.98	
31		27.72	105.08	
32		27.79	105.09	
33		27.97	105.10	16.240
34		27.63	133.98	
35		27.36	133.68	
36		27.34	132.70	
37		27.17	120.29	-7.000
38		27.26	118.57	
39		27.65	133.98	

40		27.96	121.40	19.040
41		27.67	137.02	
42		27.36	133.58	
43		27.35	133.19	
44		27.76	137.06	
45		31.64	137.07	
46		32.35	137.07	
47		37.94	137.08	
48		39.06	137.09	
49		42.57	137.10	
50		43.17	137.10	54.040
51		27.76	137.03	
52		27.75	118.64	
53		27.76	102.31	
54		27.76	100.00	0.002
55		27.76	102.37	
56		27.88	102.38	
57		27.88	38.15	
58		27.88	100.00	0.002
59		27.92	102.40	
60		28.57	102.40	50.120
61		27.74	118.60	
62		27.72	108.13	
63		27.68	111.54	
64		29.00	120.09	
65		29.37	120.10	22.680
66		26.63	111.49	
67		26.57	111.49	
68		26.01	111.45	
69		25.83	111.44	
70		25.77	111.44	
71		25.74	111.43	
72		25.68	111.43	
73		25.55	111.42	
74		25.50	111.42	
75		25.47	111.41	
76		25.43	111.41	

77		25.31	111.40	
78		25.27	111.40	
79		25.19	111.39	
80		25.13	111.39	
81		25.09	111.39	
82		25.00	111.38	
83		24.21	111.32	-17.000
84		24.04	111.32	
85		20.58	111.26	
86		19.41	111.24	
87		19.13	111.23	
88		18.55	111.22	
89		17.92	111.21	
90		17.56	111.20	
91		17.19	111.20	
92		16.77	111.19	
93		16.44	111.18	
94		15.79	111.17	
95		15.28	111.16	
96		14.57	111.15	
97		13.27	111.12	
98		12.75	111.11	
99		12.50	111.11	
100		11.78	111.10	
101		11.27	111.09	
102		11.05	111.08	
103		10.06	111.07	
104		9.04	111.05	
105		7.92	111.03	
106		7.66	111.02	
107		7.34	111.02	
108		7.03	111.01	
109		6.60	111.00	
110		6.34	111.00	
111		6.13	110.99	
112		5.80	110.99	
113		5.24	110.98	

114		4.75	110.97	
115		4.44	110.94	
116		4.34	110.94	
117		4.25	110.93	
118		4.10	110.92	
119		3.97	110.91	
120		3.91	110.90	
121		3.70	110.88	
122		3.60	110.88	
123		3.48	110.87	
124		3.42	110.86	
125		3.40	110.86	
126		3.36	110.86	
127		3.30	110.85	
128		3.27	110.85	
129		3.22	110.85	
130		3.16	110.84	
131		3.11	110.84	
132		3.06	110.83	
133		3.03	110.83	
134		3.00	110.83	
135		2.93	110.82	
136		2.90	110.82	
137		2.78	110.81	
138		2.75	110.81	
139		2.72	110.81	
140		2.59	110.80	
141		2.52	110.79	
142		2.48	110.79	
143		2.29	110.77	
144		2.23	110.77	
145		2.16	110.76	
146		2.04	110.71	
147		1.92	110.66	
148		1.61	110.53	
149		1.51	110.48	
150		1.33	110.41	

151		1.15	110.33	
152		0.86	110.21	
153		0.83	110.19	-2.000
154		2.13	110.76	
155		2.07	110.75	
156		2.00	110.75	
157		1.98	110.74	
158		1.87	110.73	
159		1.70	110.71	
160		1.39	110.68	
161		1.26	110.66	
162		1.16	110.65	
163		1.05	110.64	
164		0.98	110.63	-11.000
165		1.93	110.72	
166		1.89	110.70	-16.000
167		26.56	112.17	
168		26.56	121.82	
169		26.56	121.88	
170		26.57	122.80	1.000
171		26.48	112.00	
172		26.48	111.99	
173		26.42	111.88	
174		26.39	111.82	-15.000
175		22.84	132.00	
176		23.95	132.02	
177		26.24	132.05	
178		26.84	132.06	
179		27.03	132.06	
180		27.25	132.06	
181		27.48	132.06	
182		27.67	132.07	
183		28.27	132.08	
184		30.08	132.10	31.640
185		27.95	121.40	-9.000
186		27.84	102.39	
187		27.91	102.40	

188		4.70	110.97	-19.000

4. Pipe data

[Summary]()	[General data]()	[Node data]()	Pipe data	[Pipe data (f, v, hl, hg)]()

pipe	node		name		L	diam	fix	c	type	costs
	1	2	1	2	[m]	[m]		[%]		NLGx1000
1	1	3			9.7	0.3000	no	100.0	no match	
2	1	2			19.6	0.1500	no	100.0	no match	
3	1	175			24.1	0.1500	no	100.0	no match	
4	3	4			28.8	0.3000	no	100.0	no match	
5	175	176			50.0	0.1500	no	100.0	no match	
6	176	177			102.7	0.1500	no	100.0	no match	
7	4	5			109.3	0.3000	no	100.0	no match	
8	177	178			26.9	0.1500	no	100.0	no match	
9	5	6			27.2	0.3000	no	100.0	no match	
10	178	179			8.5	0.1500	no	100.0	no match	
11	6	7			26.5	0.3000	no	100.0	no match	
12	179	180			10.0	0.1500	no	100.0	no match	
13	7	8			78.4	0.3000	no	100.0	no match	
14	180	181			10.0	0.1500	no	100.0	no match	
15	8	9			66.7	0.1500	no	100.0	no match	
16	8	13			84.0	0.3000	no	100.0	no match	
17	9	10			8.0	0.1500	no	100.0	no match	
18	181	182			8.5	0.1500	no	100.0	no match	
19	13	17			14.4	0.3000	no	100.0	no match	
20	13	14			77.7	0.1500	no	100.0	no match	
21	17	20			26.4	0.3000	no	100.0	no match	
22	182	183			26.9	0.1500	no	100.0	no match	
23	10	11			45.5	0.1500	no	100.0	no match	
24	17	18			50.6	0.2000	no	100.0	no match	
25	14	15			51.8	0.1500	no	100.0	no match	
26	20	21			9.5	0.1000	no	100.0	no match	
27	11	12			10.7	0.1500	no	100.0	no match	
28	20	22			14.1	0.3000	no	100.0	no match	
29	15	16			14.6	0.1500	no	100.0	no match	
30	183	184			81.6	0.1500	no	100.0	no match	
31	18	19			92.6	0.1500	no	100.0	no match	
32	22	23			10.0	0.1000	no	100.0	no match	

33	22	25			90.8	0.3000	no	100.0	no match	
34	23	24			7.8	0.1000	no	100.0	no match	
35	25	26			27.1	0.1500	no	100.0	no match	
36	25	27			49.3	0.3000	no	100.0	no match	
37	27	30			38.3	0.3000	no	100.0	no match	
38	27	28			47.4	0.1000	no	100.0	no match	
39	30	34			8.7	0.3000	no	100.0	no match	
40	30	31			17.0	0.1500	no	100.0	no match	
41	28	29			17.1	0.1000	no	100.0	no match	
42	31	32			11.0	0.1500	no	100.0	no match	
43	34	39			11.7	0.3000	no	100.0	no match	
44	34	35			45.7	0.0500	no	100.0	no match	
45	35	42			12.0	0.1000	no	100.0	no match	
46	39	41			15.3	0.3000	no	100.0	no match	
47	39	40			16.2	0.1000	no	100.0	no match	
48	32	33			29.2	0.1500	no	100.0	no match	
49	185	40			5.5	0.1500	no	100.0	no match	
50	42	43			47.5	0.1000	no	100.0	no match	
51	41	44			81.3	0.3000	no	100.0	no match	
52	44	51			18.8	0.3000	no	100.0	no match	
53	43	36			58.7	0.1000	no	100.0	no match	
54	44	45			61.0	0.1500	no	100.0	no match	
55	45	46			11.1	0.1500	no	100.0	no match	
56	36	37			28.2	0.0500	no	100.0	no match	
57	51	52			33.5	0.3000	no	100.0	no match	
58	52	53			10.4	0.3000	no	100.0	no match	
59	38	37			12.5	0.1000	no	100.0	no match	
60	52	61			46.3	0.3000	no	100.0	no match	
61	46	47			87.7	0.1500	no	100.0	no match	
62	47	48			17.6	0.1500	no	100.0	no match	
63	53	54			26.0	0.1500	no	100.0	no match	
64	53	55			54.4	0.3000	no	100.0	no match	
65	61	62			63.8	0.3000	no	100.0	no match	
66	62	63			20.2	0.3000	no	100.0	no match	
67	55	56			25.8	0.1500	no	100.0	no match	
68	48	49			55.2	0.1500	no	100.0	no match	
69	62	186			55.8	0.2500	no	100.0	no match	

70	56	59			8.7	0.1500	no	100.0	no match	
71	49	50			9.4	0.1500	no	100.0	no match	
72	186	187			28.7	0.2500	no	100.0	no match	
73	56	57			86.6	0.1500	no	100.0	no match	
74	63	64			112.8	0.1500	no	100.0	no match	
75	63	66			272.7	0.3000	no	100.0	no match	
76	59	60			11.8	0.1500	no	100.0	no match	
77	66	67			16.4	0.3000	no	100.0	no match	
78	57	58			28.7	0.1500	no	100.0	no match	
79	64	65			31.9	0.1500	no	100.0	no match	
80	67	167			8.7	0.3000	no	100.0	no match	
81	67	68			211.1	0.3000	no	100.0	no match	
82	167	168			9.5	0.1500	no	100.0	no match	
83	68	69			65.0	0.3000	no	100.0	no match	
84	167	171			201.5	0.2500	no	100.0	no match	
85	168	169			7.0	0.1500	no	100.0	no match	
86	171	172			8.6	0.2500	no	100.0	no match	
87	69	70			22.9	0.3000	no	100.0	no match	
88	70	71			14.2	0.3000	no	100.0	no match	
89	169	170			103.2	0.1500	no	100.0	no match	
90	172	173			141.5	0.2500	no	100.0	no match	
91	71	72			21.6	0.3000	no	100.0	no match	
92	173	174			67.0	0.2500	no	100.0	no match	
93	72	73			47.3	0.3000	no	100.0	no match	
94	73	74			20.3	0.3000	no	100.0	no match	
95	74	75			11.8	0.3000	no	100.0	no match	
96	75	76			14.7	0.3000	no	100.0	no match	
97	76	77			46.8	0.3000	no	100.0	no match	
98	77	78			15.1	0.3000	no	100.0	no match	
99	78	79			29.4	0.3000	no	100.0	no match	
100	79	80			22.1	0.3000	no	100.0	no match	
101	80	81			13.3	0.3000	no	100.0	no match	
102	81	82			36.0	0.3000	no	100.0	no match	
103	82	83			297.2	0.3000	no	100.0	no match	
104	83	84			14.9	0.2000	no	100.0	no match	
105	84	85			299.7	0.2000	no	100.0	no match	
106	85	86			101.4	0.2000	no	100.0	no match	

107	86	87			23.7	0.2000	no	100.0	no match	
108	87	88			50.9	0.2000	no	100.0	no match	
109	88	89			54.7	0.2000	no	100.0	no match	
110	89	90			30.5	0.2000	no	100.0	no match	
111	90	91			32.4	0.2000	no	100.0	no match	
112	91	92			36.7	0.2000	no	100.0	no match	
113	92	93			28.0	0.2000	no	100.0	no match	
114	93	94			56.9	0.2000	no	100.0	no match	
115	94	95			43.5	0.2000	no	100.0	no match	
116	95	96			62.2	0.2000	no	100.0	no match	
117	96	97			111.8	0.2000	no	100.0	no match	
118	97	98			45.8	0.2000	no	100.0	no match	
119	98	99			21.0	0.2000	no	100.0	no match	
120	99	100			62.3	0.2000	no	100.0	no match	
121	100	101			44.2	0.2000	no	100.0	no match	
122	101	102			19.8	0.2000	no	100.0	no match	
123	102	103			84.9	0.2000	no	100.0	no match	
124	103	104			88.8	0.2000	no	100.0	no match	
125	104	105			96.5	0.2000	no	100.0	no match	
126	105	106			22.5	0.2000	no	100.0	no match	
127	106	107			27.8	0.2000	no	100.0	no match	
128	107	108			27.1	0.2000	no	100.0	no match	
129	108	109			37.6	0.2000	no	100.0	no match	
130	109	110			22.1	0.2000	no	100.0	no match	
131	110	111			18.3	0.2000	no	100.0	no match	
132	111	112			28.8	0.2000	no	100.0	no match	
133	112	113			48.4	0.2000	no	100.0	no match	
134	113	114			42.8	0.2000	no	100.0	no match	
135	114	188			5.5	0.1500	no	100.0	no match	
136	114	115			70.0	0.2000	no	100.0	no match	
137	115	116			23.1	0.2000	no	100.0	no match	
138	116	117			21.8	0.2000	no	100.0	no match	
139	117	118			34.6	0.2000	no	100.0	no match	
140	118	119			29.6	0.2000	no	100.0	no match	
141	119	120			14.2	0.2000	no	100.0	no match	
142	120	121			46.4	0.2000	no	100.0	no match	
143	121	122			24.0	0.2000	no	100.0	no match	

144	122	123			27.7	0.2000	no	100.0	no match	
145	123	124			13.7	0.2000	no	100.0	no match	
146	124	125			4.8	0.2000	no	100.0	no match	
147	125	126			8.4	0.2000	no	100.0	no match	
148	126	127			15.2	0.2000	no	100.0	no match	
149	127	128			7.1	0.2000	no	100.0	no match	
150	128	129			9.4	0.2000	no	100.0	no match	
151	129	130			15.2	0.2000	no	100.0	no match	
152	130	131			10.8	0.2000	no	100.0	no match	
153	131	132			11.6	0.2000	no	100.0	no match	
154	132	133			7.0	0.2000	no	100.0	no match	
155	133	134			7.8	0.2000	no	100.0	no match	
156	134	135			15.4	0.2000	no	100.0	no match	
157	135	136			6.9	0.2000	no	100.0	no match	
158	136	137			27.7	0.2000	no	100.0	no match	
159	137	138			5.6	0.2000	no	100.0	no match	
160	138	139			9.1	0.2000	no	100.0	no match	
161	139	140			28.7	0.2000	no	100.0	no match	
162	140	141			16.4	0.2000	no	100.0	no match	
163	141	142			9.5	0.2000	no	100.0	no match	
164	142	143			44.1	0.2000	no	100.0	no match	
165	143	144			13.2	0.2000	no	100.0	no match	
166	144	145			15.1	0.2000	no	100.0	no match	
167	145	154			7.8	0.2000	no	100.0	no match	
168	145	146			16.2	0.0650	no	100.0	no match	
169	146	147			15.6	0.0650	no	100.0	no match	
170	154	155			17.6	0.2000	no	100.0	no match	
171	155	156			16.4	0.2000	no	100.0	no match	
172	147	148			40.8	0.0650	no	100.0	no match	
173	156	157			7.2	0.2000	no	100.0	no match	
174	148	149			13.3	0.0650	no	100.0	no match	
175	157	158			14.2	0.1250	no	100.0	no match	
176	149	150			23.5	0.0650	no	100.0	no match	
177	157	165			35.3	0.2000	no	100.0	no match	
178	150	151			23.3	0.0650	no	100.0	no match	
179	158	159			24.3	0.1250	no	100.0	no match	
180	165	166			26.9	0.2000	no	100.0	no match	

181	151	152			38.8	0.0650	no	100.0	no match	
182	159	160			42.7	0.1250	no	100.0	no match	
183	152	153			4.5	0.0650	no	100.0	no match	
184	160	161			17.7	0.1250	no	100.0	no match	
185	161	162			13.3	0.1250	no	100.0	no match	
186	162	163			15.1	0.1250	no	100.0	no match	
187	163	164			9.2	0.1250	no	100.0	no match	
188	187	59			5.5	0.2500	no	100.0	no match	
189	52	38			66.8	0.1000	no	100.0	no match	

5. Pipe data (f, v, hl, hg)

Summary	General data	Node data	Pipe data	Pipe data (f, v, hl, hg)

pipe	flow	velocity	head loss	
	[kg/s]	[m/s]	[Pa]	[Pa/m]
1	-139.530	-2.043	-1132.80	-116.90
2	-45.640	-2.674	-8976.25	-456.81
3	-31.640	-1.853	-5367.29	-222.89
4	-139.530	-2.043	-3371.52	-116.90
5	-31.640	-1.853	-11135.80	-222.89
6	-31.640	-1.853	-22897.92	-222.89
7	-139.530	-2.043	-12772.98	-116.90
8	-31.640	-1.853	-6004.77	-222.89
9	-139.530	-2.043	-3183.31	-116.90
10	-31.640	-1.853	-1894.60	-222.89
11	-139.530	-2.043	-3101.47	-116.90
12	-31.640	-1.853	-2228.94	-222.89
13	-139.530	-2.043	-9165.31	-116.90
14	-31.640	-1.853	-2228.94	-222.89
15	-0.002	-0.000	-0.00	-0.00
16	-139.528	-2.043	-9823.20	-116.90
17	-0.002	-0.000	-0.00	-0.00
18	-31.640	-1.853	-1894.60	-222.89
19	-139.526	-2.043	-1680.99	-116.90
20	-0.002	-0.000	-0.00	-0.00
21	-89.126	-1.305	-1287.12	-48.79
22	-31.640	-1.853	-6004.77	-222.89
23	-0.002	-0.000	-0.00	-0.00
24	-50.400	-1.661	-6420.90	-127.00

25	-0.002	-0.000	-0.00	-0.00
26	-0.002	-0.000	-0.00	-0.00
27	-0.002	-0.000	-0.00	-0.00
28	-89.124	-1.305	-685.98	-48.79
29	-0.002	-0.000	-0.00	-0.00
30	-31.640	-1.853	-18190.40	-222.89
31	-28.000	-1.640	-16259.88	-175.61
32	4.000	0.527	325.05	32.44
33	-93.124	-1.364	-4822.85	-53.13
34	4.000	0.527	251.41	32.44
35	-35.000	-2.050	-7360.36	-271.50
36	-58.124	-0.851	-1052.98	-21.35
37	-67.124	-0.983	-1079.67	-28.18
38	9.000	1.186	7279.31	153.44
39	-50.884	-0.745	-143.22	-16.54
40	-16.240	-0.951	-1036.87	-61.10
41	9.000	1.186	2625.40	153.44
42	-16.240	-0.951	-673.32	-61.10
43	-51.754	-0.758	-200.07	-17.09
44	0.870	0.459	2687.88	58.82
45	0.870	0.115	23.08	1.92
46	-41.714	-0.611	-173.11	-11.31
47	-10.040	-1.323	-3076.16	-189.65
48	-16.240	-0.951	-1782.29	-61.10
49	-9.000	-0.527	-108.66	-19.76
50	0.870	0.115	91.28	1.92
51	-41.714	-0.611	-919.48	-11.31
52	12.326	0.181	21.49	1.14
53	0.870	0.115	112.64	1.92
54	-54.040	-3.166	-38837.24	-636.78
55	-54.040	-3.166	-7087.37	-636.78
56	0.870	0.459	1659.78	58.82
57	12.326	0.181	38.29	1.14
58	-13.834	-0.203	-14.74	-1.42
59	6.130	0.808	916.03	73.22
60	20.030	0.293	130.81	2.82
61	-54.040	-3.166	-55852.01	-636.78

62	-54.040	-3.166	-11213.70	-636.78
63	-0.002	-0.000	-0.00	-0.00
64	-13.832	-0.203	-76.95	-1.42
65	20.030	0.293	180.16	2.82
66	56.320	0.825	406.18	20.10
67	-13.832	-0.810	-1159.04	-44.87
68	-54.040	-3.166	-35137.54	-636.78
69	-36.290	-0.765	-1210.26	-21.67
70	-13.830	-0.810	-390.73	-44.86
71	-54.040	-3.166	-5960.26	-636.78
72	-36.290	-0.765	-622.68	-21.67
73	-0.002	-0.000	-0.00	-0.00
74	-22.680	-1.329	-13142.90	-116.57
75	79.000	1.157	10529.25	38.62
76	-50.120	-2.936	-6479.33	-549.10
77	79.000	1.157	634.86	38.62
78	-0.002	-0.000	-0.00	-0.00
79	-22.680	-1.329	-3714.98	-116.57
80	14.000	0.205	12.55	1.45
81	65.000	0.952	5590.34	26.49
82	-1.000	-0.059	-3.29	-0.35
83	65.000	0.952	1721.92	26.49
84	15.000	0.316	816.76	4.05
85	-1.000	-0.059	-2.44	-0.35
86	15.000	0.316	34.86	4.05
87	65.000	0.952	606.29	26.49
88	65.000	0.952	375.06	26.49
89	-1.000	-0.059	-35.75	-0.35
90	15.000	0.316	573.74	4.05
91	65.000	0.952	572.38	26.49
92	15.000	0.316	271.61	4.05
93	65.000	0.952	1252.57	26.49
94	65.000	0.952	538.75	26.49
95	65.000	0.952	312.28	26.49
96	65.000	0.952	388.83	26.49
97	65.000	0.952	1238.53	26.49
98	65.000	0.952	399.69	26.49

99	65.000	0.952	778.19	26.49
100	65.000	0.952	586.42	26.49
101	65.000	0.952	352.01	26.49
102	65.000	0.952	953.00	26.49
103	65.000	0.952	7872.19	26.49
104	48.000	1.582	1721.77	115.48
105	48.000	1.582	34608.59	115.48
106	48.000	1.582	11707.10	115.48
107	48.000	1.582	2734.51	115.48
108	48.000	1.582	5872.03	115.48
109	48.000	1.582	6312.00	115.48
110	48.000	1.582	3520.91	115.48
111	48.000	1.582	3738.00	115.48
112	48.000	1.582	4239.18	115.48
113	48.000	1.582	3229.90	115.48
114	48.000	1.582	6564.89	115.48
115	48.000	1.582	5023.27	115.48
116	48.000	1.582	7182.70	115.48
117	48.000	1.582	12915.00	115.48
118	48.000	1.582	5286.56	115.48
119	48.000	1.582	2426.18	115.48
120	48.000	1.582	7189.63	115.48
121	48.000	1.582	5106.41	115.48
122	48.000	1.582	2282.99	115.48
123	48.000	1.582	9808.65	115.48
124	48.000	1.582	10253.24	115.48
125	48.000	1.582	11145.88	115.48
126	48.000	1.582	2598.24	115.48
127	48.000	1.582	3207.96	115.48
128	48.000	1.582	3123.66	115.48
129	48.000	1.582	4338.49	115.48
130	48.000	1.582	2548.59	115.48
131	48.000	1.582	2117.86	115.48
132	48.000	1.582	3321.13	115.48
133	48.000	1.582	5587.95	115.48
134	48.000	1.582	4941.28	115.48
135	19.000	1.113	454.97	82.72

136	29.000	0.956	3044.78	43.48
137	29.000	0.956	1002.32	43.48
138	29.000	0.956	949.26	43.48
139	29.000	0.956	1505.00	43.48
140	29.000	0.956	1286.70	43.48
141	29.000	0.956	618.35	43.48
142	29.000	0.956	2018.55	43.48
143	29.000	0.956	1044.50	43.48
144	29.000	0.956	1206.26	43.48
145	29.000	0.956	593.56	43.48
146	29.000	0.956	210.46	43.48
147	29.000	0.956	365.27	43.48
148	29.000	0.956	658.79	43.48
149	29.000	0.956	307.87	43.48
150	29.000	0.956	409.62	43.48
151	29.000	0.956	662.70	43.48
152	29.000	0.956	468.33	43.48
153	29.000	0.956	502.68	43.48
154	29.000	0.956	303.96	43.48
155	29.000	0.956	339.61	43.48
156	29.000	0.956	668.36	43.48
157	29.000	0.956	298.74	43.48
158	29.000	0.956	1204.95	43.48
159	29.000	0.956	242.21	43.48
160	29.000	0.956	396.14	43.48
161	29.000	0.956	1248.00	43.48
162	29.000	0.956	714.01	43.48
163	29.000	0.956	412.67	43.48
164	29.000	0.956	1919.84	43.48
165	29.000	0.956	573.56	43.48
166	29.000	0.956	657.92	43.48
167	27.000	0.890	295.94	37.89
168	2.000	0.624	1230.41	76.00
169	2.000	0.624	1187.85	76.00
170	27.000	0.890	666.15	37.89
171	27.000	0.890	623.33	37.89
172	2.000	0.624	3101.49	76.00

173	27.000	0.890	273.58	37.89
174	2.000	0.624	1007.74	76.00
175	11.000	0.928	1031.77	72.71
176	2.000	0.624	1785.20	76.00
177	16.000	0.527	491.58	13.93
178	2.000	0.624	1770.00	76.00
179	11.000	0.928	1763.96	72.71
180	16.000	0.527	374.15	13.93
181	2.000	0.624	2950.26	76.00
182	11.000	0.928	3105.48	72.71
183	2.000	0.624	338.19	76.00
184	11.000	0.928	1285.53	72.71
185	11.000	0.928	969.96	72.71
186	11.000	0.928	1100.11	72.71
187	11.000	0.928	668.21	72.71
188	−36.290	−0.765	−119.49	−21.67
189	6.130	0.808	4891.34	73.22