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Piping Network Design for IZTECH Campus Geothermal District Heating System, Izmir Turkey

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ABSTRACT

Izmir Institute of Technology (IZTECH), founded in 1992, has a geothermal resource at the border of the Campus with a temperature of 33°C. At present, the Campus is still under development and each faculty building has an individual fuel-fired boiler heating system.

The district heating system design consists of two parts; heating system design and piping network design. In this study, piping network design of Izmir Institute of Technology (IZTECH) Campus is given in detail. Heating system design is given in another paper (Yildirim *et al.*, 2005**).**

Piping network design consists of material selection, determination of target pressure loss (TPL), heat centre location, piping installation type and economy of the system. The piping network of the campus has been considered with two loops, one as "geothermal loop" and the other as "campus loop". Each loop contains supply and return mains. To design the optimum network for the campus, various design alternatives are studied for various heat centre location and installation type. Using Pipelab software, the optimum diameter of each pipe used in the network is calculated. The total length of considered network of the district heating system is 9,486 m. The heat centre is located almost in the middle of the campus. Underground (buried) pipeline installation is preferred. While carbon steel pipes are installed for the campus loop, composite (FRP) pipes are installed for the geothermal loop.

1. INTRODUCTION

District heating systems (DHS) are defined as the heating and/or cooling of two or more structures from a central heat source. The thermal energy is distributed through a network of insulated pipes consisting of supply and return mains (Bloomquist, 2001).

The construction of the buildings of IZTECH Campus was started in November 1994. The number of existing buildings has reached 15 with 50,730-m^2-floor area and the campus is still under development. Individual HVAC (Heating, Ventilation and Air Conditioning) systems are employed at each department. Exploration studies in the field started in 1995. In 2002, 5 gradient wells were drilled, one of which is production well with a 33°C temperature and a 30 kg/s flowrate.

Campus total heat load was determined as 11,207 kWt (3,662 kWt for existing buildings and 7,545 kWt for the buildings, which are under construction/planned) in this study (Yildirim, 2003).

Piping network has an important share of the total investment cost. Thus, the design of the district heating piping network is of vital importance to the economics of the system. There is a trade-off between economics and reliability depending upon the pipe material, the target pressure loss (TPL) per unit length of the pipe, location of the heat centre and installation type of the piping network. Therefore, they are common design parameters of the piping network.

Piping materials for geothermal heating systems have been of numerous types with great variation in cost and durability. The temperature and chemical quality of the geothermal fluids, in addition to cost, usually determines the type of piping network material used. Carbon steel is now the most widely used material for geothermal transmission lines and distribution networks, especially if the fluid temperature is over 100°C. On the other hand, composite (FRP) pipes are used because of the corrosive effects of the geothermal fluid.

For piping network design, Pipelab software, which has been created under Matlab program by Valdimarsson (Valdimarsson, 2002), is used. For IZTECH Campus DHS, various alternatives for heat centre location are studied and 3 of these alternatives are given in this study.

Target pressure loss (TPL) is a common design parameter of piping network. The district heating practice is to design for 50-200 Pa/m pressure loss (Valdimarsson, 2001). There is a trade-off between pressure loss of piping network and economy of the system. If the pressure loss is high, investment cost of the pipe is low, but operational cost is high. On the other hand, if the pressure loss is low, the investment (pipe diameter are larger) is badly utilized, but the pumping cost is low. Heat loss in a district heating pipe is higher for badly utilized pipes.

Pipelines are installed either aboveground or underground. For underground installation there are two options, which are directly buried into the soil and in concrete tunnel. Concrete tunnels have the advantages, providing access for maintenance, easing future expansion, and a corridor for other utilities such as domestic water, electrical cables, phone lines, etc. But because of the high investment cost of the concrete tunnel, directly buried into the soil installation type is preferred.

2. DESIGN OF DISTRICT HEATING SYSTEM FOR IZTECH CAMPUS

Design of a district heating system, initially requires a thermal load inventory.

2.1. Thermal Load Density of the Campus

Thermal load density is an important indication on the decision as to whether the district heating system should be installed or not. The buildings in the Campus are distributed in an area as large as 71.3 ha as it is shown in Figure 1.

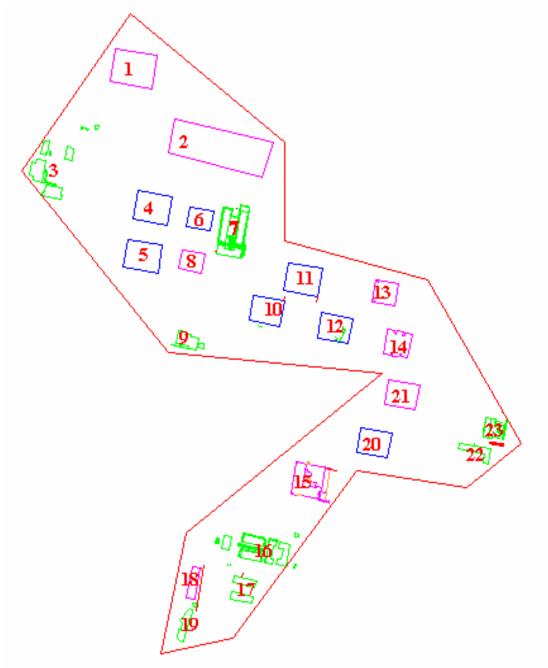


Figure 1: Location of the buildings in the Campus (Yildirim, 2003).

Table 1: Favourability Based on Thermal Load Density (Bloomquist, 2001).

Type of Land-Use	Thermal Load Density (MW/ha)	Desirability for District Energy
Downtown; high rises	Greater than 0.70	Very favourable
Downtown; multi-storied	0.51 - 0.70	Favourable
City core; commercial buildings & multi-family apartments	0.20 - 0.51	Possible
Two-family residential	0.12 - 0.20	Questionable
Single-family residential	Less than 0.12	Not possible

The criteria for DHS favourability based on thermal load density are given in Table 1. Using the area and total heat load, thermal load density of the Campus is calculated as 0.16 W/ha. According to the criteria, which are given in Table 1, favourability of district heating system for IZTECH Campus is questionable, because of the widespread distribution of the buildings. On the other hand, only heating requirements are considered in this study. If cooling is also considered, the favourability ratio increases depending on the total heat load. Considering the futuere development and cooling requirements, Campus DHS is appeared to be possible (Yildirim, 2003).

2.2. Heating System Design

The type of geothermal heating system considered is “Heat Pump Heating System (HPHS)” given the low geothermal fluid temperature. Heat pump only (HPO) layout is selected for the Campus heating system because it exhibits better performance than heat pump assisted (HPA) at geothermal fluid temperatures below 40°C. Various heating regime alternatives have been studied for HPHS for the various condenser outlet temperature and geothermal fluid flowrate. Consequently, the heating regime with 35°C condenser inlet and 45°C condenser outlet temperature with 120 kg/s geothermal fluid flowrate considered to be the best option. For IZTECH Campus DHS, 4 separate heat pump units of the same capacity are considered because of the improved performance, reliability and operational flexibility. Each heat pump is fed by each production well and heat pumps are operated depending on outdoor temperature. For each heat pump unit, one heat exchanger is employed (Yildirim et al., 2004).

3. DESIGN OF PIPING NETWORK FOR THE CAMPUS

Schematic of the district heating system is shown in Figure 2.

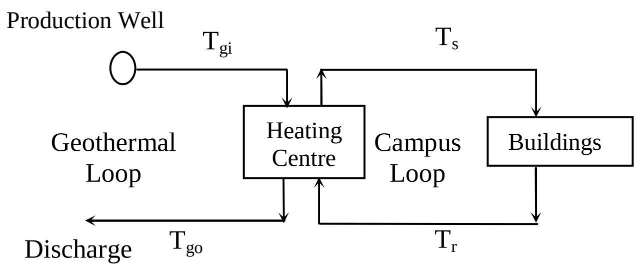


Figure 2: Schematic of the district heating system.

As can be seen from the figure, the piping network of the Campus is considered as two loops, geothermal and Campus loops. And each loop is considered with two-pipe system as supply and return mains. District heating network is designed considering not only existing buildings but also future development.

3.1. Materials

Unit cost of carbon steel and composite pipes are given in Table 2. The table points out that carbon steel pipes, which are commonly used in geothermal applications, are nearly 13-35% cheaper than composite pipes depending on the pipe diameter. But carbon steel pipes are not suitable for geothermal loop, because of the corrosive effects of the geothermal fluid. Thus, composite (FRP) pipes are preferred for geothermal loop while Campus loop is installed with carbon steel pipes.

Table 2: Unit cost of the carbon steel and composite pipes (Teknoplas, 2003).

	Unit cost (US$/m)	
Diameter (DN)	Carbon Steel Pipe (Steel+PU+PE)	Composite Pipe (CTP+PU+CTP)
65	13	20
80	15	23
100	25	31
125	26	32
150	31	42
200	47	54
250	57	76
300	72	87
350	95	115
400	128	155
450	165	199

3.2. Heat Centre Location Alternatives

The location of heat centre is important based on the economy of the district heating system Therefore, several alternatives have been studied and 3 of which are given in here.

- Alternative 1: Heat centre is close to the Campus entrance (Figure 3);
- Alternative 2: Heat centre is close to the production well (Figure 4);
- Alternative 3: Heat centre is almost in the middle of the Campus (Figure 5).

The Pipelab software, which has been created as a Matlab program by Valdimarsson (2002), is used for piping network design. Necessary input file includes number of nodes in the system, their xyz coordinates, connectivity relation to the nodes of the pipes with their length, diameter, roughness and heat loss, boundary conditions, necessary flowrate and the pressure head at the starting point. Initially, pipe diameters are assumed and using Pipelab software optimum diameter for each pipe is calculated. Pressure drop of the critical line and pipe diameters are calculated for the Campus loop (45/35°C) and 62.5 Pa/m TPL, which is default TPL of Pipelab Software. Table 3 gives total pressure drops and pipe lengths in various diameters for each alternative. Alternative 2 has the highest-pressure drop and requires the longest pipeline. Alternative 1 and 3 are close to each other in pipe length but Alternative 3 requires shorter piping for larger diameters. This makes it cost effective. Because of the lowest piping cost and pressure drop, Alternative 3 seems to be the best option.

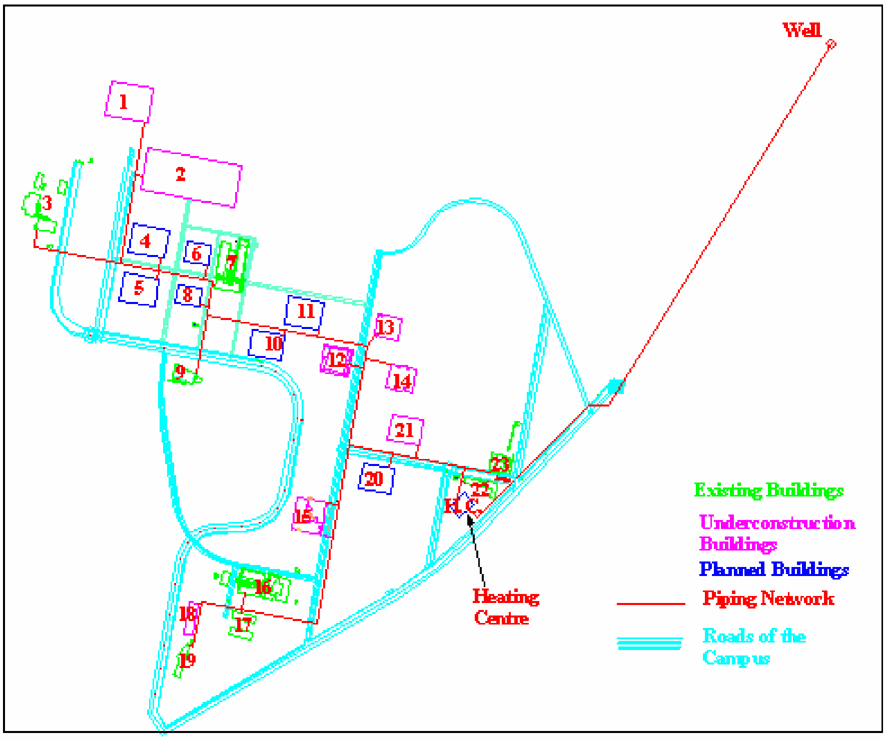


Figure 3: Heat centre location, Alternative 1 (Yildirim, 2003).

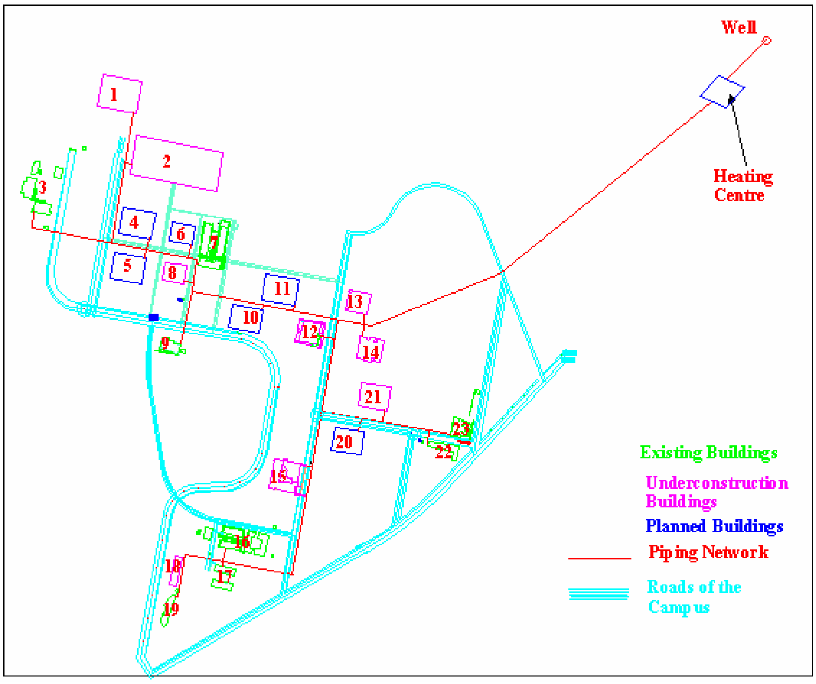
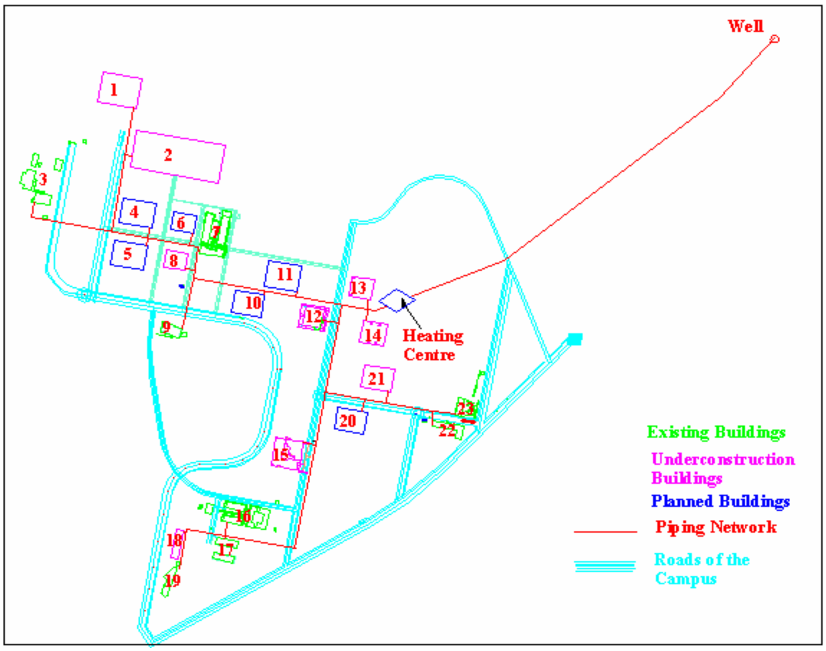


Figure 4: Heat centre location, Alternative 2 (Yildirim, 2003).



1: Staff houses
2: Dormitories
3: Architecture Faculty
4: Buildings A
5: Buildings B
6: Buildings C
7: Science Faculty
8: Buildings D
9: Cafeteria
10: Buildings E
11: Buildings F
12: Research & Development. Centre
13: Sport Centre
14: Medical Centre
15: Chemical Engineering
16: Engineering Faculty
17: Mechanical Engineering
18: Mechatronic Building
19: Incubator Building
20: Buildings G
21: Library
22: Presidency of Depart. Building
23: Rectorship Building

Figure 5: Heat centre location, Alternative 3 (Yildirim, 2003).

Table 3: Design alternatives for various heat centre location (45/35°C, TPL: 62.5 Pa/m, supply main of Campus loop).

Alternative of the piping network		Alternative 1	Alternative 2	Alternative 3
Total pressure drop (m)		14.8	17.1	11.2
Pipe Length (m)	DN80	41.36	41.36	41.36
	DN100	639.28	632.17	632.17
	DN125	494.64	494.97	494.97
	DN150	304.58	423.68	423.68
	DN200	728.56	894.28	894.28
	DN250	537.62	534.88	534.88
	DN300	175.86	374.47	374.47
	DN350	193.94	0	0
	DN400	324.26	70.44	70.44
	DN450	39.27	1120	52.92
	Total	**3,479.37**	**4,586.25**	**3,519.17**
Total Piping Cost (Campus+ Geothermal Loops) (US$)		**713,774**	**687,981**	**532,117**

Based on this temperature regime, pipe diameters of the selected piping network (Alternative 3) are calculated by Pipelab software for 150 Pa/m TPL and listed in Table 4.

Table 4: Pipe diameters in the supply main of the Campus loop for 150 Pa/m TPL (Yildirim, 2003).

Diameter(DN)	Pipe Length (m)
65	41
80	489
100	638
125	205
150	1000
200	565
250	457
300	0
350	123
Total	**3,520**
Pipe Cost (US$)	124,495

3.3. Installation type

Pipelines are installed either aboveground or underground. Underground installation is preferred here to avoid heat losses and esthetic concerns. Underground installation could be directly buried into the soil or in concrete tunnels. Unit construction cost for underground (buried) installation is 33.4 US$/m and for underground (concrete tunnel) is about 200 US$/m (Trane, 2003).

Total piping cost of the Campus and geothermal loops is 248,991 US$ and 185,896 US$, respectively using the values in Table 2 and Table 4 (for 150 Pa/m TPL). Thus, the total piping cost of the district heating system amounts to 434,887 US$ approximately. Cost of fittings and wages for the workers are assumed to be 30% of total cost of pipeline. Total piping cost including construction and fittings and wages is given in Table 5. Table 5 clearly indicates that piping cost is 2.3 times more expensive for concrete tunnel. Therefore, for IZTECH Campus DHS underground (buried) pipeline installation is selected. All pipes are insulated in the piping network.

Table 5: Total piping cost for DHS for underground installation.

Cost (US$)	Buried	Concrete Tunnel
Total pipe cost	434,887	434,887
Fittings and wages	130,466	130,466
Construction	158,132	948,600
TOTAL	**723,425**	**1,672,085**

4. RESULTS

Length of each pipe diameter for the supply main can be seen in Table 4 for 150 Pa/m TPL. The largest nominal diameter in the network is DN350 and the smallest diameter is DN65. Number of the nodes in the supply main is 46 and total pipe length is 3,520 m. Return main is assumed to have the same pipe diameter and length as supply main. Pipelab software also exhibits the head loss distribution on the network. The h/L diagram of the supply main of the Campus loop is shown on Figure 6. Pressure drop is calculated as 24.6 m for the supply and return mains. Heat centre pressure drop is assumed as 25 m. Thus, pressure head for the system is 80 m.

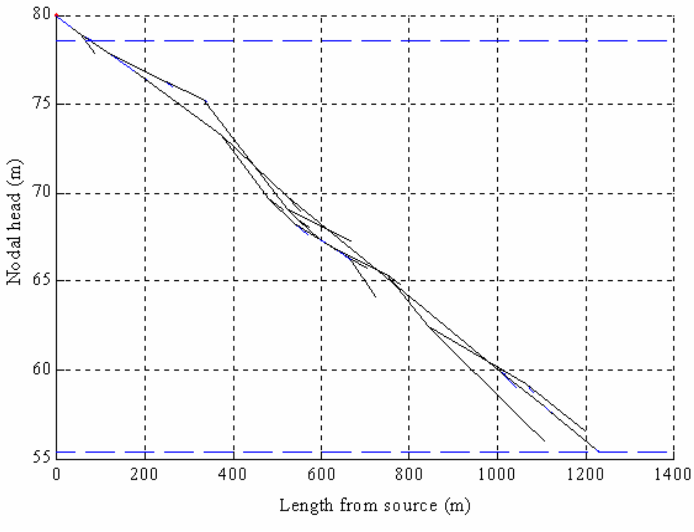


Figure 6: h/L diagram for Campus loop supply main of DHS.

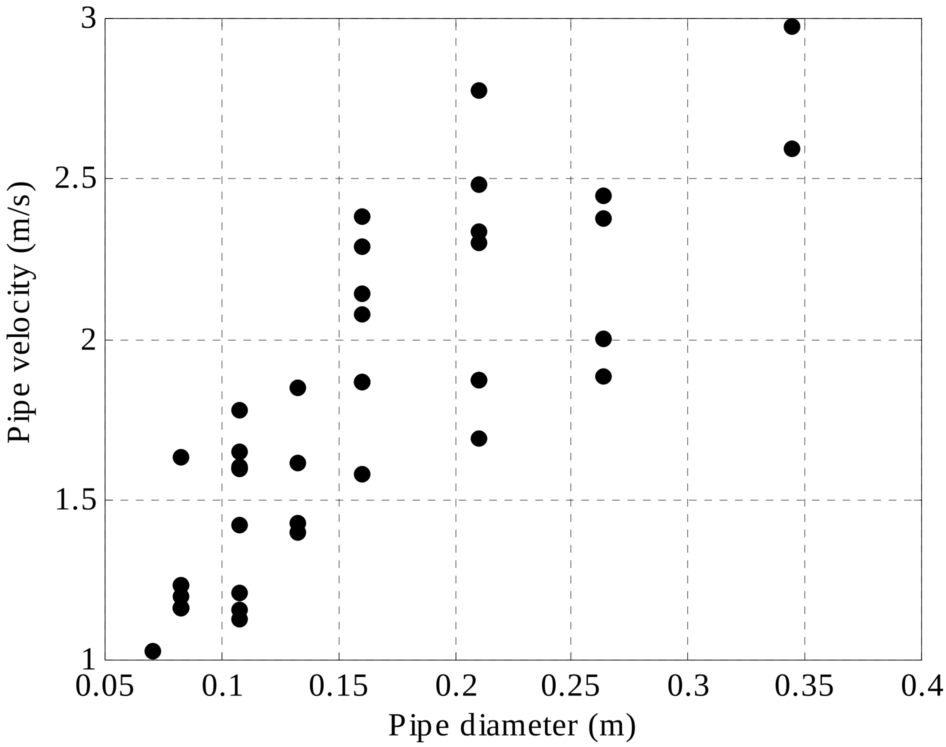


Figure 7: Relationship between pipe diameter and velocity of water.

Water velocities in each pipe are calculated by the help of Pipelab software. The relationship between the pipe diameter and the water velocity is displayed in Figure 7. Velocity range is calculated as 1.03-2.98 m/s. The results are also the same for the Campus return main.

Geothermal loop supply main has a total pipe length of 1,223 m, a total pressure drop of 25.3 m for DN250. Geothermal fluid disposal can be managed in two ways depending on chemical properties of the geothermal fluid and reservoir properties. One is reject the fluid to the waterways or the sea, the other one is to drill an injection well and inject the fluid into this well. First alternative is chosen since the chemical properties of the fluid are very close to the seawater (Giese et al., 2000). Geothermal return main is the same as the supply main in length and diameter.

Main results of piping network design for supply mains of HPDHS are given in Table 6.

Table 6: Main results of piping network design for supply mains of HPDHS (Yildirim, 2003).

Part of the Piping Network	Total Pipe Length (m)	Pipe Material	Piping Cost (US$)	Pressure Drop (m)
Campus Loop	3,520	Carbon Steel	248,991	24.6
Geothermal Loop	1,223	Composite	185,896	25.3

Table 6 exhibits that total length of the pipes in the supply main of Campus loop and geothermal loop are 3,520 m and 1,223 m, respectively. Thus, total length of considered network of the district heating system is nearly 9,486 m.

Another outcome of Table 6 is while total pipe length of Campus loop is nearly 3 times of geothermal loop, the piping cost is only 1.34 times, since composite pipes 13-35% more expensive than carbon steel pipes depending on the pipe diameter.

5. CONCLUSIONS

Piping network simulated by Pipelab **(**Valdimarsson, 2002), which uses the Matlab program as a basis. The piping network of the Campus has been considered with two loops as geothermal and Campus. Each loop contains supply and return mains. The location of the heat centre is important for the economy of the system. Therefore, several alternatives have been studied and 3 of which are given in this study. In the first alternative, heat centre is close to the Campus entrance. For the second alternative, heat centre is close the production well and heat centre is almost in the middle of the Campus in the third alternative. With the help of Pipelab software, pipe diameters and total pressure drops of the piping network are calculated for each alternative. The results indicate that, Alternative 2 has the highest pressure drop and requires the longest pipeline. Alternative 1 and 3 are close to each other in pipe length but Alternative 3 requires shorter piping for larger diameters. Because of the lowest piping cost and pressure drop, Alternative 3 is considered to be the best option.

The pressure loss per unit length is a common design parameter. While piping cost decreases drastically with increasing TPL, operational pumping cost is nearly constant. Therefore, the highest acceptable TPL, 150 Pa/m, is selected for the district heating piping network. Total length of the pipes in the supply main of Campus loop and geothermal loop are 3,520 m and 1,223 m, respectively and because of the corrosive effects of the geothermal fluid, composite (FRP) pipes are used for geothermal loop while Campus loop is installed with carbon steel pipes. Geothermal return main is the same as the supply main in length and diameter. Thus, total length of considered network of the district heating system is 9,486 m.

Pipelines are installed either aboveground or underground. Underground installation is preferred here to avoid heat losses and esthetic concerns. For installation type of piping network two options are considered, directly buried into the soil or in concrete tunnels. Piping cost is 2.3 times more expensive for concrete tunnel. Therefore, for IZTECH Campus DHS underground (buried) pipeline installation is preferred.

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