AKRANES AND BORGARFJORDUR DISTRICT HEATING SYSTEM

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INTRODUCTION

In Iceland, there are about 30 geothermal district heating systems in operation in towns and villages. In most cases, they serve practically the total population of the respective communities, and totally about 83% of the house heating market in the country. All of them are community-owned, and they distribute and sell hot water on the basis of a monpoly. In addition to this, there are about 25 small privately-owned systems, each serving 50 people or more, mainly in rural areas, and a great number of smaller systems serving individual farms. Thus, the total share of geothermal heating in the country is about 85%. Reykjavik Municipal Heating is by far the largest of the district heating systems serving about 155,000 people, or more than half of the population of the country. The total installed capacity of all the geothermal district heating systems in Iceland is about 1,400 MW.

Akranes and Borgarnes are two towns in the western part of Iceland, about 100 km north of Reykjavik. They are situated at the coast, and have 5,200 and 1,700 inhabitants respectively. In Akranes, fishing and fish processing are the main employment, and Borgarnes is a center of commerce and services for the Borgarfjordur district, northeast of the town (Figure 1).

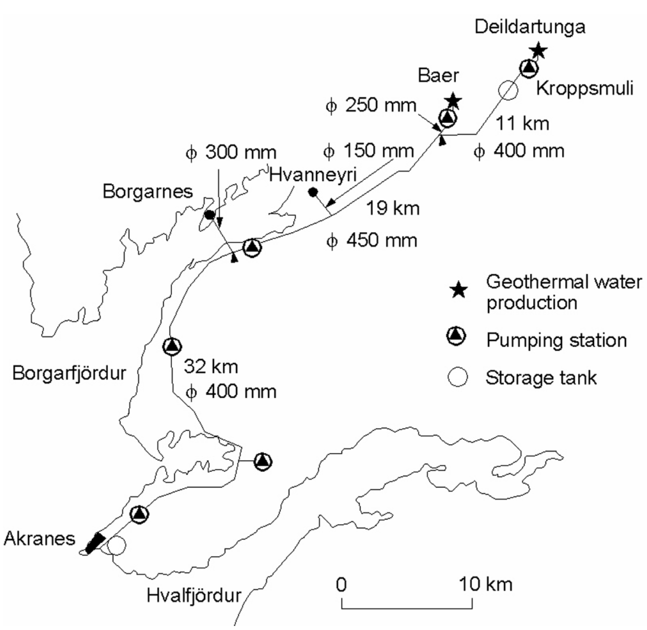

Figure 1. Overview of the district heating systems showing the transmission pipeline.

Geothermal investigations for Akranes started as early as around 1950; but in spite of several attempts, a geothemal field, which could be utilized economically, was not found for a long period. After the increase in oil prices in the early 1970s, futher studies were carried out. On the basis of the results of those studies, it was decided to build a combined district heating system for Akranes, Borgarnes, Hvanneyri (agricultural school) and some farms in the Borgarfjordur region. The water is piped from the hot spring Deildartunga, which is one of the largest hot springs in the world. Besides that, the system utilizes two wells at the farm Baer. The utilization of the hot spring makes the system different from most other district heating systems in Iceland, which are based on water from wells.

Akranes and Borgarfjordur District Heating System was established in 1979. Before that time, space heating in this area was both by oil (93%) and electricity (7%). The system has now been split into three companies: one that is responsible for all the hot water production and transmission, and one district heating system for each of the two communities.

SYSTEM DESCRIPTION

The springs at Deildartunga supply 180 L/s of water at 96°C and the wells at Baer can produce about 20 L/s in artesian flow. Thus, the combined supply capacity is 200 L/s. Currently, however, the system is using only 170 L/s at peak load, which are taken from the Deildartunga hot springs. The wells at Baer are only used if the supply from Deildartunga is interrupted for some reason and flows cannot be maintained by the storage tanks.

The collection system at the springs is very simple. An arrangement of low walls guides the boiling water into the collection pipes. These conduct the fluid to a nearby pumping station that pumps the water up to a storage tank at the highest point in the pipeline at Kroppsmuli a few km away. The system also includes two storage tanks to maintain supplies to Akranes and Borgarnes if breaks in the transmission pipeline occur. The tank at Borgarnes has a capacity of 2,500 m^3 and that at Akranes 2,000 m^3. These give the maintenance crews several hours in which to repair breaks. Pumping stations are at six different places in the system.

The distribution system is a single pipeline system, made of buried steel pipes, pre-insulated by polyurethane. The total pipe length of the distribution system is 107 km; thereof, 57 km in Akranes, 23 km in Borgarnes and 27 km in the rural areas. The water supplied is used directly by the users in their radiator systems and as domestic hot water. The return water is disposed of through the local wastewater system.

The total installed capacity of the system is about 60 MW and the annual energy supplied to the users was 382 TJ in 1997. The annual water consumption is about 2.2 million m^3. Of that, 60% is consumed in Akranes, 30% in Borgarnes and 10% in the rural areas of Borgarfjordur. In Akranes, the water temperature at the inlet to the distribution system is 77^o C and the average temperature to the users 72.5^{o}C. Corresponding values for Borgarnes are 82^o C and 76.5^o C respectively.

The original plans did not assume that the houses heated by electricity would be connected to the district heating system, as they did not have hot water radiators installed. Later, it was decided to make an effort to include these houses also, and today about 3/4 of the houses originally heated by electricity are connected to the district heating system.

The operation of the district heating system has from the beginning been based on two rather simple separate control systems, one in Akranes and another in Borgarnes. From 1993, the flow rate and water temperature at three different places in the system has been automatically monitored. These old systems have just been replaced by a new modern computerized system for control and monitoring of the whole district heating system. It gives the operatores a real time overview of all the main parameters and prepares reports of different types based on historical data. It is expected that this new system will increase the operational safety, and by better flow control and increased monitoring reduce the maintenance cost of the pipeline system.

THE TRANSMISSION PIPELINE

The transmission pipeline from Deildartunga to the storage tank at Akranes is 62 km long. It is probably the longest geothermal transmission pipeline in the world. Most of the pipeline (43 km) has a diameter of 400 mm and the rest (19 km) a diameter of 450 mm. The majority of the transmission pipeline is made of asbestos cement. A cross-section of the pipeline is shown in Figure 2. The main reason for the choice was a relatively low installation cost, which was of vital importance as the transmission pipeline represented over half of the total investment cost of the total system. Calculations showed that pre-insulated steel pipes would have made the system uneconomical compared to oil heating. The difference in installation cost lies mainly in the simple layout method possible with asbestos pipes; while, steel pipes require good protection against water. Also, asbestos has good thermal properties for this type of application. However, it is rather fragile and the pipeline suffers from frequent breaks. It should be pointed out that the system was built short time before asbestos was recognized as hazardous to people's health and later forbidden as a pipe material. Insulated steel pipes of a total length of 2.7 km are used where the conditions are unfavorable, like where the pipeline crosses streams and the fjord to Borgarnes.

No foundations as such were laid under the asbestos pipe. The ground was simply leveled and a layer of volcanic ash laid as a bedding material. The pipeline was laid directly on the ash and the exposed surface was covered by 50 mm thick rockwool segments. About 2/3 of the pipe surface is insulated in this way. A trench was dug alongside the pipeline and the excavated earth used to cover the pipeline. The parallel trench serves as a drainage channel.

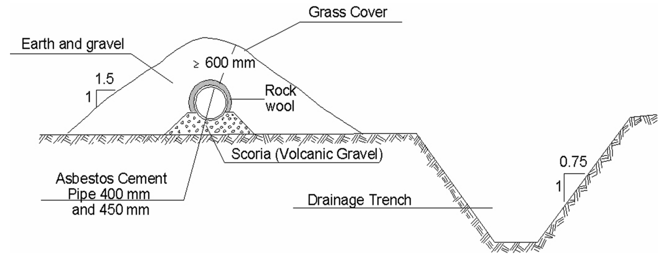

Figure 2. Cross-section of the asbestos tranmission pipeline.

The inlet water temperature to the transmission pipeline at Deildartunga is 96^{o}C. The temperature drop along the pipeline depends strongly on the flow rate, resulting in considerable temperature drop at low flow rates. Also during periods of heavy rain, the insulation gets wet and the temperature drop can be very high. The flow rate is regulated to keep a constant supply temperature of 77^{o}C from the pumping station at Akranes. During summer, a typical flow rate is 120 L/s and 170 L/s during winter. The excess flow, spilled to keep the water temperature at an acceptable level, can vary from 80 L/s during summer to no excess flow during winter peaks.

The asbestos pipeline has performed satisfactorily in spite of between 20 and 30 breaks each year. They are detected automatically and repaired quickly, and with high cost. In most cases, the users do not notice these breaks. The frequency of the breaks has not increased over the years and even decreased over the past few years.

One of the most important factors influencing the lifetime of an asbestos pipeline is the dissolution of calcium from the cement, which is the binding material of the pipe. This reduces the strength of the pipe and destroys it over time if the dissolution continues. The rate of dissolution depends mainly on the chemical composition of the water. Monitoring of the calcium dissolution from the pipeline between Deildartunga and Akranes over the years shows that it decreasing, indicating that the pipeline will keep sufficient strength for at least the next 20 to 30 years.

One problem with the transmission pipeline is that the earth cover has eroded and in some places consolidated due to drying, so the pipeline has sunken below the original ground surface level. In attempt to solve this problem, trenches have at some places been dug on both sides of the pipeline. It is important to have some vegetation on the earth covering the pipeline, mainly to stabilize it and also to improve the insulation and prevent water infiltration. This has been difficult to achieve without building fences on both sides of the pipeline.

Steel pipes mounted above the ground on foundations have required some maintenance. These pipes have an aluminum sheet, which protects the rockwool insulation and prevents water from coming in contact with the steel. It has shown to be difficult to make the sheet tight enough and keep the insulation dry, especially at the foundations, with the result of an external corrosion of the pipes. This problem is well known by other district heating systems in Iceland.

Figure 3. Collection and pumping station at Deildartunga.

TARIFF SYSTEM

From the beginning, Akranes and Borgarfjordur District Heating System used a tariff system based on maximum flow restriction. The user was charged by the maximum flow selected, but not by the volume of the water consumed. This kind of system was widely used in Iceland in earlier days; but, today this method is mostly restricted to rural areas.

In 1992, a new tariff system was introduced. The basis for that is the conventional tariff system used in Iceland, that is a fixed-annual charge and a variable charge proportional to the quantity of water used. In addition to that, a new method was introduced including tariff corrections based on the water supply temperature at the individual user.

The tariff correction is based on a calculated average water temperature at each individual user. The calculations use the measured annual water consumption of each user in the previous year and an overall water consumption history for the whole system on a daily basis. By using the water temperature at the inlet to the distribution system (77°C in Akranes and 82°C in Borgarnes), a computer model calculates the temperature drop in every single pipeline in the system. From that, an average water temperature at each user can be drived. A water temperature of 80°C at the user is used as a basis for the tariff correction. For every 1°C below that temperature, the waterprice is reduced by 2%. This price reduction is approximately proportional to the reduced useful energy content in the water because of the temperature reduction. Thus, all users should in principle pay the same energy price.

In the beginning, the new tariff system was met by criticism by many users. To give the users opportunity to be better informed about the water conditions, a big sign was installed at the pumping station in Akranes, showing the temperature of the water leaving the station. After few years experience, the model now calculates the temperature drop with a high accuracy and is considered to result in much fairer prices for the services. Comparison between groups of houses with different inlet water temperatures shows that they have similar heating costs. The new tariff system has resulted in considerably lower water consumption, both during summer and winter. This is because the old tariff system based on maximum flow restriction did not encourage customers to maximize the heat extracted from the water. Similar reduction in water consumption has been observed in other district heating systems in Iceland, which have changed the tariff system from maximum flow restriction to water meters.

HEATING COST

The total investment cost of the system was about 43 million US$ (1998 prices). This cost was divided as follows: wells, 1.2 million US$ (3%); transmission pipeline and pumping stations, 24 million US$ (55%); and distribution system, 18 million US$ (42%). These figures are only rough estimates, as the system was built at a time of high inflation rate in Iceland, which makes the 1998 comparison difficult.

Because of the high investment costs of the system, the heating costs for the customers of Akranes and Borgarfjordur District Heating System have been among the highest of all district heating systems in Iceland. Lower oil prices than predicted at the time of construction have also made the system less favorable economically, compared to other alternatives, than expected. Despite this, the system will unquestionably prove to be a good investment in the long run, especially if factors like savings in import of oil and environmental benefits are considered.

While the original tariff system was used, the customers tried to reduce their heating costs by choosing low-maximum flow settings, and in some cases, even met peak demand periods by heating by electrical ovens. This resulted in lower revenues for the system than expected. As the operating costs of the system were mainly fixed-capital costs, this resulted in financial problems for the operators. In the late eighties, the state took over 4.5 million US$ (1998 prices) of the total debt and this made it possible to lower the water prices. From that time until 1993, the water price was index regulated to keep it at a constant real value. Since then, the water price has been reduced by about 10%. Taking into account the inflation rate, this corresponds to about 25% reduction in real water prices.

Figure 4. Aboveground steel insulated pipe and buried asbestos cement pipe.

A typical family house of the size 535 m^3, built in the late eighties, uses about 630 m^3 of water each year, or 1.2 m^3 water per m^3 house volume. This water consumption is low compared to many other district heating systems in Iceland wher the water prices are lower. The heating costs is about 1,100 US$ per year. Of that, 25% is fixed-annual charge and 75% variable charge according to the amount of water used. In spite of the water price reduction, the last years the heating cost in Akranes and Borgarnes is still among the highest of all district heating systems in Iceland. It is, for example, about 60% above the heating cost in Reykjavik. Compared to alternative heating methods, the heating cost in Akranes and Borgarnes is similar to electricity, which is subsidized by the state. Heating cost by oil is now about 30% higher.

ORGANIZATIONAL CHANGES

According to an agreement between the Ministry of Energy and the communities in the Borgarfjordur area, the organization of production, distribution and sale of energy was changed in the area from January 1, 1996. The partners contributed by holdings or by taking over loan so the total debt of the district heating system was reduced by 50%. The purpose of this was to achieve more economical energy distribution and thereby, lower energy prices. As a part of this reorganization, Akranes and Borgarfjordur Distirct Heating System was split in three parts. The function of the original company was reduced to providing only hot water production and transmission from Deildartunga to Akranes and Borgarnes as well as distribution in the rural areas. The hot water distribution and sale in Akranes was taken over by a new community-owned company, Akranes Energy Utility, which also produces and distributes electricity as well as cold water. In a similar way, the hot water distribution and sale in Borgarnes was taken over by a new community-owned company, Borgarnes District Heating. Akranes and Borgarfjordur District Heating System now sells hot water in wholesale to the other two companies, Akranes Energy Utility and Borgarnes District Heating. It has no employees, but is served by the two community utilities with maintenance work and other services.

Before the reorganization, the number of employees was about 17 and most of them were transferred to the two community utilities. In connection to these changes, a thorough inspection of the whole production and transmission system was carried out by a consulting engineering company (Gunnarsson, 1996).

CONCLUSIONS

The 18 years experience with the 62 km long transmission pipeline, made of asbestos cement, from the hot springs at Deildartunga to Akranes and borgarfjordur is good. In spite of high investment cost, the district heaing system has been able to produce hot water at reasonable prices, thus reducing the import of oil in favor of an indigenous energy source. The organizational changes made are expected to result in more economical operation and lower energy prices in the future.

Last summer, a tunnel under the fjord Hvalfjördur was opened, shortening the driving distance between Reykjavik and Akranes by some 50 km. The distance between the northernmost part of the Reykjavik District Heating distribution system and Akranes is now less than 20 km. This has created the idea that in the future, it might be found economical to connect these two systems through the tunnel instead of maintaining the long transmission pipeline to Akranes.

REFERENCES

Harrison R.; Hrólfsson, I. and J. S. Gudmundsson, 1990. "Description and Economics of Hitaveita Akranes og Borgarfjardar in Iceland." Geothermics, V. 19-4, p. 359-365.

Harrison, R.; Mortimer, N. D. and O. B. Smárason, 1990. "Geothermal Heating." Pergamon Press, NY, p. 476-486.

Gunnarsson, Á., 1996. "Hitaveita Akranes og Borgarfjardar. Úttekt á ástandi mannvirkja í janúar 1996." Report (in Icelandic).

Magnússon, Th. V., 1998. Private communications.

GEO-HEAT CENTER QUARTERLY BULLETIN
ISSN 0276-1084
A Quarterly Progress and Devlopment Report
on the Direct Utilization of Geothermal Resources

This article is in the Vol 19, No. 2 bulletin

This material was prepared with the support of the U.S. Department of Energy (DOE Grant No. DE-FG07-90ID 13040). However, any opinions, findings, conclusions, or recommendations expressed herein are those of the author(s) and do not necessarily reflect the view of DOE.