The Feasibility of Direct Connection in District Heating System in Korea through the Case Studies

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District Heating System(DHS) is one of the most excellent systems in terms of energy saving and environmental protection. But as the current indirect connection in Korea is applied to the case of big scale, it brings about heat loss in its network. Moreover, high-priced heat exchanger facilities are required. However, the application of direct connection can cause the decrease of heat loss through the heat supply and return of low temperature. So, the purpose of this paper is to offer basic materials for the application of direct connection suitable for Korea through comparative analysis of some cases that the direct connection is applied. In order to ensure the stability of its consumers, it is reasonable to apply the operating conditions of the temperature of less than 90 ℃ and the pressure of less than 6 bar are applies to the results of this research.

Key words: District Heating System(DHS), Direct Connection, Supply Pressure, Supply Temperature, Foreign Examples

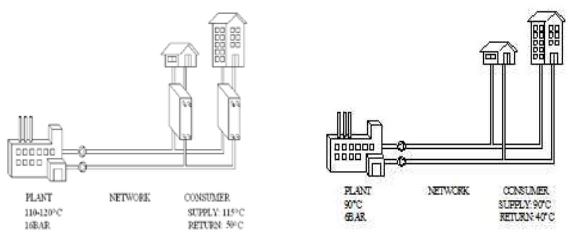
1. INTRODUCTION

For the recent 10 years, lots of interest in the diversity of energy and the efficient use of energy has leaded to the expansion of the spread of DHS and the research on the subject has been actively conducted. In Europe, the DHS is considered as the most excellent type of heating in the level of energy saving and environmental protection and all sorts of policies for the development of district heating industry have been continued to promote the system. However in Korea, indirect connection is applied to DHS since the indirect connection is suitable for large-scale supply. However, the indirect connection caused so much heat loss in its network. Moreover, as it requires expensive heat exchangers and auxiliary apparatus and so on. On the other hand, the direct connection makes it possible to decrease the amount of heat loss through the low temperature heat supply and return, and has an effect on energy saving in small-scale supply. In comparison with indirect connection, direct connection is more economical and has the advantage to decrease its initial investment. So, this paper is to study the comparative analysis of the present statuses through foreign examples of Japan and Denmark and to provide the fundamental data of the application plan for the indirect connection of the DHS in Korea.

2. PROCEDURE

2.1 District Heating System and Connection

DHS is a system for distributing the thermal energy from central heating plant to residential areas, commercial areas or industrial areas, and so on for space heating and hot water. In comparison with the existing heating system, it is more effective in terms of energy saving and reduction of pollutants. The supply method of DHS is classified the indirect connection and the direct connection. Figure 1 shows DHS by methods of connection and the supply conditions. Indirect connection is the method to install a heat exchanger between a consumer and a central heating plant and to separate working fluid. Direct connection is the method that the heat source or the hot water supplied from the network is directly used for heating without passing through heat exchanger in the consumer facilities.



a) Indirect connection b) Direct connection

Fig. 1. DHS by methods of connection and the supply conditions

2.2 Constraint to apply direct connetion

The material of the pipe and the temperature and pressure of supply water should be considered to supply heat source to consumer stably. XL pipe is generally installed in the floor heating system(The operating temperature is 0~95℃, the operating pressure is less than 6.5bar).

2.3 Process of study

This study investigated the direct connection in the foreign countries to suggest the plan of the application of direct connection to the DHS in Korea. The process of the study is shown in Figure 2.

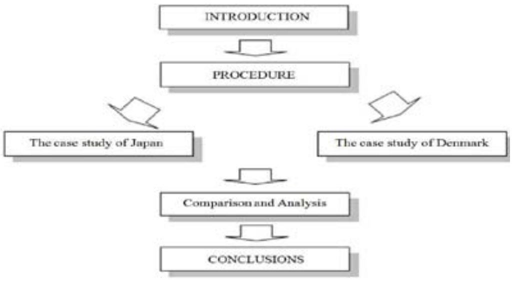


Fig. 2. Process of study

3. RESULTS

3.1 The cases of direct connection in Japan

At Sapporo in 1967, the DHS in Japan first started in the 180 households of apartment complex as the method to protect the air pollution by coal heating. At present, the business of heating supply consists of the DHS and the District Heating and Cooling System. Especially the District Heating and Cooling System has been widely spread on a national scale centering around the office areas in downtown. Based on the year of 2007, 87 businesses operated the DHS and there were 151 business divisions. In Tohoku, Kanto area, the DHS took up 52.73% which was the highest rate, and in Hokkaido area it took up 36.64%.

1) Bannaguro complex in Hokkaido Ishikari

Bannaguro complex is the cold district which is similar to Seoul, Korea. As to consumers, bleed-in method is applied for residential area and heat exchanging method is applied for business facilities. The temperature is controlled to 80℃ for heating and 60℃ for hot water. The pressure to supply heat source is 10 bar, but the range of pressure which is operated in substance is less than 7 to 8 bar. Figure 3 shows the distribution diagram of Bannaguro complex.

2) Hikarigaoka complex

As to the number of households, Hikarigaoka complex is the largest apartments in Japan. The heating system in this district uses the hot water which was heated by steam heat recovery(50~55℃) from the power plant in the resource recovery facility as its heat source water. They supply heated water at about 45℃ directly to the business facilities which are close to the center plant. As to the business facilities and housing complexes which are far from the center plant, they supply the heat source water at about 25℃ from heat reservoir and the substations of each facility raise the temperature of water with its heat pump and supply the water for consumers. Moreover, the temperature of the heated water is adjusted to 25℃ as heat source water to reduce the heat loss. And the supply pressure of heated water is 6 bar which is possible to supply heated water up to 14th floor. Figure 4 shows the concept diagram of the heat supply in Hikarigaoka complex.

3) Tomakomai West

In this area, heat supply is operated on a small scale comparing with other areas. The system provides the heated water at 140℃ with the pressure of 9.9 bar which is the highest utility pressure by nitrogen pressure of the main plant to its substations. As the differential pressure between the supply pipe and the return pipe is 3.5 bar, the actual operating pressure is 6.4 bar. Substations produce the heated water at 75~80℃ using the heat exchanger. Therefore, the standard of the supply temperature and the return temperature is Δt=15℃. Figure 5 shows the concept diagram of the heat supply of Tomakomai West.

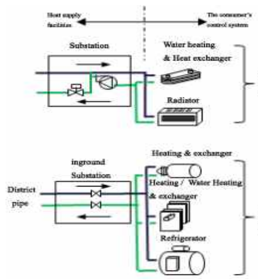


Fig. 3. Distribution diagram of bannaguro complex

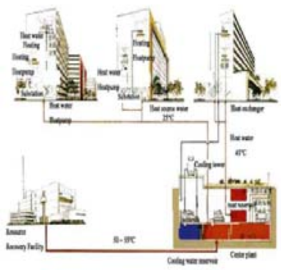


Fig. 4. Concept diagram of the heat supply in Hikarigaoka complex

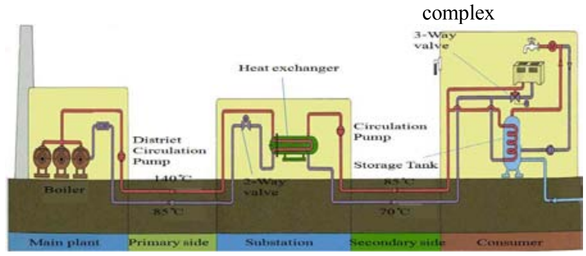


Fig. 5. Concept diagram of the heat supply of Tomakomai West

4) The midtown area of Tomakomai

The basic system is the same to that of Tomakomai West, but maximum temperature of the heated water is 155℃ supplied to substations. Substations produce the heated water at 70℃ and supply it to the consumers. The pressure is the same to that of the West area.

5) Nitshin complex of Tomakomai

The heating system in Nitshin complex of Tomakomai is the way to supply the high-temperature water which is produced in a plant to each substation. As bleed-in method is applied to the heating system in the substations, after controlling it with Outdoor air temperature compensation control, the heated water is supplied directly to the consumers.

6) Sapporo Station Kitaguchi

The system of this district is to supply cold water and hot water which produced in a plant to the Air Handling Unit(AHU) of each building. The heat exchanger is not required but it is required for hot water. And the supply pressure is 8.8 ~ 9.8 bar. However, the differential pressure between the supply pipe and the return pipe is 2 bar, so the actual operating pressure is 6.8 ~ 7.8 bar.

7) Sapporo Station Minamiguchi

The system of this district is the Co-generation method. In this system, heating and hot water is produced by the steam which comes from the heat power generator. The supply pressure is 6 ~ 7 bar. Moreover, the Free Cooling System using a cooling tower makes it possible to supply cold water to the place where the air cooling is required in winter.

3.2 The cases of direct connection in Denmark

Denmark has applied the indirect connection as a result of the establishment of the energy plan in accordance with the energy crisis in 1970s. Due to the social background to satisfy the needs of heat consumers and to supply energy efficiently on the basis of economical efficiency rather than to manage the system intensively, the direct connection has been applied. The direct connection could be applied effectively since the geographical condition was flat field. In Denmark, there are about 350 companies related to DHS. These companies purchase heat from the heat producer and sell it to the related local governments through the transportation pipes. However, as the supply and return temperature of the DHS in Denmark is not controlled by central management system, each supplier of heat source controls it efficiently. In generally, primary side transmission network is operated by indirect connection and secondary side distribution network is operated by direct connection.

1) Odense (RAMBOLL)

RAMBOLL's DHS which was applied to Odense is composed of 4 stages of power plant, transmission network, distribution network, internal heating system. Transmission network is the part to transmit the big-scale heat generated from heat source. Distribution network, as a part to distribute the heat to consumers, is operated at lower pressure and lower temperature than transmission network. The consumers who consume heat lastly are connected to the network through direct connection and indirect connection. Figure 6 shows the network of direct connection heat use facilities of RAMBOLL Company. As the direct connection is the system which not classified the working fluid of primary and secondary sides, the leak detection system is equipped. Generally, considering valve, pump, radiator and so on, consumer heating system adopt the maximum pressure 6 bar system(In case of floor heating, the maximum pressure 6 bar is applied because XL pipe is used).

2) Odense (Fjervarme Fyn A/S)

Fjervarme Fyn A/S's distribution diagram of heat source in Odense is described in Figure 6 In Odense and surrounding areas, the direct connection by pressure reduction which utilizes 8 individual transmission networks (600A /500A) from heat source is applied to supply heat source. Figure 7 shows the summary diagram of heat supply in this district.

3) Frederiksværk in the northern part of Copenhagen

In Frederiksværk area in Denmark which is a small plain area, the direct connection by mixing loop is partially applied. Figure 8 shows the geographical location of Frederiksværk and its network. The current rate of direct connection is less than 10% and has been declining. Moreover, oil is used as auxiliary heater and 6 units of PLB are operated for the stable supply. Figure 9 shows the boiler required for heat source facilities. On the basis of the cases above-mentioned, the direct connection of DHS is classified according to characteristics of pressure and temperature in Table 1.

Fig. 6. Heat network in Odense

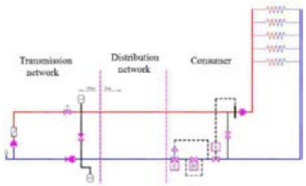


Fig. 7. Outline P&ID of heat Supply

Fig. 8. Heat source facilities of Frederiksværk

a) Wood chip Boiler

b) Wood chip Boiler

c) Pellet Boiler

d) Oil Boiler

Fig. 9. Heat source facilities of Frederiksværk

Table 1. Classification on the types and characteristics of direct connection in DHS in Japan and Denmark

Country	District		Scale of supply	Supply pressure	Supply temperature	Summary of system	Remarks
JAPAN	Hokkaido Bannaguro complex		APT and individual houses: 1,207 households business facilities: 19 cases	7 ~ 8bar	Heating: 80℃ Hot water: 60℃	Supplying heated water at 135 ℃ produced at a plant to 7 substations and controlling temperature and supplying them it to consumers.	The length of pipe will be extended to max 4.2km. Heat loss happens in pipe.
	Hikarigaoka complex		house: 12,000 households Business facilities: 70 cases	6bar	Heating: 45~60℃ Hot water: 60℃	Generating through the heat from waste incineration, and applying the heat pump using steam heat recovery as heat source.	The reason of supplying the heated water at 25℃ as heat source water is to reduce heat loss by lowering temperature.
	Tomakomai	West	house: 2,680 Business facilities: 17 cases	6.4bar	Maximum: 140℃ Heat exchange: 75 ~ 80℃ Return temperature : Δt = 15℃	Supplying heated water to substations by nitrogen pressure of the main plant and supplying to consumers through heat exchanger.	Installing double pipes and the chemical treatment for anti-corrosion.
		Midtown	house: 849 Business facilities: 15 cases	6.4bar	Maximum: 155℃ Heat exchange: 70℃	The same to West.	The same to West.
		Nitshin complex	-	-	Winter season: 120~140℃ Summer: 100 ~ 120℃	Supplying the high temperature water produced in a plant to each substation.	Installing double pipes and using silicon calcium as laggings.
	Sapporo Station	Kitaguc-hi	-	6.8~7.8bar	Heating: 90℃	Producing water and supplying it to the AHU if each building.	Heat exchanger is unnecessary, but heat exchanger for hot water is needed.
		Minamig-uchi	-	6~7bar	-	Co-generation method. In the process of producing electricity, heat generator to produce the steam which issued for heating and hot water.	The free cooling system using a cooling tower makes it possible to supply cold water to the place where the air cooling is necessary in winter.
DENMARK	Odense	Ramboll	-	6bar	Transmission: 120℃ Distribution: 80℃	The 4 stages of Power Plant, Transmission network, Distribution network, Internal heating system at the consumer.	In applying mixing loop, installing circulation pump, check-valve, pressure control valve etc. will lead to reduction of power consumption and lowering of the return temperature.
		Fjervarm-e Fyn A/S	-	6bar	78 ~ 95℃	From one CHP plant, heat is supplies to 21 Preak load plants. Max heat demand is 800MW.	Distribution network is divided into transmission network and pressure reduction valve. Ensuring the safety of distribution network through air vessel.
	Copenhagen	Frederik-sværk DH company	3,600	6bar	72 ~ 88℃	Applying mixing loop.	Made up of twofold pipe(double -tube) In case of new distribution network, PEX pipe is applied.

4. CONCLUSION

This study analyzed the characteristics of DHS in order to offer the direct connection suitable for Korean system. As the result of case analysis of Japan and Denmark, considering valves, pumps, radiators and so on, the maximum pressure 6 bar system is generally used by consumer heat system. In case of Korea, because of all kinds of auxiliary apparatus and XL pipes for floor heating, the maximum pressure 6 bar system can be applied. In order to ensure the stability of consumers, the operating conditions of the temperature of less than 90℃ and the pressure of less than 6 bar are general. In the future study, supply condition and method of district heating water will be optimized by investigating pressure distribution of district heat network based on the proposed supply standard. Also, supply method applicable to Korea will be continuously examined by making a comparative study on direct and indirect connection methods in terms of economic efficiency.

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