Investigation on the District Heating Supply and Possibility of Using Waste Heat Energy in Changchun, China

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Abstract
In this paper, we analyzed the current situation of district heating in the city of Changchun, including heat source, the rate of propagation and total pipeline length. And we investigated the water temperature, water flux of waste energy source. Based on the investigation, we predicted available waste heat energy storage and the environment benefits when the low-temperature waste energy can be made use of. As a result, we found district heating mainly supplies heat for residence area in Changchun. About 37% of the total heating energy in Changchun is provided by a co-generation system. For the possible waste energy use, we found there is steady source in Changchun from sewage and river. If we can make use of all those sources, about 6.7% of the heating energy consumption can get from the sewage and river. The benefits of decreasing the pollutant are also important.

Keywords: district heating; waste heat energy; pollutant

1. Introduction
Due to the functions of saving energy, reventing from polluting atmosphere, improving economical profit and beautifying city, district heating (DH) has become a fundamental facility in a city, especially in Europe. In addition, with the development of economy and technology, DH becomes more and more important to utilize available heat and improve our environment in the city. As one of the waste heat source in the city, the sewage is being paid more and more attentions, because of its stable amount and temperature, easiness to collect, high available heat. With the continuing development of heat pump system, it become more practical to utilize the sewage in the city, and it becomes clear that the available energy in the sewage can be used as one kind of energy resource.

Since there are few research reports on the present condition of districted heating supply and utilization of waste heat energy resources in Changchun, China, we have a investigation on some existing problems for those aspect. Meanwhile, we analyzed and discussed how to utilize the low-temperature waste heat energy source, and how to reduce environment pollutions, which can be referred when designing, planning, operating, running and managing district heating. We also hope that we can make best use of the low-temperature waste heat energy to protect our environment.

2. Investigation of the Present Condition of the District Heating Supply in Changchun
2.1 Outline about Changchun
The Chandchun city is located in the north part of China and is the capital of Jilin (figure 1). The four seasons change in temperature are intense, winter season time is long, temperature is low. The year average temperature of the city is about 4.8˚C, the maximum temperature is 39.5˚C, lowest temperature is -39.8˚C. The heat supply was paid attention in the winter season, because the heating period consists in 170 days. The heat supply by boiler system began from 1906 and until 1949, the many big buildings was supplied by heat of boilers. The heat supply business has been developed quickly after 1949. The heat supply has changed from small-scale boiler system to large-scale boiler system and co-generation system. In the middle of 50s, an automobile company, Changchun Daiichi Automobile, started a co-generation heat supply. Heating supply to the factory ward and life ward with a large boiler system began with establishment of some large company. As of March, 2000, the heat supply enterprise number extends 32 company and the floor area of district heating is about 32,000,000 m2 and is increasing steadily (figure 1, table 1).
2.2 The rate of propagation for district heating

The Changchun has about 67 million m² of building floor area in city. Among those, about half is heating supply area. Here we define that a rate of propagation (PR) is the ratio of DH supply floor area to total building floor area in the city. The total building floor area, total DH supply floor area and residence area with DH supply are shown in Figure 2. The PR is 48%. Among this, residence area with DH supply has a large percentage of about 68%. Therefore, DH mainly supplies heat for residence area. As mentioned previously, there are 32 suppliers in district heating. Figure 3 shows those suppliers’ supply floor area. The largest is supplier No.1, which has about 6,800,000m² of the heating floor area and the smallest is supplier No.32, which has only about 100,000m² of a total heating floor area.

2.3 Heating energy consumption

According to our investigation, the heating energy consumption per building floor area can be transferred as about 34.31kg coal for one year. If the Calorific value of coal in Changchun is assumed to be 5000kcal/kg (about 21000KJ/kg), the total heating energy consumption will reach at about 5500Tcal/year. The statistical data showed about 5000Tcal has been spent for one year in table 1. From figure 3, we can see the energy consumption increased with heated floor area.

The district heating system also consumes the electricity. The yearly electricity consumption per building floor area is about 2.53KWh. Therefore, Changchun used about 81 million KWh electricity for their heating system.

The heating areas supplied by different heat sources are shown in Figure 4, where there are three kinds of heat source: combined heat and power system (co-generation), boiler system, and waste heat energy utilization system. The building area supplied by combined heating and power system is about, 11,820,000 m², about 37% of the total heating supply area. The building area with central boiler system is about 20,110,000m², about 63% of the total heating supply area. By far, there is no area supplied by waste heat energy. We should consider how to utilize more waste heat energy in the future to reduce environment load, such as pollution, etc.

2.4 Length of pipeline and heating capacities

As showed in table 1, the total length of pipeline in Changchun is about 1,780km. The length of No.1 (YQ=Changchun Daiichi Automobile) supplier occupies about 1/3 of the total length of pipeline in Changchun. Except of No1. supplier, figure 5 illustrated the relationship between the length of pipeline and heating capacities. The length of pipeline is almost lined with the heating capacities.
3. The Existed Problems and Several Suggestions on District Heating of Changchun

3.1 Heat supply system

1) Because distributed boilers have been used for many years as was shown in figure 1, and district heating in cities has just been developed for several decades, so there are many small boiler system, which occupy a large part of city area, waste much energy, and pollute environment heavily. In addition, the management of small boiler system and heat efficiency also needs to be improved.

2) The design of some boiler rooms and type of devices are not proper, which lack high efficient and energy-saving pumps, fan machine, dust-clean machine etc.

3) A lot of undertakings is to supply heating energy only. They cannot supply hot water for life and also can not satisfy cooling need, which make the devices operate with a low efficiency. In addition, there are no suppliers to make use of waste heat energy to save energy.

3.2 Pipe network

1) A large-scale pipe networks have supplied heat energy with heat transfer equipment and can be managed well because of this indirect supply mode. Middle and small-scale pipe networks supply heat energy directly to users. Therefore, the supply pressure balance cannot be guaranteed because of poor quality of installation and the management of operation becomes very difficult.

2) The quality of insulation in some pipe network is poor. The pipe welding is not qualified, which waste many heat resources, and lead to a poor heat supply. Moreover, there are many malfunctions to make the life year of pipe network become short.

3.3 Users’ side

1) On the users’ side, the supply pressure of some heating systems is not adjusted well to make some users too hot and some users’ room temperature be lower than the design need. As a result, some users open the window to keep the room comfort and some users cannot get a comfort environment.

2) Because the price of heat fee depends on building floor area, some building contractors do not pay enough attention to energy saving. The measures to save energy are not taken well, and a lot of heat energy has been wasted. We suggest that some laws on saving energy should be created, and the design and execution of building in the planning should be based on relative laws.

3) Operating management level is low, especially in some middle and small heating supplier, management staffs often lack management knowledge and professional techniques.

4) The laws in heat supply are not enough, and the existing laws are not executed completely. It is very difficult for heating enterprises to develop themselves due to that some users do not pay their heat fee on time. We suggest that corresponding policies should be issued to enhance market management of heating supply.

4. Study on Effective Use of Low-temperature Waste Heat Energy

In addition to conventional energy sources such as gas, electricity, petroleum and coal, DH systems can utilize various sources of waste heat energy throughout the city. These include heat drawn up from water in rivers and sewers, and heat given off by incineration plants and underground high-voltage power cables.

Here, we try to analyze its efficiency and environment saving when the heating suppliers make use of waste heat energy in Changchun.

4.1 Analysis method

The present heating supply system can be shown in figure 6(A), where there is no use of waste heat energy. We suggest a heat pump system figure 6(B), which has been used widely in Japan, to make use of waste heat energy.

The available waste heat energy storage $Q_w$ for river...
or sewage can be calculated by

\[ Q_w = c_p \times V_w \times \Delta t_w \] (1)

where \( Q_w \) = the available waste heat energy storage (kcal/h).

\( V_w \) = the flux of water or sewage (m³/h).

\( \Delta t_w \) = the difference between entrance and exit temperature(˚C). The value is 3.3˚C for heating, which is a value for sewage disposal station in Tokyo.

\( c_p \) = The mal capacity of water(kcal/m³ ˚C)

The reduction amount of air pollution compared with conventional system (figure 6) can be calculated by the following steps.

For a conventional system (boiler), the energy consumption \( E_b \) is,

\[ E_b = \frac{Q}{\eta_b} \] (2)

\( \eta_b \) = boiler efficiency.

For a heat pump with the use of waste energy, the energy consumption \( E_h \) is,

\[ E_h = \frac{Q}{\eta_h \times \text{COP}} \] (3)

\( Q \) = supplied heating energy (kcal/h). \( \eta_h \) = power import efficiency of heat pump which includes power generation efficiency(\( \eta_p \)) and Power transmission lose(\( \eta_t \)).

\[ \eta_h = \eta_p (1 - \eta_t) \]

For heat pump system, if we get \( Q_w \) from the waste energy (sewage or river and assume the efficiency of heat pump system is COP, \( Q \) can be calculated,

\[ Q = Q_w \frac{\text{COP}}{\text{COP} - 1} \] (4)

So the heat pump system can save energy compared with conventional system as,

\[ \Delta E = E_b - E_h = Q \left( \frac{1}{\eta_h} - \frac{1}{\text{COP}} \right) = Q \frac{\text{COP}}{\text{COP} - 1} \left( \frac{1}{\eta_h} - \frac{1}{\text{COP}} \right) \] (5)

If we assume \( P \) as a unit release of air pollution for one heat energy output, which is shown in table 3, the reduction amount \( \Delta P \) of air pollution compared with conventional system is,

\[ \Delta P = P \Delta E = P \frac{Q_w}{\text{COP} - 1} \left( \frac{1}{\eta_h} - \frac{1}{\text{COP}} \right) \] (6)

The machine efficiency and unit release of air pollution for heat energy are showed in Table 2 and Table 3, respectively.

4.2 Investigation of low-temperature waste heat energy source

Low-temperature waste heat energy source includes sewage disposal station, sewage pump station and river. The distribution is shown in Figure 7. There are three sewage disposal stations, two sewage pump stations and one river. The river is located in the suburbs.

We have a survey of sewage and river water temperature on 8th, January 2000. The measuring results
of sewage disposal water temperature, and river water temperature are shown in Figure 8. The north suburb sewage disposal station (No.1) water temperature is 3.5-4°C. West suburb sewage disposal station (No.2) water temperature is 3.7-4.1°C. The FAW sewage disposal station (No.3) water temperature is 4.2-4.6°C. The Daiichi sewage pump station (No.4) water temperature is 3.8-4.2°C. The Daini sewage pump station (No.5) water temperature is 3.7-4.1°C. Therefore, the temperature of sewage heat energy source in Changchun are in a range of 3.5-4.6°C. The sewage temperatures are more stable than the air temperature. The FAW sewage disposal station (No.3) water temperature has a high sewage temperature because there is a hot water supply for living.

The sewage flux change of waste heat energy source is shown in Figure 9. The north suburb sewage disposal station (No.1) water flux is about 14,500m³/h. West suburb sewage disposal station (No.2) water volume is about 5,500m³/h. The FAW sewage disposal station (No.3) water volume is about 950m³/h. The Daiichi sewage pump station (No.4) water flux is about 2,500m³/h. The Daini sewage pump station (No.5) water flux is about 600m³/h. The river water flux is 200m³/h.

The day sewage and river flux has been shown in figure 10. The north suburb sewage disposal station (No.1) has the highest water flux about 351,000m³/day. The next is west suburb sewage disposal station (No.2), which is about 135,000m³/day. Daini sewage pump station (No.5) has its lower value about 14,400m³/day among the sewage system. The water flux of river is about 4,800m³/day.

4.3 Results of available waste heat energy storage and the environment benefits

The prediction of city available low-temperature waste heat storage is shown in Figure 11. The north suburb sewage disposal station (No.1) has the highest heat storage about 1200Gcal/day. The next is west suburb sewage disposal station (No.2), which is about 450Gcal/day. Daini sewage pump station (No.5) has its lower value about 48Gcal/day among the sewage system. Available low-temperature waste heat storage for river is about 16Gcal/day. If we assume the water fluxes are steadily, the possible waster energy amount from sewage and river is about 330Tcal for heating season, which is about 6.7% of the total energy need for whole heating season.

Figure 12 shows the environment benefits due to make use of the low temperature waste heat in comparison with conventional system A. The air pollution (SOx, CO2, NOx, Powdered dust) reducing amount of north suburb sewage disposal station, west suburb sewage disposal station, FAW sewage disposal station, Daiichi sewage pump station, Daini sewage pump station, and river are 0.45-32.82ton/day, 0.06-4.65kton/day, 0.02-1.74ton/day, 0.03-2.12 ton/day, respectively.
5. Conclusions

In this paper, we analyzed the current situation of district heating in the city of Changchun, including heat source, the rate of propagation and total pipeline length. And we investigated the water temperature, water flux of waste energy source. Based on the investigation, we predicted available waste heat energy storage and the environment benefits when the low-temperature waste energy can be made use of. As a result, we found district heating mainly supplies heat for residence area in Changchun. About 37% of the total heating energy in Changchun is provided by a co-generation system. For the possible waste energy use, we found there is steady source in Changchun from sewage and river. If we can make use of all those sources, about 6.7% of the heating energy consumption can get from the sewage and river. The benefits of decreasing the pollutant are also important. We expect Changchun could pay attention on the waste energy use in order to save energy and environment.

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