DISTRICT HEATING

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SAPPORO: MODERN JAPAN, START-UP OF NEW DISTRICT HEATING SYSTEM

by **Senya Akagi**
Specialist and Department Chief,
Environmental Improvement Plant Department
Hitachi Zosen, Hitachi Shipbuilding & Engineering Co., Ltd
Osaka, Japan

and

Louis Malfitani
Project Manager and Chief of District Heating Division
American Hydrotherm Corporation
New York, N. Y.

Editor's Note
We wish to thank Mr. Akagi who supplied the technical data for this timely article about the new installation in Sapporo. If you watched the recent 1972 Winter Olympic Games which were held in that city, you saw some of the buildings which are served by this new district heating system.
Great appreciation goes to Mr. Malfitani for his invaluable assistance in preparing the article for publication: translating monetary values from Yen to Dollars; transposing the physical measurements and characteristics from the metric to the English system of units; and for other assistance and guidance he gave us.

The first stage of the new district heating system in the City of Sapporo was completed on October 1, 1971 and the Hokkaido Heat Supply Company, Ltd., started to supply heat to the central zone of the city.

The City of Sapporo has a population of about one million and is the capital of Hokkaido, Japan's northernmost major island. The city was newly created in 1871 as a center for the development of Hokkaido, and the citizens have retained the "frontier spirit" even now. The climate in Sapporo is cold, and heating is required about seven months of the year.

This big project, which converts individual building heating in an existing town to a district heating system for the purpose of preventing air pollution, was discussed at a symposium on dust problems at the municipal assembly in 1955. Since then, continued promotion and planning by city authorities have continued with the cooperation of the Hokkaido Government, Hokkaido University and many other persons concerned, and this project has now been realized as the fruit of more than ten years of effort. Engineering was performed with close cooperation between the offices of Hitachi Zosen and American Hydrotherm, and final design, cost estimates, planning and construction for the project were executed by Hitachi Zosen under license of the American Hydrotherm Overseas Corporation.

FEATURES OF THE SAPPORO DISTRICT HEATING SYSTEM

There are several types of district heating: "new-town," "redevelopment," "reconstruction," and others. This project belongs to the reconstruction type, and has the following features.

Prevention of Air Pollution

The main object of this project is the prevention of public nuisance due to air pollution. The air pollution in Sapporo is caused mainly by the combustion of fuel for the heating of all buildings, including apartment houses. By the conversion of fuel from coal to oil, the amount of dust fall tends to reduce gradually, but the amount of sulfur dioxide gas tends to increase steadily. In the central zone of the city, many buildings are concentrated in an area of 0.6 sq mi, which is only 0.15 per cent of the city area, whereas the fuel consumption in this area for coal and oil are about 16 and 30 per cent of the entire city respectively. Accordingly, the amounts of dust fall during the winter in 1966 were 34 tons per sq mi for the whole city, and 148 tons per sq mi for the central zone only. The amounts of sulfur dioxide were 0.76 and 1.46 (unit: SO_3 mg/day/100 cm^2 PbO_2 [1]respectively. As shown by these data, the air pollution in the central zone of the city is very serious.

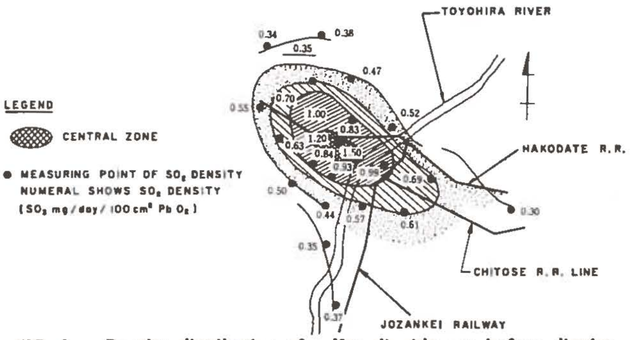

FIG. 1 — Density distribution of sulfur dioxide gas before district heating.

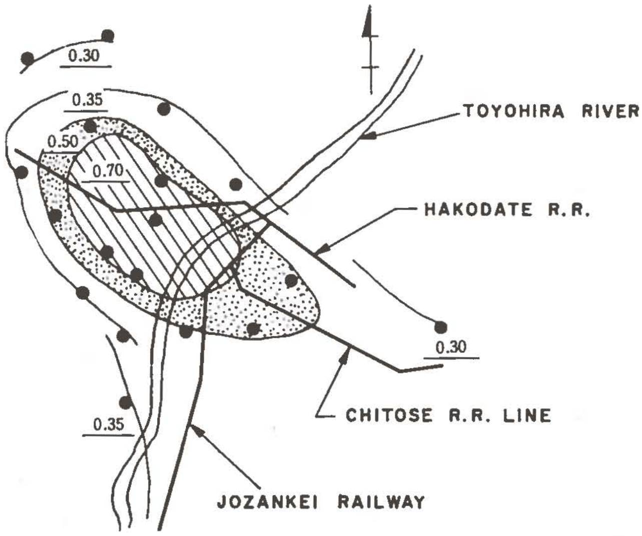

FIG. 2 — Density distribution of sulfur dioxide gas after district heating.

By converting the heating in this central zone from individual heating to district heating, the air pollution in Sapporo will be very much improved. It is expected that the pollution will be lowered to 50-60 per cent of former amounts in the central zone, and to 70 per cent on the periphery. Figs. 1 and 2 show the estimated density distribution of sulfur dioxide gas before and after the completion of the district heating system, as estimated by the City government. According to these figures, the air pollution generated in the central zone will be reduced greatly after the completion of the project, and it will no longer influence the surrounding areas.

Since coal is mined nearby in Hokkaido and its sulfur content is low, coal is used as fuel for the two first-stage 100 million Btu/hr boilers. However, this coal supply tends to be short; therefore, kerosene or light oil will be used instead of coal for the additional three 160 million Btu/hr boilers presently being installed in the second stage of construction.

Piping in the Existing Town

There were many problems encountered during the installation of the underground heat supply piping in the existing town: problems of interferences with the City water, sewer, and gas piping; electric and telephone cables, etc. Careful plans had to be formulated to minimize obstructions to traffic, and to provide security for cars and passers-by. There were many difficult conditions existing in Sapporo—shallow sewer piping, parallel construction of a new subway, heavy traffic, etc., and the underground piping work was completed with the assistance and cooperation of many persons. Because of the conditions which had to be considered, the system was designed for the largest possible temperature difference between supply and return high-temperature water in order to minimize the pipe sizes. Also, the number of expansion loops and manholes was minimized, and the safety of the piping considered, when the system was designed.

Heat Supply to the Existing Buildings

Most of the buildings which are to be connected to the district heating system are existing buildings. Accordingly, to make it possible to continue use of the existing heating installations as they were, it was necessary to install heat exchangers to generate steam or hot water to meet the same conditions as that of the existing boilers. Since the temperature of the secondary steam or hot water system of each building had already been determined by the existing installation, the return temperature of the high-temperature water from the outlet of the heat exchangers could not be lower than 120-130 C (248-266 F). To obtain a large temperature difference between the supply and return high-temperature water, it was decided to use the maximum temperature of 215 C (419 F) for the high-temperature water supply.

FIG. 3 — Central heating station.

OUTLINE OF THE PROJECT

In the original plans, the service area of the district heating project was to be about 0.6 sq mi in the central zone of the city where the air pollution was most serious. The central heating station (Fig. 3) occupies an entire city block and is located about 1,600 ft from the service area to the northeast. According to a survey of the area in 1967, the following data were reported:

Number of buildings	295
Number of boilers	433
Total rated output of boilers	1.1 billion Btu/hr
Fuel consumption—Coal	23,000 tons/yr
Oil	6,350,000 gal/yr

A later survey indicated that there would be more customers than originally estimated, and unexpectedly plans had to be made for new buildings. Therefore, the first ten-year program was advanced by three years, and it was decided that the whole project should be completed by 1974. The total capacity of the central heating station is kept at 680 million Btu/hr in the initial plan, but the service area is reduced to about 0.4 sq mi as shown in Fig. 4. For the southern area, which has been deferred to a later date, a second or third heating station will be constructed.

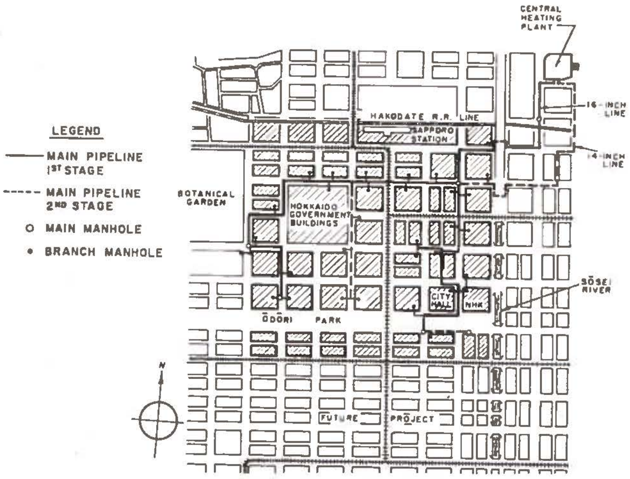

FIG. 4 — Sapporo downtown area, district heating service area, and main piping route.

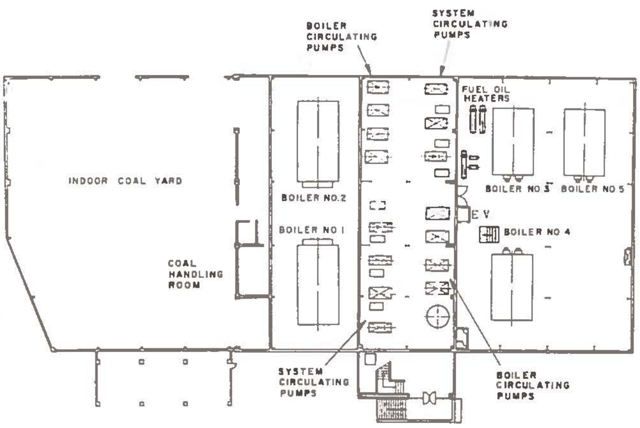

FIG. 5 — Plan of central heating station.

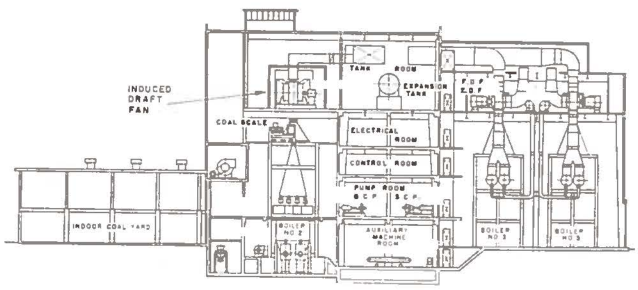

FIG. 6 — Section of the central heating station.

CENTRAL HEATING STATION

The general arrangement of the central station is shown in Figs. 5 and 6. The station occupies one block of 125,000 sq ft and the floor areas of the station are as follows:

Indoor coal yard	8,500 sq ft
Boiler rooms and center core	55,500 sq ft

Pollution Control

As this project was started to control public nuisance, special attention has been given to the selection of pollution control equipment, especially since the central station is located close to the center of the town.

To keep the dust from the smoke stack under a concentration of 0.09 grains per cu ft, cyclone dust separators are installed and the height of the smoke stack is 295 ft, allowing enough diffusion of smoke.

The noise from the station is controlled by arrangement of the equipment, windowless building construction, type of wall construction, etc. The facility fully complies with the anti-noise law. There is no problem with waste water at this station. Dry-type, ash-removal equipment is used to avoid discharging of dirty water, and a dustless unloader is equipped to prevent ash scattering.

Boiler Equipment

The hot water boilers are of Hitachi Zosen Corner-tube forced-circulation water-tube type. Two 100-million Btu/hr boilers for the first stage are equipped with spreader stokers for coal firing. Ash is stored in an ash silo through the pneumatic ash-removal system.

The additional three 160 million Btu/hr boilers are kerosene or light oil fired. In the boiler and pump rooms, spare spaces are provided for another 160 million Btu/hr boiler unit.

Each boiler has its own boiler circulating pump, assuring stable operation. The maximum boiler outlet temperature is 220 C (428 F), and the pressure is 327 psig. The boilers are fully automatically controlled.

High-Temperature Water Pumping System

The basic pumping system for the Sapporo project is the so-called two-pump type. Two expansion drums are installed to take up the expansion of the water, and at the same time to achieve steam pressurization. As the heat load will increase year by year, variable speed system circulating pumps are used to provide the most economical operation. The system supply and return temperature are 215 C (419 F) and 120 C (248 F) respectively, and the supply temperature will be changed according to the heat load. In the main system supply and return lines, emergency cut-off valves are installed to isolate the distribution system from the central station.

HIGH-TEMPERATURE WATER DISTRIBUTION SYSTEM

The high-temperature water from the central station is transported to the service area through the distribution piping as shown in Fig. 4. The main distribution pipes are laid under the street at a depth of four to ten ft. The main pipelines leaving the central station have a capacity of 680 million Btu/hr; that is, the maximum capacity of the central station, even though they are installed in the first stage. So it is impossible to avoid the increased initial investment for the pipelines.

The plant is designed for two separate distribution system zones, one having a 16-in. line and the other a 14-in. line from the central station. To reduce the advance investment to the first stage, only the 16-in. line is installed, and the two distribution zones are connected to this line. When the 14-in. line from the station is completed later, the two distribution zones are to be separated by switching the valves in the manhole. The final length of the main distribution pipeline will reach about 40,000 ft.

The underground distribution system consists of supply and return pipes. Each pipe is of the prefabricated metal-cased type. The high-temperature water service pipe, covered with calcium-silicate-type insulation, is installed within a spiral-welded steel conduit. The outer surface of the conduit is coated with coal-tar enamel. Also, a cathodic protection system has been installed. All joints are welded. Service pipe is hydrostatically tested at 850 psig, and X-ray examined. For pipe expansion, U-loops and L-bends are used and no mechanical-type joints are employed.

On the main line of the distribution system manholes are installed as occasion demands, to make possible the insolation of each distribution zone by the valves in the manholes. A branch manhole is installed in each block branched off from the main distribution pipeline.

The high-temperature water is supplied to each user through the branch pipe connections from the branch manholes. The branch pipes are of the same construction as the main distribution piping, and laid under the street or sidewalk. The final length of the branch piping will be about 56,000 ft.

CONVERTER ROOMS

The high-temperature water, supplied to each building through the branch piping, is converted to hot water or steam in the converter room. In the existing buildings, only the existing boilers are replaced with new heat exchangers which generate hot water or steam at the same conditions as that of the existing boilers. Thus, the existing heating installations in the buildings have been kept as they were. In new buildings, which are designed to use the heat exchangers initially, the converter rooms are much smaller than traditional boiler rooms, and cooling can be accomplished by absorption refrigeration using secondary hot water or steam.

The heat exchangers have been standardized for hot water and steam for several capacity ranges. The primary high-temperature water is controlled automatically by the secondary hot water temperature or steam pressure. In each building a Btu meter is installed to meter the consumption of heat.

By the end of 1971, 21 buildings were connected to the district heating system, and the total connected heat load of these buildings is 176 million Btu/hr.

HEAT SERVICE RATE

Similar to the rate charges of public utilities, the heat rate charges of the district heating system should be inexpensive as well as a uniform schedule corresponding to the customer's usage. At the same time, the rates should be sufficient to enable the enterprise to operate as an independent heat supply company. According to a research study of 47 buildings in Sapporo made by Hokkaido University in 1965 and 1967, the heat cost of the existing buildings was determined as follows:

	Dollars per Million Btu(2) 1965	Dollars per Million Btu(2) 1967	Avg Annual Increase Per Cent
Fuel cost	1.306	1.286	− 0.77
Maintenance expenses	0.2155	0.2433	+ 6.5
Personnel expenses	1.763	2.258	+14.0
Total	3.285	3.785	+ 7.6

The above costs are the mean values of the 47 buildings of different sizes. The heat costs in 1967 for the different sizes are as follows:

	Dollars Per Million Btu(2)
Small building heat consumption, under 1,000 x 10^6 Btu/yr	5.45
Large building heat consumption, over 8,000 x 10^6 Btu/yr	2.28
Average building floor area 65,000-107,000 sq ft	2.64

In the above heat costs, the amortization of the installation cost is not included because of the difficulty in obtaining individual installation costs.

The official operation of the Sapporo district heating plant was started on October 1, 1971, and the mean heat service rate is $2.64 per million Btu. This rate would be attractive for the heat customers because the heat cost without amortization was $2.64 per million Btu for the average building, even in 1967.

The heat service rate consists of a demand charge and a consumption charge. The former is calculated based on the installed heat load of each customer. Details of the service rate are as follows:

Demand Charge Per Therm (100,000 Btu/hr)

$18.75 per month for the first 2,000,000 Btu/hr of demand or any portion thereof.
$15.98 per month for the next 4,000,000 Btu/hr of demand.
$13.90 per month for all over 6,000,000 Btu/hr of demand.
(From May 1 to September 30, an 80 per cent discount is allowed on the above charges.)

Consumption Charge Per Million Btu/Month(2)

$2.50	for the first	200
2.22	" " next	320
1.95	" " "	400
1.67	" " "	600
1.39	" " "	1,000
1.11	" " "	1,400
0.834	for all over	3,920

(From May 1 to September 30, a 20 per cent discount is allowed on the above charges.)

The Sapporo district heating project has been a realization of the steady endeavour and decision of the City authorities, with the cooperation of many other persons concerned. This project of unprecedented size has introduced district heating in a densely populated area of an existing city, and it is the first big undertaking of its kind in Japan. The first stage has been completed satisfactorily and now the second stage is proceeding on schedule. The three 160 million Btu/hr oil-fired boilers were scheduled for completion in early 1972.

It is hoped that this project may serve as a model for reducing air pollution in big cities. □

Notes

(1) A method of measuring the extent of atmospheric pollution by sulfur dioxide, known as the lead peroxide (PbO_2) method. The results of this test (sampling method) are reported as milligrams of SO_3 per 100 cm^2 of PbO_2 per day. A value of about 0.03 mg of SO_3 per 100 cm^2/day is considered to be a realistic value for clean air.

(2) The rate of foreign exchange used was the official rate prior to the devaluation of the Dollar (360 Yen to One Dollar).