# DISTRICT HEATING AND COOLING

Vol. 72-No. 4
2nd Quarter 1987

## Development of District Heating in Buffalo

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# Development of District Heating in BUFFALO, NEW YORK

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**Introduction**

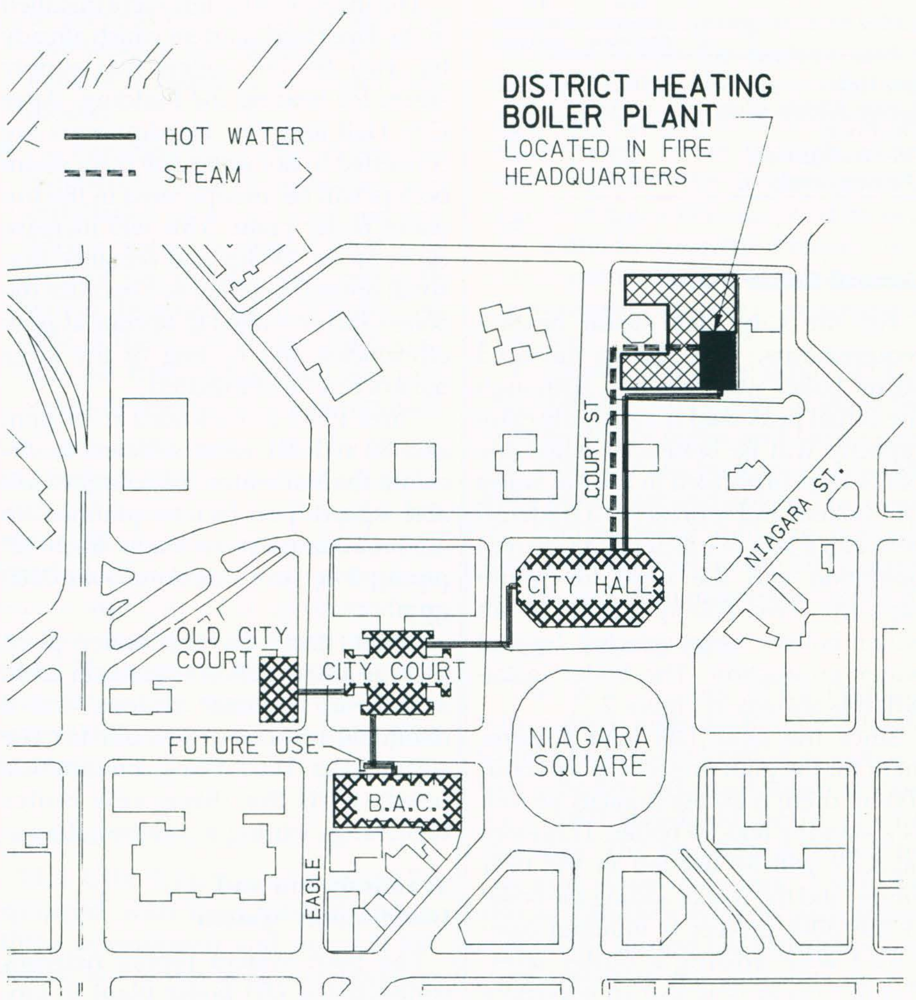
The City of Buffalo, New York, has joined the growing number of communities in the United States that enjoy the advantages of hot water district heating (DH). These advantages include improved air quality, high reliability, stabilized energy costs, lower maintenance and operating costs, reduced space requirements for boiler equipment, and consequently improved urban economic development and commercial revitalization opportunities.

The Buffalo DH project began in August 1983 with a feasibility study financed by the New York State Energy Research and Development Authority. The study indicated that DH is feasible in downtown Buffalo. In April 1986, Development Downtown, Inc. and the Energy Authority, in cooperation with the Mayor's Office and the Department of Public Works, contracted with Burns and Roe Company to design a pilot project for DH development and implementation in downtown Buffalo. The circumstances were favorable for construction because the Buffalo City Hall steam boiler plant required replacement after 60 years of service, and City Hall represents a substantial heating load. Four nearby buildings were also considered as prospective customers for the DH system: the city owned City Court and Fire Headquarters, and the privately owned Buffalo Athletic Club and Old City Court Buildings (Figure 1).

It was decided to install a gas-fired boiler plant in Fire Headquarters to supply heat to the five buildings. Since it was not practical to modify City Hall and Fire Headquarters to accept hot water DH within the short time allowed for construction, a new steam boiler, adaptable for later conversion to hot water, was installed in the Fire Headquarters to supply City Hall. Two new hot water boilers were installed to supply the other buildings in the DH system.

A two-pipe system between Fire Headquarters and City Hall initially will serve the steam requirements of the latter. The pipes are sized to accommodate hot water after conversion of City Hall and can serve as the beginning of the northern branch of the main transmission piping when the DH system is expanded in that direction. Another two-pipe system from Fire Headquarters passes hot water through the basement of City Hall toward the south, where the pilot project customers are located.

**FIGURE 1**
**Pilot Buffalo District Heating System**



Construction of the pilot system began in September 1986 and the system was started up in January 1987. The City of Buffalo and the Energy Authority jointly financed the pilot project with Development Downtown, Inc.

**Building Heat Load Assessments**

Peak heat loads for comfort heating were determined based on the heating degree days for the heating season in which fuel records were obtained, and adjusted to account for site-specific parameters. The comfort heating loads are based on a 3°F outdoor design temperature. Estimated heat usage rates for domestic hot water were assumed constant throughout the year and to occur during normal hours. This internal heat use rate was determined based on fuel consumption in summer months judged to reflect non-comfort heating use throughout the year. The heat loads for the buildings are:

| | Peak Demand (MMBtu/h) | Annual Consumption (MMBtu/yr) |
|---|---|---|
| City Hall | 10 | 19,035 |
| Buffalo Athletic Club | 5.1 | 8,917 |
| City Court | 5 | 6,650 |
| Fire Headquarters | 2.3 | 3,523 |
| Old City Court | 1.5 | 840 |
| | 23.9 | 38,965 |

**Central Boiler Plant**

For the City Hall steam heating requirements, one 500-hp gas-fired steam boiler was selected. Although the actual peak load is lower, the extra capacity will be beneficial when the boiler is incorporated in the hot water DH system and represents a trade-off between a loss in efficiency in current operation and the need for future capacity. Two 800-hp gas-fired hot water boilers were selected for hot water production. The boiler installation is shown in Figure 2.

Since the peak DH load requirement for the pilot project is only about 700-hp there is excess capacity as well as a standby 800-hp boiler. This extra capacity will be needed in the near future, and the cost of adding the boiler to the pilot project is minimal compared with adding a boiler later. Standby capacity is also an important consideration for customers without backup heating system capacity.

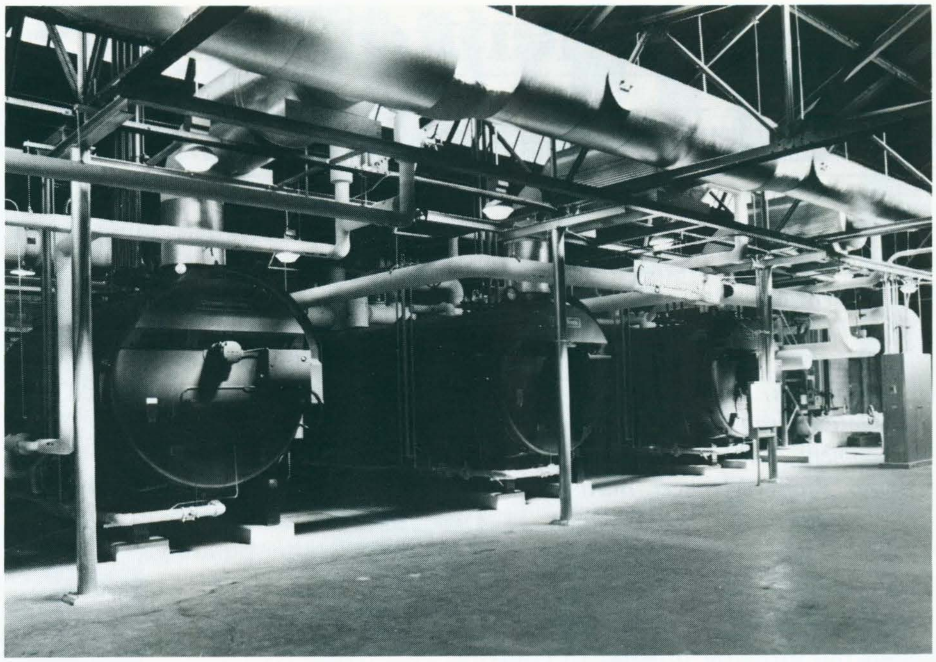


**FIGURE 2**
**Central Boiler Plant Installation**

The three new boilers were installed in the Fire Headquarters which already has two 100-HP boilers that supply steam for heating the building. After City Hall and Fire Headquarters are converted to hot water, the three steam boilers will be incorporated in the hot water boiler plant. This will increase capacity by 700-hp and enhance seasonal operating efficiency because the boilers can be staged to operate at peak efficiencies and cycling of the large boilers can be eliminated.

Three 15-hp pumps rated at 300 gpm and 80 ft-TDH were selected to circulate the hot water. Two larger variable speed pumps are planned to accommodate future loads. Each 12" piping loop can circulate over 3000 gpm.

Other items for the boiler plant include a 4000 gallon expansion tank, a make-up softener system, and a chemical treatment system for the steam boiler. The existing chimney was used, with the three new boiler breechings joining a common flue.

**Transmission and Distribution System**

The pilot system piping network connects the DH boiler plant in Fire Headquarters with City Hall, City Court, Old City Court and the Buffalo Athletic Club buildings. The piping system is designed for peak supply temperature of 250°F and return temperature of 160°F. The supply temperature will vary based upon outdoor air temperature. With an outdoor temperature of 3°F or below, the supply temperature will be 250°F. At an outdoor temperature of 50°F and above, the supply water temperature will be 160°F. The water temperature will vary linearly between 250°F and 160°F when the outdoor temperature is between 3°F and 50°F.

Of the several types of piping system designs available for DH systems, a prefabricated conduit design was selected. It consists of a thin-walled carbon steel carrier pipe, polyurethane insulation, polyethylene casing, and a lead detection system. The conduit is manufactured and shipped to the field in lengths of 40 feet. All fittings and valves are preinsulated. The customer branches are smaller conduits of similar design.

The steel piping system expansion is accommodated by a technique utilizing the mechanical plasticity of the pipe at stress ranges up to the elastic limits. A steel pipe is anchored at one end, and heated from the installation temperature of 60°F to about 160°F. The pipe is then anchored at the opposite end; this does not change the physical state of the pipe, and the tension in the steel is zero. When the temperature of the pipe is increased to the operating temperature of 250°F, a compressive stress is generated in the steal pipe within allowable limits. When the temperature is reduced, a tensile stress within the allowable limits is generated. Special pipe fittings allow the system to be installed in accordance with this procedure. The pilot system transmission and distribution piping is shown in Figure 1. Hot water lines (not shown) run through the basements of City Hall and City Court reduced installation costs significantly since they did not require excavation and site restoration.

### Building Adaptation to Hot Water DH

The rationale for the building modifications can be summarized as follows:

- Plate-type heat exchangers are used to transfer heat from the DH water supply to the building distribution system for comfort heating and internal uses.
- The DH water supply temperature varies according to outdoor temperature from a maximum of 250°F on the design day (3°F outdoor temperature) to approximately 160°F in summer. The building heating system distribution temperature is varied to correspond.
- Building system operating temperatures are selected to optimize the size of system components while providing for the lowest possible DH water return temperatures and maximum differential temperatures.
- Existing comfort heating equipment was evaluated for performance and adaptability when being changed from steam to hot water service.
- Existing building control systems were evaluated to determine appropriateness to the hot water DH system. Controls were revised when necessary.
- The adaptability of building domestic hot water systems to hot water DH was evaluated. These systems were not modified in cases where hot water demands did not justify the change.

As most of the building heating systems were steam, converting heating units to hot water service constituted a significant portion of the overall conversion work. Generally, heating unit modification involved the following:

- Cast-iron and fin-tube radiators required removal of steam traps and installation of thermostatic radiator valves and air vents. Steam supply valves were replaced with thermostatic radiator valves to ensure positive shutoff.
- Cabinet and unit heaters required removal of the steam trap and installation of a balancing valve, air vent, and automatic shutoff valve to prevent circulation through the unit when it is shut off either manually or in response to a room thermostat.
- Air handling units with steam coils required removal of steam traps and installation of an air vent and balancing valve. Steam shutoff and control valves were replaced with valves designed for hot water service. If the coil was exposed to outside air, freeze protection was provided by a small circulation pump.

Only the City Court, Old City Court, and Buffalo Athletic Club are equipped with hot water DH in the pilot hot water DH system. At present, the Fire Headquarters serves only as the heat source and City Hall accommodates the hot water conduits in its basement. The latter buildings will be converted from their steam systems to hot water DH in an expansion of the pilot system.

### City Court

The City Court was originally equipped with four 540-kW boilers (three operational) and one 420-kW electric hot water boiler for building heating. Two 30-kW electric heaters provided domestic hot water. A single plant heat exchanger now provides hot water DH to the building. The building is zoned in two heating sections, one for finned-tubed radiation and the other for reheat coils in the air handling system. Existing building controls are used except for addition of DH control valves which operate with the existing pneumatic control system. For the two separate domestic hot water systems, two heat exchangers, each with a capacity of 104,000 Btu/hr, provide a desirable increase in capacity from the original systems. The existing electric hot water boilers were retired to serve as backup. The existing electric domestic hot water tank heaters were also retired in place. Appropriate DH control and isolation valves were added and a single Btu meter was installed for the building.

### Old City Court

The Old City Court building was a simple conversion to hot water DH, since it had a heat pump system which circulates water for heating and/or cooling. The heat for the system was supplied by a gas fired steam boiler which passes steam through a convertor that heats the circulating water. Domestic hot water, supplied by several individual electric heaters, was not adapted to the DH system because the conversion was not considered cost effective.

The conversion to hot water DH was accomplished by retiring in place the existing steam boiler and steam convertor (for use as a backup) and installing a plate heat exchanger. The existing computerized building controls were used to operate the DH control valves, and a Btu meter was installed.

### Buffalo Athletic Club

This is a 12-story office building which also houses the Buffalo Athletic Club. The present heating system is a two-pipe low pressure steam system with two gas-fired boilers (one standby). The building is heated by cast-iron steam radiators. There are also air handling systems with steam coils on the second and fifth floors and supplementary fan coil units on the upper floors.

The steam distribution system is served by several risers. One 8″ riser supplies steam to a down-feed two-pipe system which serves the 6th through 12th floors. There is also a single condensate return for the upper floors, with condensate collected by the single pipe in a pipe chase located between the 5th and 6th floors. Domestic hot water requirements for a restaurant and the athletic club are supplied by gas-fired heaters.

For building heating, three plate-type heat exchangers are required (one for standby). Each is sized at 2,500,000 Btu/hr because of cost savings offered by manufacturing three identical units. The units are also capable of operating with the steam boilers. Separate domestic hot water heat exchangers, along with separate Btu meters, are installed for the restaurant and the Buffalo Athletic Club domestic water heating systems.

Circulating pumps, expansion tanks, and air removal equipment are provided for each of the two building heating zones, and supply temperature controls are installed. The existing steam boilers are retired to standby capability. The existing condensate collection system is modified to allow for use of the plate heat exchangers for steam-to-hot-water generation as standby.

Individual radiators are modified, including removal of the steam trap internals, installation of a thermostatic radiator valve and installation of an air vent. Steam coils in air-handling equipment are replaced with coils able to accept hot water. Isolation valves are provided on the steam and condensate piping, and the upper loop condensate return line is increased in size to allow hot water circulation.

### System Expansion Strategy

The objective is to develop the system in stages, spreading the capital expenditures out in incremental investments over the development period and allowing the system to generate revenues to offset the capital investments. The first stage of the pilot project was completed at a cost of about $1.7 million. The average annual heat load is expected to be about $39 \times 10^9$ Btu.

The DH boiler plant was designed with sufficient capacity to allow for expansion. One proposed expansion includes installation of service connections and tie-ins for four nearby buildings owned by Erie County. Another proposed expansion is north from City Hall along Delaware Avenue for as much as 2½ miles to Gates Circle where many prospective customers are located. Figure 3 shows these proposed expansions. Expansion to other areas is also feasible and desirable.

### Economic Analysis

The economic analysis for the pilot hot water DH system in Buffalo indicates a payback of about four years. That is sold. For the system expansion, the economic analysis used the required revenue approach to determine the necessary charges for district heating. Annual carrying charges for the DH investment were calculated based on 100% debt financing with a bond rate of 7%. Total system costs were developed and compared with the total quantity of heat to be sold to determine the minimum required charges. The total system costs include fixed expenses, operating expenses, and gross receipt taxes.

Capital costs were derived in 1987 dollars and escalated to the year of expenditure at a rate of 4%. Capital costs include all direct and indirect costs associated with the boiler plant and the transmission and distribution piping systems. Annual carrying charges were based on the assumption that the project would be financed by municipal bonds. The income and property tax rates are 0%, and the insurance rate is 0.5%. Costs were analyzed for a 20-year period.

The operating expenses for the DH system are comprised of pumping, operating and maintenance manpower and material, and gas costs. Pumping costs were calculated using $60/MWh in 1987 dollars, escalated at 4%. Operating and maintenance manpower for the system was estimated at $27,000 per man-year, including overhead and benefits, escalated at 4%. Operating and maintenance material costs were estimated at 1.7% of the capital costs, escalated at 4%. Natural gas cost was assumed to be $3.40/MMBtu escalated at 4%. Calculated on the basis of these assumptions, the unit cost of DH in Buffalo from 1987 through 2006 is shown on Figure 4.

**FIGURE 3**
**Proposed Buffalo District Heating System Expansions**

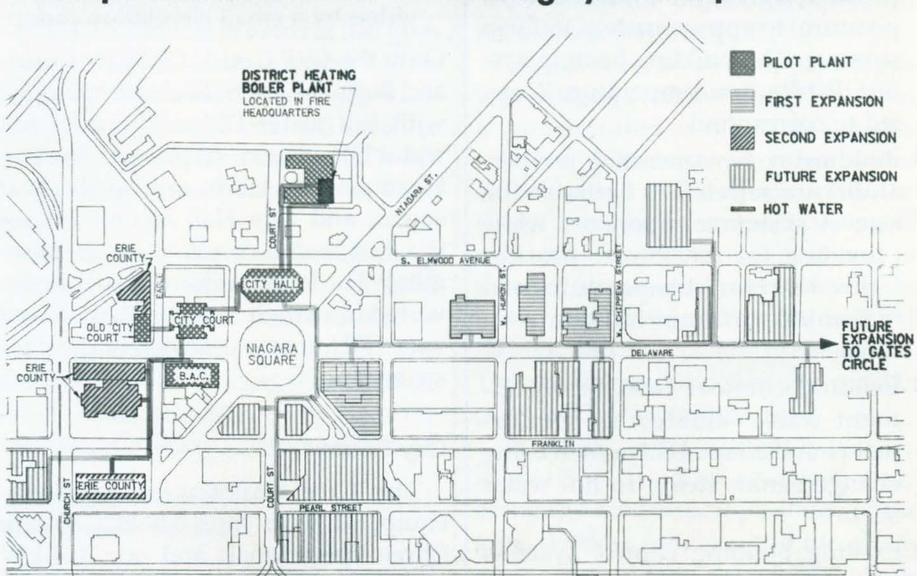
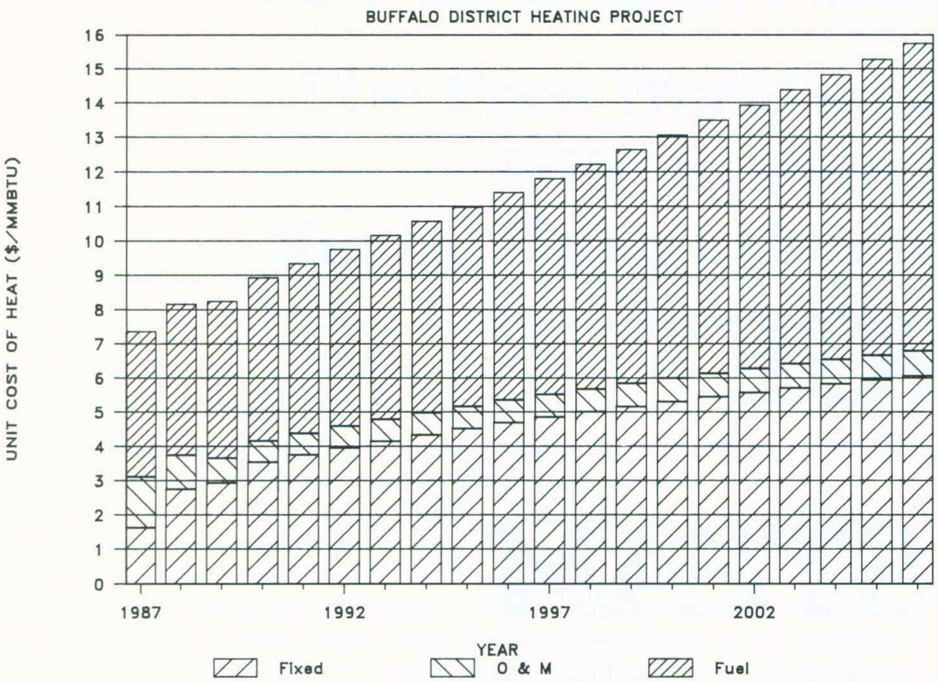


**FIGURE 4**
**Unit Cost of District Heat in Buffalo**




Twenty-year economic analyses were performed for selected customers to determine the annual cash flows and paybacks. Modification costs were actual or estimated. An annual loan payment was determined based on the percentage of the modification cost and the financing terms of a 7% loan for 15 years. The customer's annual energy costs with natural gas were determined based on present annual consumption and average cost of gas escalated at 4% per year. The customer's annual energy costs with DH were determined based on average annual fuel consumption, seasonal boiler efficiency, potential end use energy savings, and the calculated unit cost of DH. Potential end use energy savings from conversion to hot water (eliminating trap losses and decreasing line losses) were included. The analysis demonstrated that the current average cost of heat to the customer is between $10 and $12/MMBtu, and the paybacks for converting to hot water DH would be between 4 and 7 years.

### Conclusion

The new hot water DH system in Buffalo is an example of what can be achieved by a cooperative effort. The state and municipal authorities and the business community, along with competent equipment manufacturers and efficient engineering and construction contractors, accomplished installation of the pilot system within a short period of time. The end users of the hot water DH system are satisfied with the results. Expansion of the system has already been undertaken.


### Acknowledgments

The authors acknowledge the invaluable contributions of the following persons:

City of Buffalo: R. A. O'Hara, Joan Barrali, V. J. Coughlin, David Comerford, Paul Walsh, Frank Bodeckar, Howard Melcher, Edward Standish, Bernard Hoare, Wayne White, Albert Duke

Burns and Roe Company: R. J. Wojcik, Vincent Hunt, Bashir Shaikh, David Gray, Eugene Eng

Joseph David Inc: Mark Jarnot

B. J. Muirhead Co. Inc: Michael Muirhead


IDHCA