BUFFALO DISTRICT HEATING SYSTEM DESIGN AND CONSTRUCTION

New York State Energy Research and Development Authority

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. . . that accelerated development and use within the State of new energy technologies to supplement energy derived from existing sources will promote the State's economic growth, protect its environmental values and be in the best interests of the health and welfare of the State's population . . .

The legislation further outlines the Authority's mission as:

. . . the development and utilization of safe, dependable, renewable and economic energy sources and the conservation of energy and energy resources.

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BUFFALO DISTRICT HEATING SYSTEM
DESIGN AND CONSTRUCTION

Final Report

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ABSTRACT

This report addresses the introduction of district heating in Buffalo, N.Y. from feasibility study to implementation. The reemergence of district heating in the U.S. and associated advantages are reviewed. Advanced piping technology which has enabled district heating to compete economically with alternative technologies is summarized. Identification and analysis of the customer heat load considered in downtown Buffalo for the pilot system and future expansion is discussed. Various options for initiating construction of a district heating system were considered as exemplified by the configuration for the pilot system which was selected to serve five downtown buildings. A conceptual plan is presented which permits the system to expand in an economically viable manner. The report concludes with an economic analysis which simulates the operation and expansion of the system.

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DISTRICT HEATING IN BUFFALO

A phase II study of district heating was authorized in April of 1986 to expand on the previous study and plan for construction of a pilot project. Options for phased implementation were conceived to provide gradual expansion recognizing immediate needs and the future development for the city. The scope of the pilot project included five downtown buildings in the vicinity of Niagara Square. Construction of the pilot system began in September 1986 with startup in January 1987.

DISTRICT HEATING TECHNOLOGY AND ITS ADVANTAGES

District heating has reemerged in this country as a viable energy conservation alternative, having recognized its inherent operating efficiency, advanced technology and new piping products. The benefits of centralized thermal production include reduced installed capacity for the same heating load furnished by individual systems, improved fuel utilization efficiencies, attentive maintenance and safety programs and better adaptability to alternate fuel sources. The enhanced operating efficiencies translate to a favorable environmental impact. The success of hot water district heating has been established through European experience where advanced products have been developed to reduce cost and improve reliability. This is particularly evident in the superiority of underground piping technology which features prefabriated sections, shallow burial, leak detection systems and a technique to control thermal expansion without piping offsets or expansion joints. These features substantially reduce costs associated with excavation, underground interferences and system fabrication in the field.

HEAT LOAD ASSESSMENT

The immediate downtown in the vicinity of Niagara Square was selected for a heat load assessment based on the high thermal load and density in this area. Additional potential customers were identified along Eagle Street and Delaware Avenue from Niagara Square to Gates Circle. Information to support the load analysis was collected primarily by on-site surveys and included fuel consumption, indoor temperature settings and building use characteristics. On-site visits also enabled an evaluation of the compatibility of existing building systems to a hot water district heating system. Steam systems are particularly attractive candidates for conversion due to inherent inefficiencies including steam traps and inflexible control.

IMPLEMENTATION STRATEGY

The overall approach for implementation in Buffalo was based on establishing a pilot system in the vicinity of Niagara Square with provisions to expand along Eagle Street and Delaware Avenue. Five customers anchored the pilot system and were supplied from a new central plant located in the existing Fire Headquarters building. Several options were evaluated for the central plant, however, the selected version demonstrated the most flexibility to meet schedule and future expansion plans.

THE PILOT SYSTEM

To provide rapid implementation, a conventional heating plant consisting of a steam boiler and hot water generators were installed for the pilot project with sufficient capacity to enable expansion of the system. One 500 hp steam boiler was selected to fulfill the heating requirements of City Hall while two 800 hp hot water generators served the other customers. A four-pipe system was installed between Fire Headquarters and City Hall, two pipes carrying steam to the City Hall and two pipes carrying hot water to remaining customers. Distribution piping was routed through basement areas to evade additional excavation and reduce cost.

ECONOMIC ANALYSIS

The economic analysis was performed using the required revenue approach. The magnitude of the economic advantage is measured through the determination of the unit cost of district heating by weighing thermal sales against the annual carrying charge associated with capital investments and the expenditures dedicated to the operation and maintenance of system facilities. The resulting required price is compared to heating costs of individual building owners. After startup of the pilot project in January, 1987, customers connected to the system have experienced significant reductions in energy costs owed to improved operating efficiencies and the lower cost of fuel secured over individual buildings.

Section 1

INTRODUCTION

DISTRICT HEATING IN BUFFALO

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. After completion of the Phase II feasibility assessment which confirmed the applicability of district heating in Buffalo, the project culminated with construction of a pilot system which interconnected five downtown buildings.

The purpose of this report is to present the results of the Phase II study and pilot project for a district heating system in downtown Buffalo, New York. The objectives of the Phase II project included verifying the Phase I district heating study, and expanding this previous work by designing and supervising construction of an early-start district heating pilot project. Also considered in this study was an investigation of future strategies for expansion of district heating in Buffalo.

The Buffalo district heating project began in August 1983 with a feasibility study sponsored by the New York State Energy Research and Development Authority Energy Authority. After the favorable results of this initial study, 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 in April 1986 to expand on the initial findings and plan for implementation of a pilot project.

Options for phased implementation were conceived to provide gradual expansion recognizing immediate needs and the future development picture for the city. An initial development prospect defined the scope of the pilot project and was considered in the vicinity of City Hall, which represented a substantial heating load and required replacement of its central boiler plant after 60 years of service.

Four nearby buildings were also considered as prospective customers for a district heating system including the City-owned New City Court and Fire Headquarters and the privately owned Buffalo Athletic Club and Old City Court Building. Additional expansion strategies were investigated for future construction including incorporation of the three Erie County buildings located along W. Eagle Street and expansion north along Delaware Avenue to coincide with street repairs. Construction of the pilot system began in September 1986 with startup in January 1987.

Section 2

DISTRICT HEATING TECHNOLOGY AND ITS ADVANTAGES

THE REEMERGENCE OF DISTRICT HEATING

District heating is an energy conservation measure characterized by centralized thermal production and distribution to customer buildings in the surrounding area. District heating is noted for increased thermal efficiency which is reflected in energy savings to connected customers. District heating displays other advantages including improved air quality, reduced end-user maintenance costs and elimination of fuel handling and storage. Many cities are pursuing this technology to complement ongoing rehabilitation and modernization efforts of downtown properties.

Historically, district heating has been used since 1877. An inventor in nearby Lockport, New York, designed and constructed the first known commercial district heating system. The system used steam made at a boiler in the inventor's home, and transported the steam to a nearby neighbor. From this modest start, the use of district heating and cooling systems has expanded to include some city wide systems in places such as Moscow, Helsinki, and other European capitals; large systems such as Consolidated Edison's in New York City, and downtown systems in Baltimore, Maryland; Rochester and Jamestown, New York, St. Paul, Minnesota, Trenton, New Jersey and numerous others.

Recently, there has been a renewed interest in district heating in cities in the United States. This is partially due to the increase in fuel costs over the last 10 to 12 years, the positive experience of many European countries, and the use of modern insulating materials in the distribution piping systems. Most of the district heating systems being planned and installed are seriously investigating the use of hot water (150°-250°F) as opposed to steam for distribution. There are technical advantages associated with hot water in terms of reduced heat loss, lower maintenance, and better reliability that generally offset the reduced energy-carrying capacity of the media. Additionally, the piping distribution system for hot water is less costly, easier to install, and requires substantially less maintenance than steam piping systems.

Since World War II, the European countries, particularly in Scandanavia, have refined the use of hot water systems. It has only been in the last few years that utilities and engineers in the United States have begun to adopt these lower temperature systems and technologies. Previously, steam had been the standard in the United States.

Also during the past few years, the federal government has been increasingly conscious of the potential of modern district heating and cooling systems. The federal government's interest had also encouraged the States of New York, Minnesota, and Michigan, among others, to develop state programs to encourage development. The assessment in Buffalo is being sponsored by the Energy Authority under such an assessment program.

ADVANTAGES OF CENTRALIZED THERMAL PRODUCTION

Centralized production of thermal energy has many advantages over individual systems. They include improved fuel utilization efficiencies and more attentive maintenance and safety programs. Installation practices employed in construction of centralized plants contribute to added reliability and long life.

Total installed heating capacity required for the district heating system is less than the summation of peak thermal demands of individual customers. This observation, referred to as load diversity, has been confirmed by operating experience and tends to reduce the installed cost of central equipment to the benefit of connected customers.

Efficient operating performance, however, is the primary characterization of a district heating system. Inefficiency, apart from poor maintenance procedures is attributable to part-load operation, using equipment at conditions other than design. Proper dispatch of centralized plant equipment enables operation over a wide range of load without loss of performance. Reduction in fuel combustion efficiencies is pronounced in individual boiler installations which are subject to cyclic operation, and many experience losses of 15% to 30% below rated design efficiencies. Since the thermal load handled by the DHC system is composed of the requirements of many buildings, a higher, more levelized demand results, reducing the effects of partial loading.

Energy transfer from the district heating system to individual buildings is 100% efficient in that the consumer pays only for the energy extracted from the system. For individual conventional systems, the customer purchases a quantity of energy which exceeds his actual needs by an amount measured by the inefficiency of his equipment. The centralized facility also benefits from a lower initial cost of fuel than can be obtained by individual customers based on large quantities of fuel usage.

Since thermal energy - not fuel - is the commodity being distributed, the district heating system can use more than one fuel source for energy. Boilers, waste heat recovered from other processes, cogeneration (heat recovery from the generation of electricity), incineration of municipal solid waste, or any other method of production of thermal energy can be used at the central plant and provide energy to the distribution system. Coal, oil, natural gas, wood, solar, geothermal and energy from heat pumps can all be used as system inputs. Some are more practical than others depending on availability, environmental considerations, cost of commodities, and cost of conversion to usable energy.

District heating will prosper in the future, offering flexibility in planning and utilization of future available energy supplies. With emphasis on reducing consumption of conventional fuel sources (gas and oil), the practical alternatives include relatively inexpensive coal, surplus heat (industrial and cogenerative) and refuse incineration. Only district heating can be employed to satisfy the thermal requirements of individual buildings while utilizing these sources and attaining environmental acceptance.

ENVIRONMENTAL EFFECT

The environmental impact of a hot water district heating system will be favorable as a result of operating a new central heating source and retiring dispersed heating sources in customer buildings. For Buffalo in particular, natural gas is the primary fuel implying that retirement of any oil-fired boilers in the service area would result in decreased sulfur emissions, notably SO_2. Regardless of fuel, repeated startup and shutdown of individual boilers reduce efficiency as a result of incomplete fuel combustion as fire box temperatures fluctuate. The more efficient and continuous operation of a central district heating plant reduces area carbon monoxide and hydrocarbon emissions characteristic of incomplete combustion.

ADVANCES IN DISTRIBUTION PRACTICES

The success of hot water district heating is readily documented by the modern thermal distribution practices introduced and flourishing in European cities. Generally, the most conspicuous engineering and capital-intensive priority of a district heating system is the installation of the underground piping system. To best serve the economics of a modern hot water heating system, a primary objective is the utilization of low-temperature hot water as the thermal heating medium. This alternative is characterized by a maximum distribution temperature of 250°F permitting the employment of lower cost and very reliable piping components not generally suited to system designs with higher temperature constraints. It allows direct application of underground piping technology successfully implemented in Europe consisting of a thin-wall carbon steel carrier surrounded by polyurethane insulation and encased with a polyethylene jacket. Piping construction features shallow burial, drastically reducing installed cost portraying excellent resistance to groundwater infiltration, the major cause of piping failure.

The effects of accelerated corrosion of carbon steel piping in the 200°F range require that the supply piping be physically protected against outside water contact. Equally important, the pipe insulation must be protected from moisture penetration that would increase the thermal conductivity of the insulation. The insulation must also be protected against mechanical abuse, ultraviolet degradation, erosion and other environmental hazards. The polyurethane foam insulation must be protected against mechanical damage from weathering, handling abuse, field bending, casing pressures, water pressure, saddle-bearing forces, ground movement and damage in storage. The most economic and reliable method for providing the piping system with protection against the above problems is to use a shop-fabricated conduit design with a polyethylene casing.

A shop-fabricated conduit system can be fully shop tested, is less expensive to install, is faster to install causing less disruption of the district heating site, and can be manufactured with a high degree of quality control resulting in a product of high reliability.

Polyethylene is the preferred casing material because it will not corrode in the underground environment, has excellent water-resisting properties, is easy and cost effective to install, and is lightweight and easy to repair if physically damaged.

Polyurethane foam is preferred because of its low thermal conductivity (0.18 Btu/in./hr/ft^2/°F) which provides excellent thermal efficiency of the conduit system. During manufacture of the conduit, the foam is poured between the carrier pipe and the casing in a liquid form and expands to occupy the space between the carrier pipe and the casing. The foam bonds itself to the pipe and casing walls, providing a structurally stable insulation that will not shift, settle or shrink with time to create voids. The conduit requires no special hardware for fastening the insulation in place.

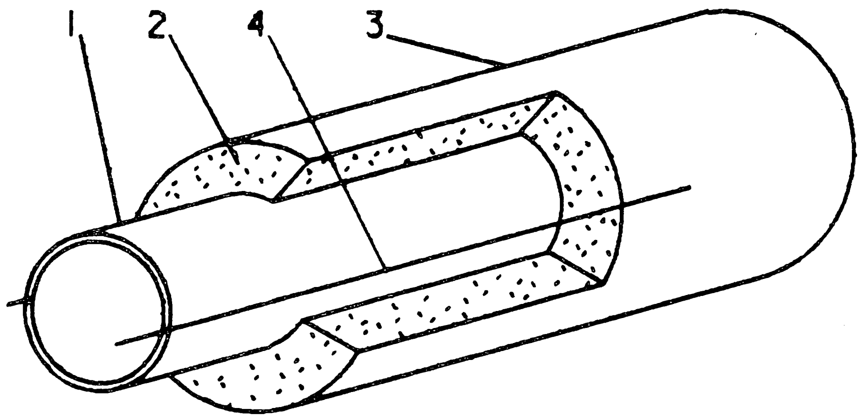
The conduit is manufactured and shipped to the field in lengths of 20 ft. All fittings and valves are also preinsulated and shipped in the form of a finished conduit section. Figure 2-1 shows the conduit design. The small customer branches are conduits of the same design, with flexible copper carrier pipe delivered in coils. Such conduit has the advantages of being flexible and requiring fewer joints.

Once buried, maintenance costs are controlled since the piping system is equipped with an integral leak detection and alarm system which not only detects leakage but enables operators to accurately locate the fault. The alarm system consists of two copper wires molded into the foam insulation during manufacture of the conduit. As the conduit sections are installed, the wires are connected, forming a continuous circuit through the piping system. The copper wires are connected to alarm/control boxes at central or remote locations. The wires carry a low voltage current. When moisture enters the piping system, it completes the circuit between the two wires and triggers an alarm. The alarm system not only detects the leak but, by measuring resistance, locates it.

The proposed technique is to install the supply and return piping side by side in a single trench within street right-of-ways. The trenches will usually be less than 5 feet deep, and require no shoring. The conduit is laid directly in the trench on a 4-inch sand bed. The excavation provides for a clearance of at least 6 inches between conduits and 6 inches between the conduit and trench wall. The conduit is covered with at least 18 inches of homogeneous stone-free sand. The street bed and pavement or sidewalk are installed directly over this sand. Proper backfilling of the conduit is very important. Table 2-1 shows the conduit diameter and required trench size for different size carrier pipes. Figure 2-2 shows the recommended conduit installation for the street and sidewalk installations required in Buffalo.

Piping installation features a technique to compensate for thermal growth of the piping system during operation without expansion loops which substantially reduces costs associated with excavation, underground interferences and piping system fabrication. To minimize the cost of expansion provisions, the steel piping

DISTRICT HEATING CONDUIT



1. CARBON STEEL CARRIER PIPE
2. POLYURETHANE INSULATION
3. POLYETHYLENE CASING
4. ALARM WIRES

Figure 2-1. District Heating Conduit

Table 2-1

CONDUIT INSTALLATION DIMENSIONS

Pipe Size Inches	Conduit Diameter Inches	Installation Envelope (wxh) Inches
3/4	4	24 x 4
1	4	24 x 4
1-1/4	5	26 x 5
1-1/2	5	28 x 5
2	6	30 x 6
2-1/2	6	30 x 6
3	7	32 x 7
4	9	36 x 9
5	10	38 x 10
6	11	40 x 11
8	14	46 x 14
10	18	54 x 18

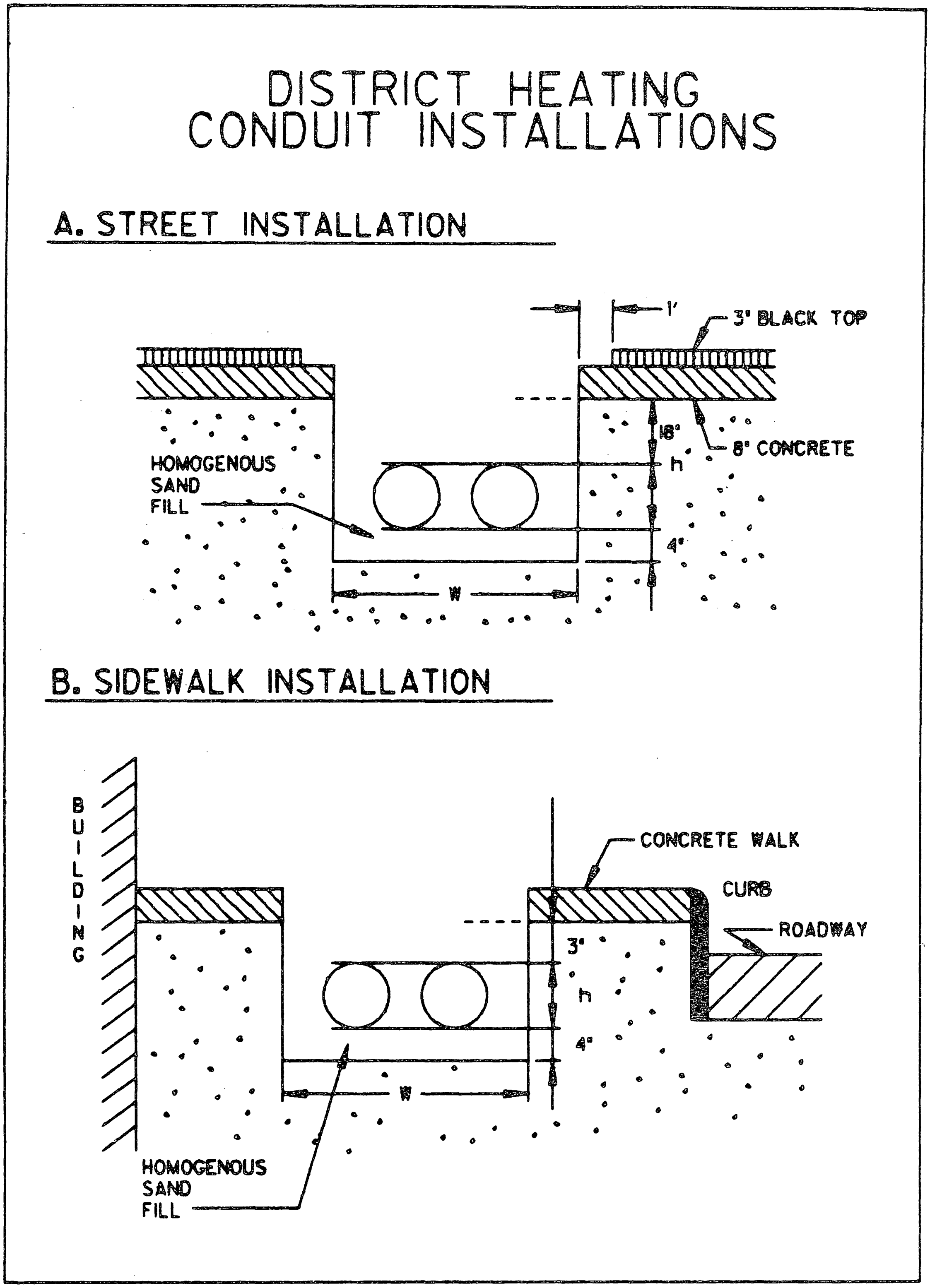


Figure 2-2. District Heating Conduit Installations

system is accommodated by a European technique utilizing the mechanical elasticity of the pipe at stress ranges up to the elastic limits. The steel pipe is anchored at one end, and heated from the installation temperature of 65°F to about 120°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 will be zero. When the temperature of the pipe is increased to the operating temperature of 250°F, a compressive stress will be generated in the steel pipe within allowable structural limits. When the temperature is reduced, a tensile stress within the allowable limits will be generated. Special pipe fittings allow the system to be installed in accordance with this procedure.

The piping system selected for installation in Buffalo was of the latest European design. According to the manufacturer, Buffalo was the first city in which this particular piping system was used in the United States. The system is as described above with the exception of the method in which the joints are covered. The joint cover is referred to as a band muff. The band muff is an outer casing made of the same material as the pipe casing. The band muff is placed over the pipe joint and it is fusion welded to the pipe casing. This ensures a long-lasting and leakproof seal. Insulation is then poured through holes in the band muff which are later sealed.

Section 3

HEAT LOAD ASSESSMENT

SERVICE AREA DEVELOPMENT

A district heating program implies the establishment of a central thermal source distributing heating to customer facilities in a surrounding service area. To properly estimate the size and cost of the central plant and associated distribution system, an evaluation of the thermal load in the designated service area must be conducted. Major factors in a heat load assessment are the area thermal load density and the proximity of the load to the thermal source. Based on the high density of buildings in the immediate downtown, this area was selected for a comprehensive heat load analysis. Thermal loads in the immediate downtown near City Hall had been analyzed in the previous Phase I study and were reviewed as part of this study. Additional customers were identified along Delaware Avenue from Niagara Square to Gates Circle.

Information to support the heat load assessment was obtained primarily by on-site surveys. Customers selected would serve to "anchor" the system, characterized by a thermal usage sufficient to permit the construction of a district heating system in an economically viable fashion. The purpose of the site visits was intended to collect information regarding technical aspects of installed heating systems, fuel consumption and cost and maintenance expenditures. Copies of engineering drawings, where available, were made and equipment/systems data was collected, as necessary, to provide a basis for developing a retrofit design and conversion cost estimate. The following discussion reviews the calculation method employed to determine heating demand from annual fuel consumption and site specific parameters pertinent to Buffalo.

HEATING LOAD CALCULATION METHODOLOGY

Quantifying the heating demand for each building was based primarily on a methodology based upon actual fuel consumption records and weather data. This methodology analyzes fuel consumption data in conjunction with site-specific parameters in lieu of the method requiring detailed information on construction types, U-values, wall and roof areas, fenestration, etc. Site-specific parameters include heating degree days (HDD), number of days in the heating season, and average outdoor air temperature during the heating season. Based on fuel consumption records during a 12 month period, both average annual and peak hourly district heating loads were determined for comfort heating and internal uses such as domestic hot water and process systems.

Of particular importance to the accuracy of the heating load methodology are the following building parameters for the 12 month period in which fuel records have been obtained:

- indoor design temperature setting during normal hours
- indoor design temperature setting during setback hours
- indoor temperature gain due to internal heat sources (lighting, people, equipment, etc.)
- indoor design temperature gain due to internal heat sources during setback hours
- average number of normal hours per week
- average number of setback hours per week

A tabulation of this data for each building is presented in Table 3-1.

Other parameters specific to the individual building operation required for this methodology are:

- Annual fuel consumption dedicated to comfort heating or internal uses such as domestic hot water.

Table 3-1

BUILDING PARAMETERS

Building	Indoor Temp Normal (°F)	Indoor Temp Setback (°F)	Internal Gain Normal (°F)	Internal Gain Setback (°F)	Normal Hours (hr/wk)	Setback Hours (hr/wk)
City Hall	70	60	3	0	50	118
New City Court	70	60	4	0	50	118
Buffalo Athletic Club	70	60	5	0	50	118
Old City Court	70	60	0	0	50	118
Fire Headquarters	70	65	1	0	70	98
Rath Building (Erie County)	68	50	2	1	50	118
25 Delaware Avenue and Old County Hall (Erie County)	68	68	2	0	50	118
120/134 W. Eagle Street (Erie County)	68	68	1	0	50	118

o Annual boiler/system efficiency which is estimated based on age, heating medium, distribution design and load variation. It is an overall annual efficiency accounting for losses associated with cyclic boiler operation during below-peak heating modes and/or summer operation.

The comfort heating loads determined for all buildings are based on a 3°F outdoor design temperature which is conservative since ASHRAE defines the design temperature as 6°F for Buffalo, N.Y. Estimated heat usage rates for purposes other than comfort heating (i.e., domestic hot water, process) were assumed constant throughout the year and for the most part occur during normal hours only. This internal heat use rate was determined based on fuel consumption in summer months judged to reflect non-comfort heating use throughout the year. Peak heat loads for comfort heating were determined based on knowing the heating degree days for the heating season in which fuel records have been obtained with adjustments to account for the site-specific parameters noted above. Results of this analysis for buildings in the pilot project area are listed in Table 3-2.

Table 3-2

BUILDING HEAT LOAD ASSESSMENT SUMMARY

Building	Peak Heat Demand (MMBtu/hr)	Annual Heat Load (MMBTU/hr)
City Hall	10	19,000
Buffalo Athletic Club	5.1	8,900
New City Court	5	6,700
Fire Headquarters	2.3	3,500
Old City Court	1.5	840
Rath Building (Erie County)	6.7	9,900
25 Delaware Avenue and Old County Hall (Erie County)	4.2	9,400
120/134 W. Eagle St. (Erie County)	10.7	22,200
Total	45.5	80,440

BUILDING HEATING SYSTEM RETROFIT ANALYSIS

The topic of heat load has been discussed in the generic sense, customers being end users of a district heating product without distinguishing characteristics of individual building systems. It must be recognized that buildings include a variety of designs, produce different thermal media and have distinct thermal requirements, all of which impact the conversion to district heating. This section has been included in the report to indicate some of the considerations pertaining to customer retrofits to district heating. Descriptions of existing building heating systems as well as the conceptual retrofit designs for the buildings incorporated in the pilot project and those of Erie County have been included in Appendix A.

Having selected low-temperature hot water as the heating medium for the district heating system, modifications to customer heating systems are naturally required to properly utilize the product.

The adaptability of buildings' internal process and domestic hot water systems to hot water district heating is evaluated. These systems remain in their present configuration in cases such as when minimal hot water demands do not justify associated retrofit costs (i.e., heat exchanger, extensive piping runs), or when process system requirements cannot be met due to high temperature or extensive retrofit requirements.

Due to the high temperatures and pressures in the district heating system distribution network, plate-type heat exchanger(s) are utilized in each building to safely transfer heat from the district heating water supply to the building distribution system for comfort heating and internal uses (domestic hot water, process, etc.). Existing control methods are evaluated for all building systems to determine appropriateness to the hot water district heating system. Controls are revised when necessary to optimize system temperatures and to adapt to the hot water district heating operating characteristics. Building systems' operating temperatures are selected to optimize size of system components while providing for the lowest possible district heating water return temperatures and maximum differential temperatures. The district heating water supply temperature varies according to outdoor temperature from a maximum of 250°F on the design day (3°F outdoor temperature) to approximately 170°F during the summer months. Consequently, the building heating system distribution temperature must also be reset from the outdoor temperature to satisfy the heating load as it varies with outdoor temperature.

Although steam systems command a high retrofit cost relative to other system types, several incentives encourage building owners to convert to hot water for long-term benefits. Energy savings are the primary advantage, recovered from the inherent inefficiencies in steam systems, particularly associated with trap losses and inflexible control. Faulty steam traps waste a substantial quantity of steam. Passing directly into the condensate system, live steam liberates its latent heat (which accounts for about 80% of the steam's energy content) without effective utilization. Obviously any steam leaks to the surroundings are detrimental, since in addition to unused latent heat, makeup water to the boiler must be chemically treated and preheated to the steam temperature in the boiler.

Steam boilers operate by maintaining a pre-set pressure (and a corresponding temperature) and consequently are not flexible to adjust sendout temperature as a function of ambient conditions. With hot water heating, an indoor-outdoor temperature controller resets water temperature to match seasonal variations in heating demand. This temperature modulation minimizes losses and provides more uniform heating to building areas, making people feel more comfortable as well as saving energy.

Existing central and terminal comfort heating equipment are evaluated for performance and adaptability when being changed from steam to hot water service. Since the majority of present building heating systems are steam, converting terminal heating units to hot water service constitutes a significant portion of the overall conversion work. Generally, terminal unit retrofits involve removal of steam-related accessories which interfere with continuous water circulation. Cast iron and fin-tube radiators require removal of steam traps and the installation of a thermostatic radiator valve and air vent. Existing steam supply valves should also be replaced with thermostatic radiator valves to ensure positive shutoff. Cabinet and unit heaters require removal of the steam trap and installation of a balancing valve, air vent, and an automatic shutoff valve where not previously installed. The automatic shutoff valve prevents circulation through the unit when it is shut off either manually or in response to room thermostat. Air handling units with steam coils require removal of steam traps and installation of an air vent and balancing valve. Existing steam shutoff and control valves should be replaced with valves designed for hot water service. In addition, if the coil is subject to outside air, freeze protection must be provided with a small circulation pump. If the coil is not serpentine then the performance with hot water will probably not be adequate and coil replacement is necessary.

Section 4

IMPLEMENTATION STRATEGY

THE STRATEGY OF PHASED EXPANSION

This section presents the implementation strategy employed in Buffalo for district heating development. The overall approach is based on a system targeted for the Niagara Square vicinity, characterized by a high concentration of thermal load. Several options which were available for the design and construction of the district heating boiler plant and distribution system shall be reviewed. All the options considered by Burns and Roe were based on construction of an early-start pilot project in the area of Niagara Square. System development relied on installation of conventional boilers since the lower installed cost, rapid erection schedule and high degree of reliability suited the immediate requirements of the service area. Five customers came to represent the "anchors" for the pilot system and include City Hall, Buffalo Athletic Club, Old City Court, New City Court and Fire Headquarters. All the options considered require installation of boilers in Fire Headquarters selected for its proximity to Niagara Square and interior space available for such a boiler plant. The building is also owned by the City of Buffalo, owners of the district heating system.

To provide rapid implementation of a pilot system, a conventional heating plant consisting of boilers exhibit simplicity of design and installation in contrast to more elaborate cogeneration options which require a greater degree of design and political effort. Since the proposed plant incorporates conventional technologies and use fuel (oil/gas) available to individual customers, this option poses no unusual regulatory or environmental constraints which could represent scheduling delays. This short-term planning suggests establishment of a boiler plant for a limited group of facilities. A gradual expansion through interconnection of additional buildings is proposed to difuse the impact of new capital investments over several years.

A gradual expansion has several advantages. Planned expansion insures customer confidence in the system as it grows which will produce a reputation consistent with a sound operating record and continued energy savings. With a large integrated system established, construction of innovative central sources such as a cogeneration plant would enhance operating strategies and flexibility. The original equipment installed would be retained within the system to serve as peaking stations, satisfying thermal requirements above base load operation of a cogeneration facility. In addition, they would reinforce the reliability of the overall system by providing a readily available source of backup energy.

OPTIONS FOR PILOT SYSTEM DEVELOPMENT

Selection of a design option had to recognize the constraints imposed by schedule and available funding. Funding had to be allocated among the construction priorities of the district heating system including central boiler plant, distribution piping and building retrofits. Three primary design options were considered for the project which proposed alternatives for each engineering aspect of district heating development to obtain the greatest advantage for short and long term planning strategies. Since schedule was of prime importance, the engineering effort had to be limited in the initial construction phase while preserving the technical principles which mark the advantages of hot water district heating. Each option represents an attempt to negotiate these project constraints to achieve a meaningful solution to balance short term needs with flexibility for future operating strategies and expansion. The third option was ultimately selected, demonstrating the best combination of technical innovations to meet these objectives.

Option #1

Option #1 considers the distribution of only hot water which is preferred since transmission costs are reduced and there are fewer requirements associated with corrosion and chemical treatment as compared with a steam system. It should be noted that steam to hot water building retrofits would be required for City Hall, the Buffalo Athletic Club, and the Old Court buildings. Initial estimates included two 800 hp hot water boilers, one main piping loop for hot water with 12" from Fire Headquarters to City Hall and 10" from City Hall to the balance of the customers. This option was not selected because of the time constraints required to perform the steam to hot water retrofit of City Hall. This retrofit would require several weeks to hydrotest and collect data, more time to design the system and finally construct the conversion.

Option #2

Option #2 considers supplying steam from Fire Headquarters to City Hall. Some of this steam would be used for space heating and domestic hot water production at City Hall. Steam also would be converted to hot water in City Hall and distributed to the other pilot project buildings. Preliminary analysis showed that two 800 hp steam boilers are required along with the necessary chemical treatment and condensate collection systems. Other major pieces of equipment required will be an oxygen elimination system, an expansion tank and water circulating pumps. Ten-inch piping was selected for the hot water circulating pipes. A 12" pipe was selected for the steam distribution and a 4" pipe for condensate return. It should be noted that the steam supply piping was sized based on 150 lb steam. This option was rejected since future expansion would be limited by the steam supply pipe size and condensate return pipe size.

Option #3

The third alternative included the installation of both steam and hot water boilers in Fire Headquarters. This requires the installation of both steam and hot water piping to City Hall and only hot water piping to the other pilot project buildings.

This option is similar to option #2 except that hot water is generated and distributed from the Fire Headquarters rather than at City Hall and each heating medium is independent. This alternative appears attractive and is more flexible than option #2 because hot water is generated and distributed from a system entirely independent from the steam system.

This option meets the scheduling requirements of the pilot project by avoiding the immediate hot water conversion of City Hall and facilitating expansion of the system in the future by consolidating thermal distribution from Fire Headquarters. A detailed discussion of this option and the pilot system is the topic of Section 5.

SYSTEM GROWTH AFTER THE PILOT SYSTEM

Excess boiler capacity installed at Fire Headquarters during pilot system develoment shall enable expansion of the system in the first phases without additional investment in the central boiler plant.

STEAM TO HOT WATER CONVERSION OF CITY HALL AND FIRE HEADQUARTERS

The first expansion calls for converting City Hall and Fire Headquarters from steam to hot water heating. When City Hall is converted to hot water heating, the new 500 hp steam boiler will be converted to a hot water boiler and incorporated into the district hot water system. The 500 hp steam boiler has been purchased with appropriate connections to allow for conversion to hot water generation. The existing boiler room steam piping will be integrated into the hot water system by increasing the condensate line capacity and elimination of steam traps. Also, the steam piping will be tied into the hot water circulating system through a common header.

The condensate inlet to the boiler will be capped off and the hot water return will be piped into the top of the boiler which will incorporate a blend pump. The existing flue piping and economizer will be used, but the condensate tank will be abandoned.

It is also anticipated that the Fire Headquarters building will be converted from steam to hot water heating in conjunction with the City Hall conversion to hot water heating. The Fire Headquarters is currently heated by two new 100 hp steam boilers. After the Fire Headquarters is supplied by district heating these boilers will be available for incorporation into the district heating system. Based upon our preliminary investigation these boilers cannot be converted to hot water production and meet our pressure requirements safely. In order to incorporate the Fire Headquarters boilers into the district heating system it will be necessary to use a steam convertor.

Final engineering design work and hydrotesting will have to be performed before the conversion of City Hall, the Fire Headquarters and the steam distribution system to hot water service can be accomplished.

WEST EAGLE STREET EXPANSION

Additional district heating expansion includes incorporation of the three Erie County buildings located along W. Eagle Street into the hot water district heating system. Heat load data collected for these buildings are shown in Table 3-2. The average annual heat load for major "anchor" buildings at this stage of expansion is expected at approximately 80,000 MMBtu.

DELAWARE AVENUE EXPANSION

This expansion regards construction of a new distribution line north approximately 3/4 mile along Delaware Avenue and interconnected to piping emanating from the central heating plant. This option is particularly attractive since repair to underground utilities shall necessitate street excavations presenting a unique opportunity to implant district heating piping during the scheduled time period. The expected minimum annual heat load for this expansion is expected to be an additional 30,000 MMBtu/yr in the first year, interconnecting major anchor customers. Other loads will be added along this route over time and may include expansion further north along Delaware Avenue to Gates Circle which is approximately 2-1/2 miles from City Hall.

The pilot system and future phases of district heating development are illustrated in Figure 4-1. Corresponding numerical information is summarized in Table 4-1, indicating growth of the thermal load and accompanying expansion of the central heat source. It should be recognized that substantial system growth can occur with the excess capacity already constructed at the pilot project's central plant. Additional thermal capacity is based on satisfying an expanding demand while maintaining adequate backup capacity. When analyzing the cumulative peak heat load of customers, it has been demonstrated by experience that the summation of individual peak loads, tends to overestimate the peak capacity required at the central plant. A simple summation implies that all peaks occur simultaneously; however, in practice, there is a diversity between the occurrence of peaks. A diversity factor is generally applied to the total load to more accurately predict system behavior.

This section presented a strategy of phased implementation of a district heating system characterized by expansion and integration of the service area over a period of several years. It must be emphasized that the strategy presented here is only one possible scenario. Depending on the interest exhibited by potential customers, development could proceed differently. While other alternatives to continue district heating development are conceivable, the technical "logic" established through this discussion is applicable regardless of where implementation is actually pursued.

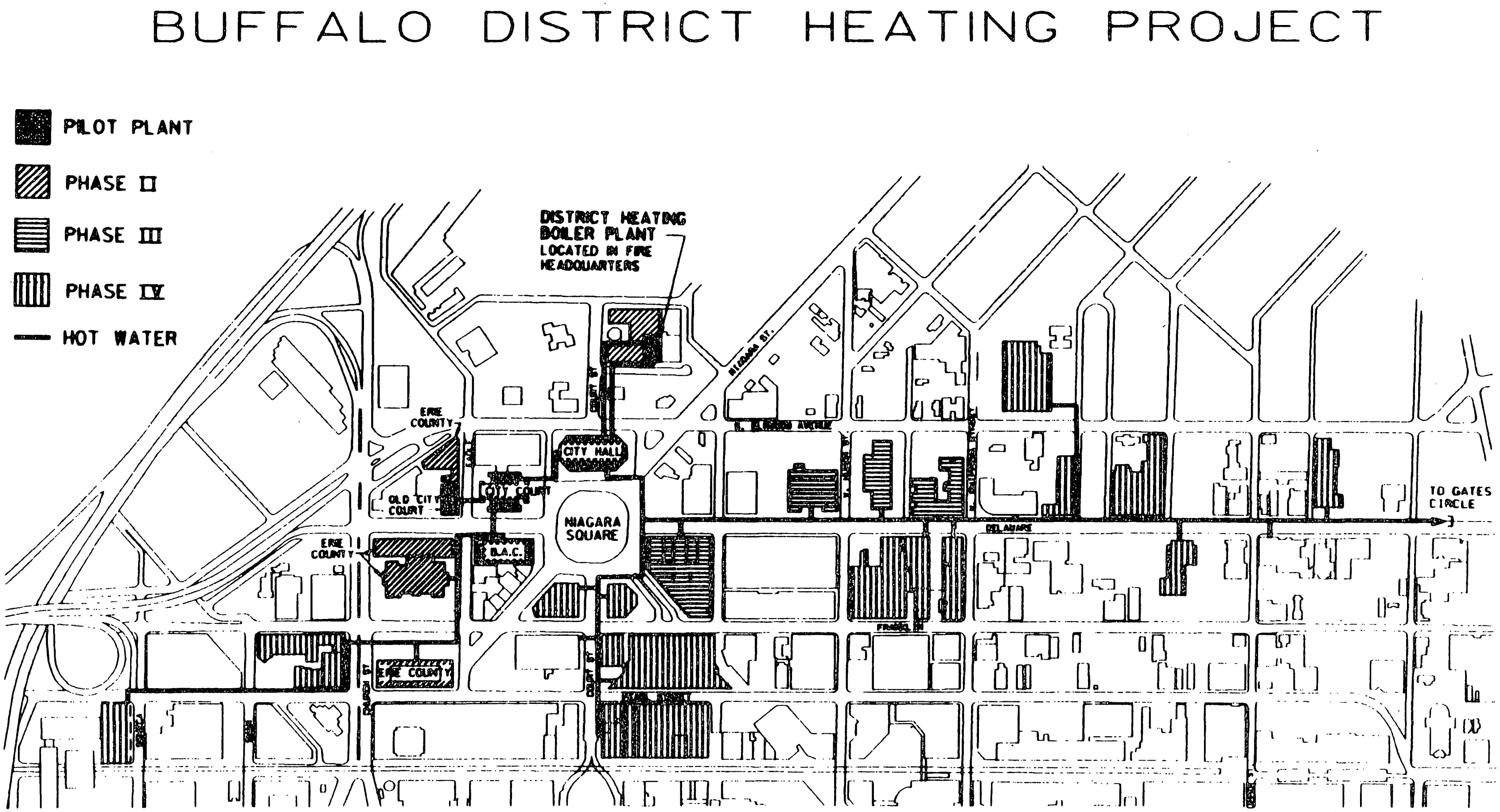


Figure 4-1. Phased Development of District Heating in Buffalo

Table 4-1

DISTRICT HEATING IMPLEMENTATION PLAN

Phase	System Heat Load (MMBtu/hr)	Diversified Heat Load (MMBtu/hr)	Installed Capacity (MMBtu/hr)	Annual Heat Load (MMBtu)
Pilot Project	24	19	70 (Pilot)	39,000
Phase II - West Eagle Street	56	48	70 7 (Fire HQ) 77	90,000
Phase II - Delaware Ave.	81	69	77 27 (New) 104	131,000
Phase IV - Delaware Ave. Extension	100	85	104 27 (New) 131	160,000

Section 5

THE PILOT SYSTEM

Central plant design for the pilot system was formalized having selected Option #3 for construction. After assessing the specific heating requirements of the customers comprising the pilot system, calculations proceeded to size major plant components. Compilation of heating load information permitted determination of annual and peak system loads which would be imposed on the central plant. Independent systems were devised for export of the two thermal media, steam and hot water, from the plant. One 500 hp gas-fired steam boiler was selected to fulfill the heating requirements of City Hall. The new boiler supplies 50 psig steam, imitating the existing installation at City Hall. Two 800 hp gas-fired hot water generators were chosen for hot water distribution to the remaining customers including the Buffalo Athletic Club and New and Old City Court buildings. Fire Headquarters would continue to utilize steam heating supplied by their two existing 100 hp boilers. Excess thermal capacity was designed into the plant for future expansion. Newly installed capacity totals 2100 hp while peak simultaneous system demand of the pilot system is approximately 700 hp.

A four-pipe system would be installed between Fire Headquarters and City Hall, two pipes dedicated solely to the City Hall steam requirements while the other two supplied hot water to remaining customers. Distribution piping was routed through basement areas of City Hall and City Court to evade additional street excavation and reduce cost.

Anticipating conversion of City Hall to hot water, the new steam and condensate lines which would supply City Hall from Fire Headquarters were recognized as future carriers of hot water. This eventuality was considered at the design stage and two 12-inch lines were provided to initially supply steam and return condensate with the understanding of future use as a hot water distribution header for City Hall and other expansion activity.

The hot water district heating piping size was determined by a heat load reflecting a fully developed system and the water temperature drop in the system. A large temperature drop between supply and return lines reduces the flow rate of circulating water, piping size and pumping power. The Buffalo system is designed for a peak supply temperature of 250°F and return temperature of 140°F. Control of the heat supply is achieved with a central temperature control system which varys the temperature in the supply network at the central plant as a function of outdoor temperature.

With an outdoor temperature of 3°F or below, the supply temperature will be 250°F. At an outdoor temperature of 40°F and above, the supply water temperature will be 170°F. The supply water temperature will vary linearly between 250°F and 170°F when the outdoor temperature is between 3°F and 40°F, as shown in Figure 5-1.

Three 15 hp pumps rated at 300 gpm and 80 ft head were selected to circulate the hot water in the pilot system. Two larger variable-speed pumps are planned to accommodate future loads. Other items which comprise the boiler plant include a 4,000-gallon expansion tank, a make-up water softener system, and a chemical treatment system for the steam boiler. The breechings of the new boilers were combined to a common flue employing the existing chimney.

A cost breakdown which reflects figures used during the actual construction of the pilot project is presented in Table 5-1.

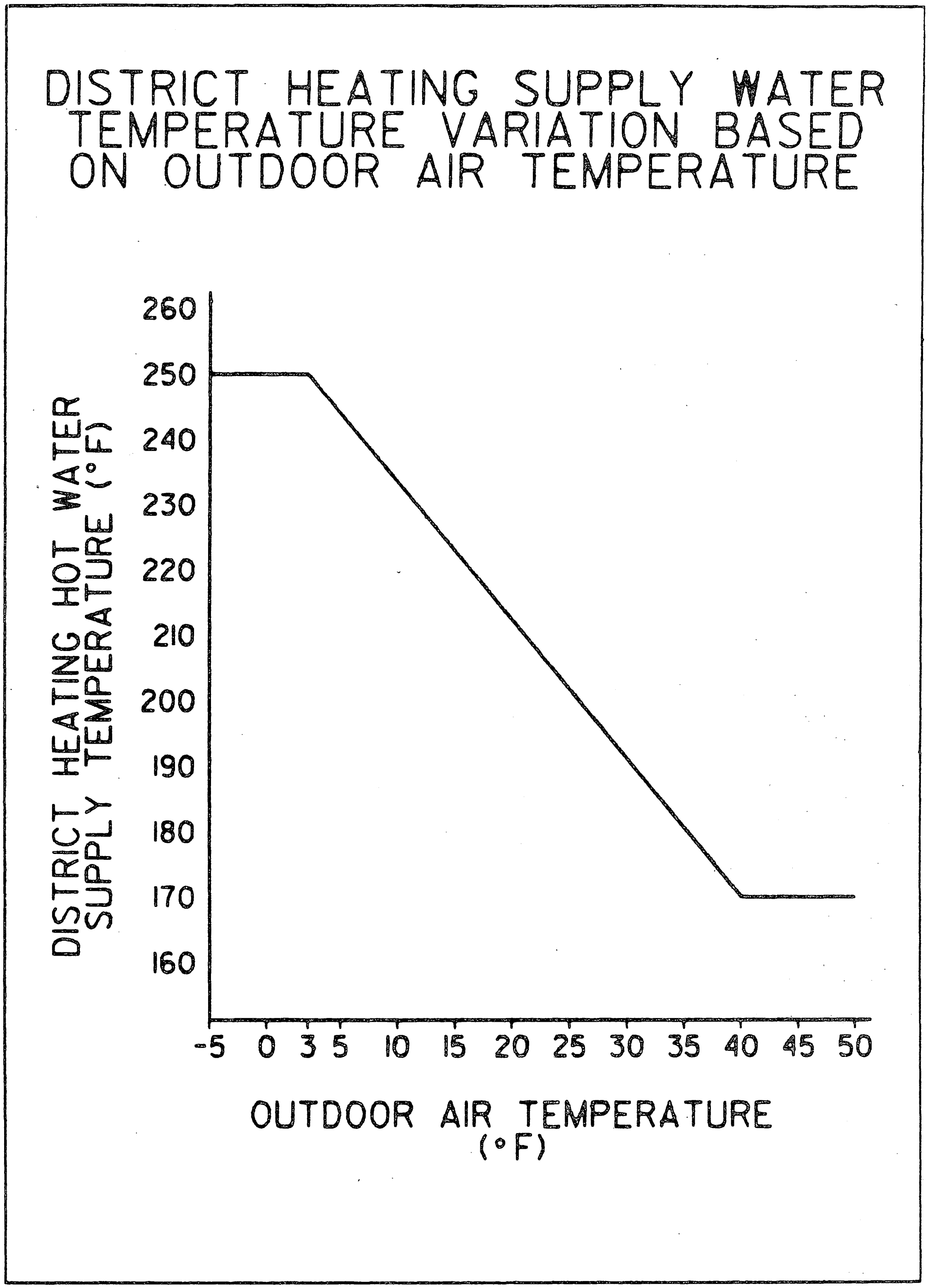


Figure 5-1. District Heating Supply Water Temperature Variation Based on Outdoor Air Temperature

Table 5-1

PILOT SYSTEM COST ESTIMATE

District Heating Central Plant	Approximate Cost	
Two (2) 800 HP Hot Water Generators	$165,000	
One (1) 500 HP Steam Boiler	$ 70,000	
Three (3) 15 HP District Heating Pumps	$ 13,000	
One (1) 4000-Gallon Expansion Tank with nitrogen system	$ 8,000	
One (1) Water Softener Package	$ 5,000	
Central Control System	$ 12,000	
Electrical Service	$ 70,000	
Miscellaneous Plant Equipment (including receiver tank, misc. valves, controls and platforms)	$ 30,000	
Mechanical Contractor (installation including balance of plant equipment and components)	$330,000	
City of Buffalo (masonry and electrical work)	$100,000	
Subtotal		$803,000
Distribution		
Underground Piping	$130,000	
Btu Meters	$ 8,000	
Mechanical Contractor (installation including interconnecting piping, misc. equipment and components)	$460,000	
Subtotal		$598,000
Grand Total		$1,401,000

Section 6

ECONOMIC ANALYSIS

The basis for proceeding with any district heating project is the comparison of anticipated system costs versus expected revenues and the subsequent margin between a reasonable value for the district service and the cost which can be achieved by building owners through individual systems. The magnitude of the economic advantage is measured through the determination of the unit cost of saleable district heating by weighing thermal sales against the annual carrying charge associated with capital investments and the expenditures dedicated to the operation and maintenance of system facilities. The analysis uses the required revenue approach to determine the necessary charges for district heating. Total system costs are comprised of fixed and operating expenses. System revenues achieved through the sale of the thermal product must breakeven or exceed these costs for profitable operation. The required price, calculated from this procedure is then directly compared to costs of heating experienced by individual building owners, the energy savings devoted to the payback of incurred retrofit costs during building conversions to district heating.

The economic analysis of hot water district heating in Buffalo was performed from the viewpoint of ownership by the City of Buffalo. Consequently, the annual carrying charges were derived recognizing the tax status and financing available to a municipality. Funding for the project was based on 100% debt financing with a municipal bond rate of 7%. Capital costs were estimated in 1987 dollars and then escalated to the year of expenditure at a general escalation rate of 4%. The capital costs include all direct and indirect costs associated with the central heating plant retrofit and the piping system. Other parameters which were employed in the carrying charge computation include a zero income and property tax rate, an insurance rate of 0.5% and a 30-year book life.

While this accounts for the capital component of total system costs through calculation of the annual carrying charge, annual operating expenses must be added to complete the analysis. The operating expenses for the district system are comprised of fuel and electric consumption costs, pumping costs, operating and maintenance manpower and operating and maintenance materials. Refer to Table 6-1 for a tabulation of equipment operating parameters employed during the evaluation of annual expenditures. For the annual heating loads anticipated for the system, estimated quantities and costs of fuel consumed by hot water generators and steam generators and electricity consumed by auxiliaries and district heating pumps were based on an estimate of annual operating hours. Annual maintenance material is assumed at 1.7% of the initial capital investment. A general escalation of 4% is applied to all costs.

The summation of the operating expenses devoted to fuel, electricity, and maintenance materials and labor plus the carrying charge for the capital investment amounts to the total revenues required to support the particular system. The unit cost of district heating is derived by dividing total required revenues by the annual heat load anticipated for each phase of expansion and represents breakeven operation. The calculated unit cost is then compared to energy expenses (fuel and maintenance) incurred by the customer. Results are presented in Table 6-2. After startup of the pilot project as of January 1987, customers connected to the system have experienced significant reductions in energy cost in the range of 20 to 40 percent. This reflects the improved operating efficiency of the central boiler plant and the lower cost of fuel secured over individual buildings.

Table 6-1

DISTRICT HEATING SYSTEM OPERATING PARAMETERS

	Pilot Project	Phase II	Phase III	Phase IV
Total Peak Customer Demand Heating (MMBtu/hr)	24	56	81	100
Total Annual Customer Demand Heating (MMBtu)	39,000	90,000	131,000	160,000
Total Annual Energy Input				
Natural Gas-Boilers (MMBtu)	46,000	107,000	156,000	190,000
Electricity-Pumps (MWhr)	50	75	100	125
Total Annual O&M Expenses				
Assumed Labor Force (men)	1	2	2	2
Materials (% of Capital Cost)	1.7	1.7	1.7	1.7

Table 6-2

DISTRICT HEATING SYSTEM INVESTMENT SUMMARY

Phase	Expansion	Central Plant	Underground Piping	Total
I	Pilot Project	$800,000	$600,000	$1,400,000
II	Eagle Street	-	$400,000	$400,000
III	Delaware Ave. to Chippewa St.	$300,000	$400,000	$700,000
IV	Delaware Ave. to Gates Circle	$300,000	$1,300,000	$1,600,000

Table 6-3 (Sh. 1 of 6)

ECONOMIC ANALYSIS

BUFFALO DISTRICT HEATING PROJECT

ANNUAL CARRYING CHARGES

Investment	1
Initial Operation	1987
Cost Basis	1987
Capital Cost - $1000	$1,100
Gen. Escalation -	4.0%
Escalation - $1000	0
AFDC - $1000	0
Total Cost - $1000	1100
Start of Evaluation	1987

Economic Factors

Preferred Stock Ratio	0	Book Life - Yrs	30
Return on Preferred Stock - %	0	Income Tax Rate - %	0
Common Stock Ratio	0	Tax Credit - %	0
Return on Common Stock - %	0	Tax Life - Yrs	30
Debt Ratio	1	Accelerated Tax Depreciation	0
Debt Cost - %	7	Property Tax - %	0
		Insurance Rate - %	0.5
Weighted Cost of Capital - %	7.00		

Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
Remaining Book Value	1100	1063	1027	990	953	917	880	843	807	770
Return on Preferred Stock	0	0	0	0	0	0	0	0	0	0
Return on Common Stock	0	0	0	0	0	0	0	0	0	0
Interest	77	74	72	69	67	64	62	59	56	54
Book Depreciation	37	37	37	37	37	37	37	37	37	37
Tax Depreciation	403	403	403	403	403	403	403	403	403	403
Income Taxes	0	0	0	0	0	0	0	0	0	0
Deferred Taxes	0	0	0	0	0	0	0	0	0	0
Property Tax	0	0	0	0	0	0	0	0	0	0
Insurance	6	6	6	6	6	6	6	6	6	6
Annual Carrying Charges	119	117	114	111	109	106	104	101	99	96

Year	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Remaining Book Value	733	697	660	623	587	550	513	477	440	403
Return on Preferred Stock	0	0	0	0	0	0	0	0	0	0
Return on Common Stock	0	0	0	0	0	0	0	0	0	0
Interest	51	49	46	44	41	39	36	33	31	28
Book Depreciation	37	37	37	37	37	37	37	37	37	37
Tax Depreciation	403	403	403	403	403	403	403	403	403	403
Income Taxes	0	0	0	0	0	0	0	0	0	0
Deferred Taxes	0	0	0	0	0	0	0	0	0	0
Property Tax	0	0	0	0	0	0	0	0	0	0
Insurance	6	6	6	6	6	6	6	6	6	6
Annual Carrying Charges	94	91	88	86	83	81	78	76	73	70

Table 6-3 (Sh. 2 of 6)

ECONOMIC ANALYSIS

BUFFALO DISTRICT HEATING PROJECT

ANNUAL CARRYING CHARGES

Investment	2
Initial Operation	1988
Cost Basis	1987
Capital Cost - $1000	$400
Gen. Escalation -	4.0%
Escalation - $1000	0
AFDC - $1000	0
Total Cost - $1000	400
Start of Evaluation	1987

Economic Factors

Preferred Stock Ratio	0	Book Life - Yrs	30
Return on Preferred Stock - %	0	Income Tax Rate - %	0
Common Stock Ratio	0	Tax Credit - %	0
Return on Common Stock - %	0	Tax Life - Yrs	30
Debt Ratio	1	Accelerated Tax Depreciation	0
Debt Cost - %	7	Property Tax - %	0
		Insurance Rate - %	0.5
Weighted Cost of Capital - %	7.00		

Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
Remaining Book Value	0	400	387	373	360	347	333	320	307	293
Return on Preferred Stock	0	0	0	0	0	0	0	0	0	0
Return on Common Stock	0	0	0	0	0	0	0	0	0	0
Interest	0	28	27	26	25	24	23	22	21	21
Book Depreciation	0	13	13	13	13	13	13	13	13	13
Tax Depreciation	0	53	53	53	53	53	53	53	53	53
Income Taxes	0	0	0	0	0	0	0	0	0	0
Deferred Taxes	0	0	0	0	0	0	0	0	0	0
Property Tax	0	0	0	0	0	0	0	0	0	0
Insurance	0	2	2	2	2	2	2	2	2	2
Annual Carrying Charges	0	43	42	41	41	40	39	38	37	36

Year	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Remaining Book Value	280	267	253	240	227	213	200	187	173	160
Return on Preferred Stock	0	0	0	0	0	0	0	0	0	0
Return on Common Stock	0	0	0	0	0	0	0	0	0	0
Interest	20	19	18	17	16	15	14	13	12	11
Book Depreciation	13	13	13	13	13	13	13	13	13	13
Tax Depreciation	53	53	53	53	53	53	53	53	53	53
Income Taxes	0	0	0	0	0	0	0	0	0	0
Deferred Taxes	0	0	0	0	0	0	0	0	0	0
Property Tax	0	0	0	0	0	0	0	0	0	0
Insurance	2	2	2	2	2	2	2	2	2	2
Annual Carrying Charges	35	34	33	32	31	30	29	28	27	27

Table 6-3 (Sh. 3 of 6)

ECONOMIC ANALYSIS

BUFFALO DISTRICT HEATING PROJECT

ANNUAL CARRYING CHARGES

Investment	3
Initial Operation	1989
Cost Basis	1987
Capital Cost - $1000	$700
Gen. Escalation -	4.0%
Escalation - $1000	57
AFDC - $1000	26
Total Cost - $1000	783
Start of Evaluation	1987

Economic Factors

Preferred Stock Ratio	0	Book Life - Yrs	30
Return on Preferred Stock - %	0	Income Tax Rate - %	0
Common Stock Ratio	0	Tax Credit - %	0
Return on Common Stock - %	0	Tax Life - Yrs	30
Debt Ratio	1	Accelerated Tax Depreciation	0
Debt Cost - %	7	Property Tax - %	0
		Insurance Rate - %	0.5
Weighted Cost of Capital - %	7.00		

Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
Remaining Book Value	0	0	783	757	731	705	679	653	627	600
Return on Preferred Stock	0	0	0	0	0	0	0	0	0	0
Return on Common Stock	0	0	0	0	0	0	0	0	0	0
Interest	0	0	55	53	51	49	48	46	44	42
Book Depreciation	0	0	26	26	26	26	26	26	26	26
Tax Depreciation	0	0	204	204	204	204	204	204	204	204
Income Taxes	0	0	0	0	0	0	0	0	0	0
Deferred Taxes	0	0	0	0	0	0	0	0	0	0
Property Tax	0	0	0	0	0	0	0	0	0	0
Insurance	0	0	4	4	4	4	4	4	4	4
Annual Carrying Charges	0	0	85	83	81	79	78	76	74	72

Year	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Remaining Book Value	574	548	522	496	470	444	418	392	365	339
Return on Preferred Stock	0	0	0	0	0	0	0	0	0	0
Return on Common Stock	0	0	0	0	0	0	0	0	0	0
Interest	40	38	37	35	33	31	29	27	26	24
Book Depreciation	26	26	26	26	26	26	26	26	26	26
Tax Depreciation	204	204	204	204	204	204	204	204	204	204
Income Taxes	0	0	0	0	0	0	0	0	0	0
Deferred Taxes	0	0	0	0	0	0	0	0	0	0
Property Tax	0	0	0	0	0	0	0	0	0	0
*	4	4	4	4	4	4	4	4	4	4
Annual Carrying Charges	70	68	67	65	63	61	59	57	56	54

Table 6-3 (Sh. 4 of 6)

ECONOMIC ANALYSIS

BUFFALO DISTRICT HEATING PROJECT

ANNUAL CARRYING CHARGES

Investment	4
Initial Operation	1990
Cost Basis	1987
Capital Cost - $1000	$1,600
Gen. Escalation -	4.0%
Escalation - $1000	200
AFDC - $1000	62
Total Cost - $1000	1862
Start of Evaluation	1987

Economic Factors

Preferred Stock Ratio	0	Book Life - Yrs	30
Return on Preferred Stock - %	0	Income Tax Rate - %	0
Common Stock Ratio	0	Tax Credit - %	0
Return on Common Stock - %	0	Tax Life - Yrs	30
Debt Ratio	1	Accelerated Tax Depreciation	0
Debt Cost - %	7	Property Tax - %	0
		Insurance Rate - %	0.5
Weighted Cost of Capital - %	7.00		

Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
Remaining Book Value	0	0	0	1862	1800	1738	1676	1613	1551	1489
Return on Preferred Stock	0	0	0	0	0	0	0	0	0	0
Return on Common Stock	0	0	0	0	0	0	0	0	0	0
Interest	0	0	0	130	126	122	117	113	109	104
Book Depreciation	0	0	0	62	62	62	62	62	62	62
Tax Depreciation	0	0	0	1155	1155	1155	1155	1155	1155	1155
Income Taxes	0	0	0	0	0	0	0	0	0	0
Deferred Taxes	0	0	0	0	0	0	0	0	0	0
Property Tax	0	0	0	0	0	0	0	0	0	0
Insurance	0	0	0	9	9	9	9	9	9	9
Annual Carrying Charges	0	0	0	202	197	193	189	184	180	176

Year	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Remaining Book Value	1427	1365	1303	1241	1179	1117	1055	993	931	869
Return on Preferred Stock	0	0	0	0	0	0	0	0	0	0
Return on Common Stock	0	0	0	0	0	0	0	0	0	0
Interest	100	96	91	87	83	78	74	70	65	61
Book Depreciation	62	62	62	62	62	62	62	62	62	62
Tax Depreciation	1155	1155	1155	1155	1155	1155	1155	1155	1155	1155
Income Taxes	0	0	0	0	0	0	0	0	0	0
Deferred Taxes	0	0	0	0	0	0	0	0	0	0
Property Tax	0	0	0	0	0	0	0	0	0	0
Insurance	9	9	9	9	9	9	9	9	9	9
Annual Carrying Charges	171	167	163	158	154	150	145	141	137	132

Table 6-3 (Sh. 5 of 6)

ECONOMIC ANALYSIS

BUFFALO DISTRICT HEATING PROJECT

UNIT COST OF THERMAL ENERGY

Start of Evaluation 1987

Unit Costs	1987	Escalation	Heat Source -	BOILER PLANT		
Elect. Purch.- $/MWh	50.00	4.0	Heat Rate - Btu/KWh	NA	Book Life - Yrs	30
Elect. Sold - $/MWh	0.00	4.0	Peak Electric Output - KW	0	Income Tax Rate - %	0
O&M Labor -$/ManYr	27,000	4.0	Peak DH Output - MWt	30	Tax Credit - %	0
O&M Materials-% Cost	1.7	4.0	Peak CW Output - Tons	0	Tax Life - Yrs	30
Property Taxes - %	0	2.5	Boiler Efficiency - %	84.0%	Accel. Tax Deprec.	0
Fuel - $/MBtu	3.4	4.0			Property Tax - %	0
					Insurance Rate - %	0.5
					Cost of Capital - %	7.00

Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
A. Annual Quantities										
1. District Heat - Mbtu/yr	39,000	90,000	131,000	160,000	160,000	160,000	160,000	160,000	160,000	160,000
2. Chilled Water - Mbtu/yr	0	0	0	0	0	0	0	0	0	0
3. Power Generated - MWh/yr	0	0	0	0	0	0	0	0	0	0
4. Auxiliary Power - MWhr/yr	0	0	0	0	0	0	0	0	0	0
5. Pumping Power - MWhr/yr	50	75	100	125	125	125	125	125	125	125
6. Power Sold - MWh/yr	0	0	0	0	0	0	0	0	0	0
7. Power Purchased - MWhr/yr	50	75	100	125	125	125	125	125	125	125
8. O&M Labor - ManYr/yr	1	2	2	2	2	2	2	2	2	2
9. O&M Material-% Invest.	1.70%	1.70%	1.70%	1.70%	1.70%	1.70%	1.70%	1.70%	1.70%	1.70%
10. Fuel - MBtu/yr	46,429	107,143	155,952	190,476	190,476	190,476	190,476	190,476	190,476	190,476
B. Unit Costs										
	50.00	52.00	54.08	57.26	59.55	61.93	67.95	70.67	73.49	76.43
2. Power Sold - $/MWh	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3. O&M Labor - $1000/ManYr	27	28	29	30	32	33	34	36	37	38
4. Fuel - $/MBtu	3.40	3.54	3.68	3.82	3.98	4.14	4.30	4.47	4.65	4.84
C. Carrying Charges - $1000/yr	119	160	241	438	428	418	409	399	389	380
D. Operating Expenses - $1000/yr										
1. Power Purchased	3	4	5	7	7	8	8	9	9	10
2. O&M	46	76	79	82	85	88	92	96	99	103
3. Fuel Cost	158	379	574	728	758	788	819	852	886	922
Sub- Total	206	458	658	817	850	884	920	957	995	1035
E. Power Sold - $1000/yr	0	0	0	0	0	0	0	0	0	0
F. Required Revenues- $1000/yr	325	618	899	1255	1278	1302	1329	1356	1384	1414
G. Unit Cost of Heat - $/MBtu										
1. Fixed Expenses	$3.06	$1.78	$1.84	$2.74	$2.67	$2.61	$2.55	$2.49	$2.43	$2.37
2. O & M Expenses	$1.24	$0.88	$0.64	$0.56	$0.58	$0.60	$0.63	$0.65	$0.68	$0.71
3. Fuel	$4.05	$4.21	$4.38	$4.55	$4.74	$4.92	$5.12	$5.33	$5.54	$5.76
Total	$8.34	$6.87	$6.86	$7.84	$7.99	$8.14	$8.30	$8.47	$8.65	$8.84

Table 6-3 (Sh. 6 of 6)

ECONOMIC ANALYSIS

BUFFALO DISTRICT HEATING PROJECT

UNIT COST OF THERMAL ENERGY

Start of Evaluation 1987

Unit Costs	1987	Escalation	Heat Source -	BOILER PLANT		
			Heat Rate - Btu/KWh	NA	Book Life - Yrs	30
Elect. Purch.- $/MWh	50.00	4.0	Peak Electric Output - KW	0	Income Tax Rate - %	0
Elect. Sold - $/MWh	0.00	4.0	Peak DH Output - MWt	30	Tax Credit - %	0
O&M Labor -$/ManYr	27,000	4.0	Peak CW Output - Tons	0	Tax Life - Yrs	30
O&M Materials-% Cost	1.7	4.0	Boiler Efficiency - %	84.0%	Accel. Tax Deprec.	0
Property Taxes - %	0	2.5			Property Tax - %	0
Fuel - $/MBtu	3.4	4.0			Insurance Rate - %	0.5
					Cost of Capital - %	7.00

Year	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
A. Annual Quantities										
1. District Heat - MBtu/yr	160,000	160,000	160,000	160,000	160,000	160,000	160,000	160,000	160,000	160,000
2. Chilled Water - MBtu/yr	0	0	0	0	0	0	0	0	0	0
3. Power Generated - MWh/yr	0	0	0	0	0	0	0	0	0	0
4. Auxiliary Power - MWhr/yr	0	0	0	0	0	0	0	0	0	0
5. Pumping Power - MWhr/yr	125	125	125	125	125	125	125	125	125	125
6. Power Sold - MWh/yr	0	0	0	0	0	0	0	0	0	0
7. Power Purchased - MWhr/yr	125	125	125	125	125	125	125	125	125	125
8. O&M Labor - ManYr/yr	2	2	2	2	2	2	2	2	2	2
9. O&M Material-% Invest.	1.70%	1.70%	1.70%	1.70%	1.70%	1.70%	1.70%	1.70%	1.70%	1.70%
10. Fuel - MBtu/yr	190,476	190,476	190,476	190,476	190,476	190,476	190,476	190,476	190,476	190,476
B. Unit Costs										
	79.49	82.67	85.98	89.41	92.99	96.71	100.58	104.60	108.79	113.14
2. Power Sold - $/MWh	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3. O&M Labor - $1000/ManYr	40	42	43	45	47	49	51	53	55	57
4. Fuel - $/MBtu	5.03	5.23	5.44	5.66	5.89	6.12	6.37	6.62	6.89	7.16
C. Carrying Charges - $1000/yr	370	360	351	341	331	322	312	302	293	283
D. Operating Expenses - $1000/										
1. Power Purchased	10	10	11	11	12	12	13	13	14	14
2. O&M	108	112	116	121	126	131	136	142	147	153
3. Fuel Cost	959	997	1037	1078	1121	1166	1213	1261	1312	1364
Sub- Total	1076	1119	1164	1211	1259	1309	1362	1416	1473	1532
E. Power Sold - $1000/yr	0	0	0	0	0	0	0	0	0	0
F. Required Revenues- $1000/yr	1446	1479	1515	1551	1590	1631	1674	1718	1765	1815
G. Unit Cost of Heat - $/MBtu										
1. Fixed Expenses	$2.31	$2.25	$2.19	$2.13	$2.07	$2.01	$1.95	$1.89	$1.83	$1.77
2. O & M Expenses	$0.73	$0.76	$0.79	$0.83	$0.86	$0.89	$0.93	$0.97	$1.01	$1.05
3. Fuel	$5.99	$6.23	$6.48	$6.74	$7.01	$7.29	$7.58	$7.88	$8.20	$8.53
Total	$9.04	$9.25	$9.47	$9.70	$9.94	$10.19	$10.46	$10.74	$11.03	$11.34

Appendix A

BUILDING HEATING SYSTEMS AND PROPOSED CONVERSIONS TO DISTRICT HEATING

CITY HALL

Existing System

Prior to construction of the pilot system, City Hall was heated by two gas-fired steam boilers rated at 12 MMBtu/hr input each. There also are two other boilers on site which are not operational. The age and condition of the operational boilers indicated that replacement was necessary in the immediate future. The distribution system is a two-pipe low-pressure steam system with condensate vacuum pumps. Terminal heating units are the original cast iron radiators with approximately 50% in use. There also are steam coils in the various building intake air ducts. The steam control is divided between two building sections each controlled by manually operated pneumatic control valves. One section serves the steam coils in the ventilation ducts while the other serves the building radiators. Typically the building operates with temperatures of about 70°F during the day and set back to 60°F at night and weekends.

Installation of New Steam Boiler at Fire Headquarters

Construction of the pilot system enabled retirement of existing boilers by supplying steam to City Hall from a new 500 hp steam boiler located in the Fire Headquarters. The addition of the new steam boiler is an interim remedy, the short construction schedule precluding conversion of City Hall to hot water heating.

The steam and condensate each are transported through new 12" underground district heating pipes. The new steam line coming from Fire Headquarters is tied directly into the existing steam header at City Hall while using existing steam controls.

The new condensate return to the Fire Headquarters is piped directly into the City Hall condensate return tank so that existing pumps can be used.

<u>Conversion to Hot Water District Heating</u>

A peak comfort heating load of 13.2 MMBtu/hr was determined based on fuel consumption records for the building and is the basis of the proposed retrofit design. The conversion to hot water district heating can be accomplished as follows:

- Hydro test existing building piping to determine condition.
- Convert the new 500 hp steam boiler located in Fire Headquarters to hot water heating.
- Modify the new underground steam distribution system to accept hot water.
- Establish a minimum of three independent heating zones, one to serve the upper floors, another to serve the lower floors, and one to serve the ventilation heating. The ability to segregate the building piping into zones will establish operating pressures below the maximum allowable rating for most of the radiators, minimizing the number of replacement units.
- Establish a primary hot water distribution system for supplying the individual heating zones. A new 100 percent capacity circulating pump will be required as well as an expansion tank and an air removal system for each zone.
- Install an indoor-outdoor temperature controller to control distribution supply water temperature to each zone.
- Remove internals or eliminate all traps and modify existing steam and condensate lines as required to achieve zone separation and to establish the best distribution system arrangement.
- Connect domestic hot water service lines to the domestic water heat exchanger.
- Install a plate-type heat exchanger in the boiler room for each zone and the domestic hot water system.

NEW CITY COURT

Existing System

The City Court building was equipped with four 540 KW (three of which are operational) and one 420 KW electric hot water boilers for building heating. Two 30 KW electric water heaters provided domestic hot water. The building is zoned for two heating sections, one for finned-tubed radiation and the other for reheat coils in the air handling system.

Conversion to Hot Water District Heating

During pilot system construction, a single building heat exchanger with a capacity of 7 MMBtu/hr was installed to provide district heating to the building. Existing building controls were used except for addition of 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 conversion to hot water district heating in New City Court was accomplished as follows:

- Retired existing electric hot water boilers, to serve as backup only.
- Installed a plate heat exchanger to replace the electric boilers.
- Retrofitted the existing domestic hot water systems by retiring in place the existing tank heater and replacing it with a plate type heat exchanger. Each of the two independent domestic hot water systems is required to have its own heat exchanger.
- Added appropriate district heating control valves and isolation valves. Retrofitted new controls into existing pneumatic control system.
- Installed a single Btu meter for the building.

OLD CITY COURT

Existing System

The Old City Court building was a simple conversion to hot water district heating, since it currently has a heat pump system which circulates water for heating and/or cooling. Supplemental heat for the system was supplied by a gas-fired steam boiler which passes steam through a convertor that heats the circulating water. The domestic hot water is supplied by several small electric heaters and were not considered in the retrofit to district heating.

Conversion to Hot Water District Heating

A peak comfort heating load of 2.1 MMBtu/hr was determined based on current capacity and fuel consumption estimates supplied by the building engineers. The capacity of the district heating exchanger was increased to 2.8 MMBtu/hr based on future needs of currently unheated areas.

The conversion to hot water district heating was accomplished as follows:

- Retired in place existing steam boiler and steam convertor and retain for backup.
- Installed a plate heat exchanger to replace the retired boiler and steam converter.
- Utilized the existing computerized building controls to operate the district heating control valves.
- Installed a Btu meter.

BUFFALO ATHLETIC CLUB

Existing System

This is a twelve 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 primarily by cast-iron steam radiators. There are also air handling systems with steam coils on the second and fifth floors and fan coil units on the upper floors.

The steam distribution system is served by several risers. One 8-inch 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 Buffalo Athletic Club are supplied by their own gas-fired heaters, and will be converted to district heating. The balance of the building's domestic water requirement is small and will not be converted.

Conversion to Hot Water District Heating

Analysis of the fuel consumption records indicates that the peak comfort heating load for the Buffalo Athletic Club building is 4.3 MMBtu/hr. The peak domestic demand for the restaurant and the athletic club combined is approximately 1.7 MMBTU/hr. For building heating, three heat exchangers are required (one for standby). Each is sized at 2.5 MMBtu/hr because of cost savings offered by manufacturing three identical units. These units also are capable of providing building heating with the existing steam boilers as the heat source, insuring standby heating capability.

The conversion to hot water district heating can be accomplished as follows:

- Retire existing steam boilers to standby capability. Existing condensate collection system must be modified to allow for use of the plate heat exchangers for steam to hot water generator as standby.
- Install three plate-type heat exchangers to satisfy the building heating loads with standby capability.
- Install separate domestic hot water heat exchangers for the restaurant and the Buffalo Athletic Club domestic water heating systems, along with separate Btu meters.
- Install circulating pumps, expansion tanks, and air removal equipment for each of the two building heating zones.
- Provide supply temperature control in response to outdoor temperature.
- Retrofit individual radiators including removal of the steam trap internals, installation of a thermostatic radiator valve and installation of an air vent.
- Replace steam coils in air handling equipment to accept hot water.
- Provide isolation valves where required on the steam and condensate piping.
- Increase the upper loop condensate return line size to allow hot water circulation.

FIRE HEADQUARTERS

Existing System

The Fire Headquarters building and hose tower are heated through a two-pipe steam system with gas-fired steam boilers. There are two new 100 hp steam boilers to supply the building heating requirements, one of which is a backup unit.

There are also several gas-fired space heaters located throughout the building. These were installed in designated areas that required constant temperatures during periods when the majority of the building is set back at night and weekends. The domestic water load is supplied by the steam boilers during the heating season and by separate gas-fired water heaters during the summer months.

Conversion to Hot Water District Heating

Analysis of fuel consumption records indicates that the peak comfort heating load for the Fire Headquarters facility is 3.5 MMBtu/hr.

The conversion to hot water district heating can be accomplished as follows:

- Utilize existing steam boilers as standby and incorporate them into the district heating system.
- Install a plate heat exchanger to replace the existing boilers.
- Convert the steam distribution and condensate return system to hot water service. This requires that all steam trap internals be removed and that an expansion tank, an air separator, and two 100% capacity pumps be installed.
- Existing radiators must be retrofitted for hot water service. This requires that steam trap internals be removed and a thermostatic radiator valve be installed.
- Connect domestic hot water to a district heating heat exchanger.
- Retire existing gas-fired unit heaters and allow for individual control in these areas.

RATH BUILDING

Existing System

The Rath Building, located on the corner of Franklin and W. Eagle Streets, is owned by Erie County. It currently is heated by two electric hot water boilers each rated at 1800 kW output (one standby).

Domestic hot water is generated by chillers in the summer months and by the electric boilers during the winter months.

Conversion to Hot Water District Heating

The peak comfort heating load was determined to be 7 MMBtu/hr. Based upon preliminary information, a single heat exchanger can be installed into the existing hot water distribution system. The existing control system can be used, but district heating control valves have to be installed.

The conversion to hot water district heating in the Rath Building can be accomplished as follows:

- Retire existing electric hot water boilers to serve as backup only.
- Install a plate-type heat exchanger to replace the electric boilers.
- Retrofit the existing domestic hot water systems by installing plate-type heat exchangers.
- Install district heating control valve and controls

25 DELAWARE AVENUE AND OLD COUNTY COURT

Existing System

The Old County Court and 25 Delaware Avenue buildings are heated by two 150 hp steam boilers. The boilers have new dual-fuel burners allowing them to burn either gas or oil.

The building at 25 Delaware Avenue generates hot water from steam using a steam convertor. Hot water is then distributed to induction units and reheat coils in the air handling system.

The Old County Court building currently is heated by steam with cast-iron radiators and air handling units.

Conversion to Hot Water District Heating

The conversion to hot water district heating can be accomplished at 25 Delaware Avenue as follows:

- Retire existing steam convertors to standby capability.
- Install plate-type heat exchangers to satisfy the building heating load. The plate heat exchangers will replace the steam convertors for building heating.
- Utilize existing hot water distribution and control system.
- Install a new district heating control system.
- Install a plate-type heat exchanger for domestic hot water production.

The conversion to hot water district heating can be accomplished for Old County Court as follows:

- Install plate-type heat exchangers to satisfy the building heating load.
- Install circulating pumps, expansion tanks, and air removal equipment for each building heating zone.
- Install a plate-type heat exchanger for domestic hot water production.
- Retrofit individual radiators including removal of the steam trap internals, installation of a thermostatic radiator valve and installation of an air vent.
- Retrofit or replace steam coils in air handling equipment to accept hot water.
- Provide isolation valves where required on the steam and condensate piping.

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