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ST. PAUL HOT WATER DISTRICT HEATING PROJECT

CONSTRUCTION EXPERIENCE

by

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The District Heating Development (DHDC) was incorporated in 1979 as a private, non-profit organization to plan and implement a hot water district heating system in St. Paul, Minnesota. Following preliminary and final feasibility studies, sufficient market acceptance, and successful financing, the project began construction in March, 1983. Service to DHDC's first customers began on September 27, 1983. Twenty-two buildings are receiving medium temperature (190 - 250o F) hot water energy. Over 50 more buildings will connect to the system in 1984 and 1985 as construction progresses.

1.0 INTRODUCTION

Currently, space heating and water heating account for 20 percent of the total U.S. energy demand. Over 90 percent of these requirements are supplied by oil and natural gas. Oil prices were decontrolled in 1981. Natural gas decontrol is difficult to forecast, but the current administration is moving toward a decontrolled market. It is expected that oil and natural gas prices in the long-term will escalate at more than inflation because of declining supplies relative to growing demand and increasing cost of production. District heating, which can use alternative domestic fuels, will result in more stable energy prices and greater national self-sufficiency.

Modern hot water district heating systems have the potential to offer consumers many major advantages over operating their own building boilers:

- competitive space heating energy costs;
- lower maintenance costs and higher reliability;
- improved air quality in the community;
- improved safety (compared with fossil fuel-fired systems);
- smaller space requirements; and
- lower initial capital costs for new buildings.

Of these advantages, the most important to the consumer is the cost of the heat energy. In numerous U.S. cities, natural gas is the alternative to district heating. The main feature that makes a district heating system competitive is its fuel flexibility which implies the use of comparatively inexpensive fuels such as coal.

The advent of the oil crisis in 1973-74 led to a resurgence of interest and development in district heating. In the mid-1970s the U.S. Department of Energy (DOE) and the Minnesota Energy Agency (MEA) initiated a study to determine the feasibility of a modern hot water district heating system for a U.S. city. The idea for such a study was the result of the large number of successful systems designed and built in northern Europe over the past 25 years. Many of the systems serve large segments of a city; several of them serve single-family residential consumers. Based on the success of the European systems, these studies were initiated to evaluate the European concept as it applied to a northern U.S. city.

The Minneapolis-St. Paul area was chosen as the site because it met the technical criteria, such as high number of heating degree days (8000oF), large potential load, and the potential for a variety of of energy sources. The object of the study was to outline the general features of a new Twin Cities-wide hot water district heating system, assumed to develop over a 20-year period. An encouraging overall feasibility study, along with other studies, resulted in the recommendation of St. Paul as the site for a closer project study.

As a result, DHDC was incorporated in July 1979 as a non-profit company by the Mayor of St. Paul, the Executive Director of the St. Paul Building Owners and Managers Association (BOMA), and the Director of the Minnesota Energy Agency (MEA). From mid-1979 to the end of 1980 constituted the study phase of the St. Paul project. One of the goals was to assess a preliminary economic feasibility of a hot water district heating system serving the commercial core area of St. Paul.

Given preliminary economic feasibililty, the idea was to market the system, prepare the final design and bid specification, and obtain firm bids. DHDC's financial advisor recommended that firm bids be obtained to receive the highest rating on the bond issue.

The final economic feasibility study was completed in September of 1982 and financing arranged in December of the same year. Construction of the project was originally based on a three-year time schedule. After the first year of successful construction it was decided to expedite the project and complete the construction in two years.

2.0 SYSTEM COMPONENTS AND DESIGN PHILOSOPHY

The preliminary project study results and their applicability to the European experience helped DHDC develop its overall design philosophy. The main study and system components are described below.

2.1. Heat Load

The market area consists of over 300 buildings. More than 50 percent of the buildings' heating systems already use hot water as a medium. At the time of the study, the existing total heat load for the area was estimated at 245 MW. Development during 1980-85 was estimated at 40 MW, for a total of 285 MW. Government buildings and hospitals represented one-third of the building load. It was necessary to be sure these facilities would sign up for hot water district heating because they comprised such a large portion of the market.

2.2. Heat Sources

Preliminary studies indicated that the 180-MW(t) coal-fired Third Street plant would be a good primary heat source for the system. It would be able to supply both hot water and steam until the latter was phased out in 1985. A 30 MW(t) back up facility at St. Paul Ramsey Medical Center was also identified. Depending on heating load growth, the turbine units at NSP's High Bridge Power Plant would be converted to cogeneration possibly in the mid-1980's to utilize heat rejected from electric power generation.

2.3 Distribution System

DHDC's mandate was to develop a cost-effective plan for a district heating system which would attract customers. In a city-wide system, reliability is a main concern. Since there are no city-wide hot water district heating systems in the USA, a piping system based on the highly successful and proven systems in Europe was developed.

Medium-temperature hot water was identified as the transport medium. Hot water is more efficient and reliable than steam and can be distributed to a wider area and therefore can adapt to meet the changing needs of a community.

The pressure in the pipes will be a maximum of 250 psi. The temperature of the water will vary as a function of the outside temperature. During the summer, when there are small heating loads, the supply temperature will be about 190o F. The 250o F maximum temperature selection for the system has been optimized for use of waste heat through cogeneration. Since the piping technology for these specifications has been proven, the piping is generally available in various designs and configurations. The St. Paul system will be prefabricated with a polyurethane-insulated steel pipe encased in a polyethylene jacket. The preliminary design outlined a hot water piping system to serve all the existing and future heat demands in the initial area, up to a total capacity of 280 MW.

2.4 Conversion of Building Heating Systems

One of the main concerns in supplying building heating systems from a medium-temperature hot water district heating system is the varying degree of need for building conversions based on the diversity of building heating systems found in the St. Paul central business district. This diversity results from the wide range of building sizes and ages from new buildings to some which are 90 years old. Therefore, building conversion cost was one of the key economic and marketing issues for implementing a medium-temperature hot water district heating system in St. Paul.

The overriding philosophy of the conversion design was to optimize the life-cycle cost rather than to minimize the first cost of connection to the hot water system. The minimum first-cost strategy would require a year-round hot water supply temperature in the range of 300-350oF. Such a high temperature hot water system could be used to heat buildings with existing steam distribution systems. This strategy has the lowest initial conversion cost but would leave the older steam distribution buildings with a system that is not only less efficient and more difficult to control, but more costly to maintain than with the medium-temperature hot water district heating system.

Therefore, the strategy followed in the DHDC project was based on the following:

1. the hot water supply temperature would be limited to 250oF to reduce the construction and operating cost of the district heating system;

2. building steam distribution systems would be converted to hot water (hydronic) systems in an economical fashion; and

3. degraded or out-moded building system equipment would be replaced and an overall system modernization would be included with the connection to the hot water district heating supply.

The investment to modernize some of the existing heating systems requires incentives to encourage the building owner to make such a commitment. However, the owner benefits from this investment because of the resulting reduced energy consumption of the more efficient hydronic system. Information on converted buildings and studies of potential conversions from steam to hydronic system operation document that 10- to 20- percent energy savings from heating result. Additional energy savings of 20 percent can also be realized when different conservation features are included in the building system conversion and modernization.

3.0 BID SPECIFICATIONS AND BIDS

3.1 Distribution System

To receive the highest possible rating on borrowed money, firm bids were necessary on the heat source modifications and the distribution system. Since it was known that the distribution system involved the highest costs and most uncertainties, a good detailed design identifying the difficulties was made. It is expected that this resulted in significant construction cost savings. DHDC was able to obtain enough money, or $700,000, to make a good final design of the pipe system. The joint venture of Metcalf and Eddy from Boston and Fjarrvarmebyran (FVB) from Sweden investigated the existing site conditions such as site surveys, subsurface exploration and utility searches before doing the final design. Metcalf and Eddy is experienced in civil engineering in American cities and FVB is the expert on hot water piping technology. Because the piping system was located in the downtown area of a major American city, thus visible to many people, five experienced contractors were preselected.

3.2 Heat Source Modification

Both the Third Street Plant and its backup facility, the St. Paul Ramsey Medical Center Plant, required modifications. A good conceptual design was made for each conversion. Because of the lack of time and money, however, it was decided to prepare bid specifications for a design/build construction based on the conceptual design rather than complete a final design first.

3.3 Building Conversion

The hot water distribution system connects the heat source to the customer's point of delivery just inside the building wall. The supply and return pipes are equipped with stopvalves. The modification of a building heating system for compatibility with the district hot water system is called building conversion. This conversion is the responsibility of the building owner. To assist district heating customers with their building conversion design and construction, DHDC developed Standards and Guidelines and a Practical Guide for buildings hooking up to district heating. The Guidelines and Guide are recommendations to ensure efficient and economical system operation.

To ensure that building owners and consulting engineers were in concert with those guidelines, several building conversion seminars were held. DHDC also specified that it must review all building conversion drawings.

3.4 Bids

Firm bids for the piping system and heat sources were within 5 percent of previous estimates. Six percent of the piping system's base bid was added to the bid price for utility relocation; 7 percent was added for contingency. Seven percent contingency was added to the heat source bid.

An approximate generalized cost breakdown of the pipe system per pipe diameter is in Table I.

TABLE I

ST. PAUL DISTRICT HEATING PROJECT

GENERALIZED COSTS

Pipe Diameter (Inches)	Total Cost per Foot of Trench (2 Pipelines) No Rock	All Rock
20	$770	$1025
16	670	850
12	550	725
10	370	485
8	250	355
6	220	330
5	190	300
4	170	265
3	150	240
2-1/2 and below	105	170

Building conversion bids for 22 buildings converted in 1983 averaged 20 percent below estimates.

The initial project cost, including construction, financing, and other expenses, but not building conversion, is $45.8 million. The cost has been financed as follows:

Tax exempt revenue bonds	$30.50 million
City/HUD-UDAG Loan	9.80
City equity loan	5.50
	$45.80 million

The funds will be used as follows:

Piping construction	$24.51 million
Heat source modifications (Third Street Plant and St. Paul Ramsey Medical Center	6.64
Mobile boilers, meters and service equipment	.74
Misc. costs including insurance, initial operating losses, and capital improvements	13.91
	$ 45.80 million

Customer heating system conversion costs in the initial system total approximately $22 million in 1982 dollars. Low interest loans to finance conversion costs are available to building owners from the St. Paul Port Authority. In addition, a consortium of foundation and corporate contributors is providing supplemental funding for non-profit organizations which sign up for district heating service.

4.0 ACTUAL VS PLANNED CONSTRUCTION

4.1 Distribution System

4.1.1 Construction Sequence. It was assumed that the Contractor would begin excavation and lay pipe at the intersections, where the most utility conflicts would arise, and would install pipe between intersections, adjusting line and grade to match the pipes already in place. The Contractor decided to do the opposite, first completing work between the intersections. There was concern that he might "be painting himself into a corner". His approach, however, has proven beneficial in some ways. The mechanical contractor's personnel had to learn the procedures for pipe welding, the pressure and leakage testing, jointing, and pre-stressing. By beginning in areas where there was a low probability of unexpected obstacles, the workers were able to concentrate on the methods of district heating pipelaying. By the time work began at intersections, crews were experienced and production rates were up. Also, in this way, the Traffic Committee was able to compensate for potential traffic problems with less difficulty.

4.1.2 Design Changes. The Contractor has suggested some minor changes in the design to ease construction and, more often, to avoid traffic problems. In most cases, a different configuration was agreed upon and some potential problems were avoided.

In the portion of Fourth Street between Robert and Sibley Streets, unexpectedly poor subsurface conditions were found and the utilities were not as conveniently located as the record drawings had indicated. The transmission pipeline in this area had been designed to use expansion bellows located between two anchors which were to be about 220 feet apart. However, due to the conditions mentioned above, the anchors and chamber for expansion bellows were redesigned.

As a result of problems with installing precast chambers (discussed below) and the additional expense of constructing the redesigned anchors, a revised plan was developed to ease construction. The revised plan called for deletion of the anchors and expansion chamber and the addition of an expansion loop. This has been the only major change to date of the design of a large diameter transmission main.

4.1.3 Cast-in-Place vs. Precast Chambers. The original design called for cast-in-place chambers for valves, expansion bellows, etc. This type of construction was based on the need for water tightness, flexibility of chamber shape, and location of pipe entrance. The Contractor proposed to substitute precast chambers in many cases to minimize the time the trenches would remain open. After several rounds of shop drawing review, compromise solutions were developed which permitted the use of pre-cast chambers.

When the first precast chamber was installed, there were problems with alignment and sealing. In general, the pieces did not fit well, and the chamber was not acceptable. The precaster has since improved his quality control and delivered an acceptable product. Another problem with the use of precast chambers became apparent when utilities were found to slightly impinge upon the location where a chamber was scheduled to be built. At present, chambers are not being fabricated until the exact location of interfering utilities are known after excavation has been completed. For many chambers, the Contractor is pouring the floor of the chamber and two walls, precasting the other two walls.

4.1.4 Rock Excavation. While rock has consistently been located as predicted by the subsurface exploration program, the degree of difficulty in its removal has varied considerably over short distances. Numerous removal techniques have been employed including water jet blasting, jack hammer, pneumatic hammer, sawing, and ripping with heavy shovel. The Contractor did finally secure permission to use explosives in limited areas. In total, the time and effort necessary to excavate rock is about as anticipated; however, difficulty varies greatly between areas and the scheduled progress of the various segments of work is different than planned.

4.1.5 Customer Service Connections. As building owners became convinced that the district heating system was a reality, they began planning for the connection of their building to the system. They retained engineers and architects who have developed plans for energy conservation made revisions to the heating system for adaptability to district heating, etc. This has resulted in numerous intances where revisions were desirable to the capacity and location of the service connection pipe. In almost every instance accomodation has been made, as the configuration of smaller service pipes can generally be changed without undue difficulty and as the arrangement of the major transmission network was, of necessity, designed to be flexible.

4.1.6 Piping and Welding. Pipe laying in itself did not cause any major problem. The sequence for doing it in a cost-effective way had its learning curve. As mentioned earlier, the concern was the intersections. The contractor might start in intersections during the 1984 construction work. Prestressing was also confusing in the beginning. The contractor had no understanding of why it was necessary, and it took some education to tell him why and how it worked. Welding has in general been excellent. DHDC demanded 10 percent x-raying of the welded length. Very few defective welds were discovered.

4.1.7 Lessons Learned The final configuration of the piping net work represents many compromises to arrive at an optimum layout, while satisfying as many of the conditions described above as was possible. A principal lesson to be learned from the St. Paul experience is that it is possible to lay a major new district heating sytem which takes up a large amount of street area within the congested downtown area of an older American city. While it would have been much more convenient to have been the first, rather than the fifteenth, utility to be installed, the final location of the district heating pipes actually represents a quite efficient configuration. It is also interesting to note that relocation of other utilities is expected to represent only about six percent of the total construction cost -- an estimate which has not changed based on actual construction.

4.2 Heat Source Conversion

Compared to a detailed design and bid construction, the design/build construction leaves more flexibility to the contractor. In the design/build contract, the owner can put more pressure on the contractor to be done on time. To convert the Third Street Plant, time was of the essence. Notice to proceed was sent to the contractor on December 22, 1982; on September 15, 1983, he was ready to deliver hot water. Fine tuning of equipment and calibration of controls took about three months because of load requirements. In general, the conversion was done to our satisfaction even if some compromises had to be made.

4.3 Building Conversion

Twenty-four buildings with a total load of 37 MW were scheduled to convert to hot water district heating in 1983. Building owners were notified to proceed with their conversions in early January of 1983. A building conversion seminar was held in January to urge the building owners to coordinate their conversion designs and begin construction as soon as possible. Customers were told that selecting a consulting engineer and then a contractor may take more than six months. On October 1, 1984, the contractual date to begin hot water service, six buildings had completed their conversion work. At the end of October, eighteen buildings were on line and in November, twenty-two buildings were on line. The other two buildings decided to move their conversion to 1984 and remain on steam in 1983-84.

With the experience of the 1983 building conversion in mind, a building conversion seminar was held in early December of 1983 to help those preparing to convert in 1984. The consensus of that meeting was as follows:

- Plan your building conversion well ahead of time.
- Good planning saves time and money.
- A typical twelve-story office building requires four months from consultant selections for bid specifications to a signed contractor contract.
- Delivery time for major equipment like heat exchangers, pumps, control valves, and coils is about two months.
- Plan construction to make the conversion run as smoothly as possible in respect to ongoing building operation.
- Control valves should be sized according to up-dated historical data not on added design loads.
- Much of the piping and equipment can be reused but historical records should be studied and reviewed.
- Piping with screwed fittings in two-to three-story buildings can be converted without major problems. Higher buildings should be hydrostatically tested and fittings reviewed before a decision on reuse can be made.
- The building heating system should be balanced as soon as possible to save energy.
- Installations designed in accordance with the Standards and Guidelines for building conversion secure a satisfactory operation and minimal maintenance. The twenty-two buildings on the hot water system have operated satisfactorily during the winter of 1983-84. This winter has been extremely cold with wind chills down to minus 70o F in St. Paul.

5.0 CONCLUSION

The first year of DHDC's construction program is now complete. Twenty-two customers totaling 37 MW of thermal demand have installed new heat exchangers and converted their building heating systems to be compatible with the hot water provided by DHDC. With the few exceptions mentioned above, the construction of the district heating piping has generally proceeded as originally planned. The construction is ahead of schedule, and the project will be finalized in two years instead of the original three. When compared to the marketing and financing of the system, the technical engineering problems seem relatively minor. However, a great deal has been learned.