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District Heating/Cogeneration Application Studies for the Minneapolis–St. Paul Area

Methods and Cost Estimates for Converting Existing Buildings to Hot Water District Heating

Ronald E. Sundberg

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METHODS AND COST ESTIMATES FOR CONVERTING EXISTING BUILDINGS TO HOT WATER DISTRICT HEATING

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Minnesota Energy Agency
St. Paul, Minnesota

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FOREWORD

INTRODUCTION

District heating is generally defined as the distribution of thermal energy from a central source for residential and commercial space heating. The central source is usually a heat-only unit or a cogeneration dual-purpose facility that produces both electricity and thermal energy. The most significant advantage of cogeneration power plants compared to conventional steam-electric generating stations is the improved fuel utilization efficiency. Figure F.1 shows graphically the comparative efficiencies of both types of plants. The overall conversion efficiency of an electric-only plant is about 33%. The remaining two-thirds of the energy is rejected to the environment through once-through cooling

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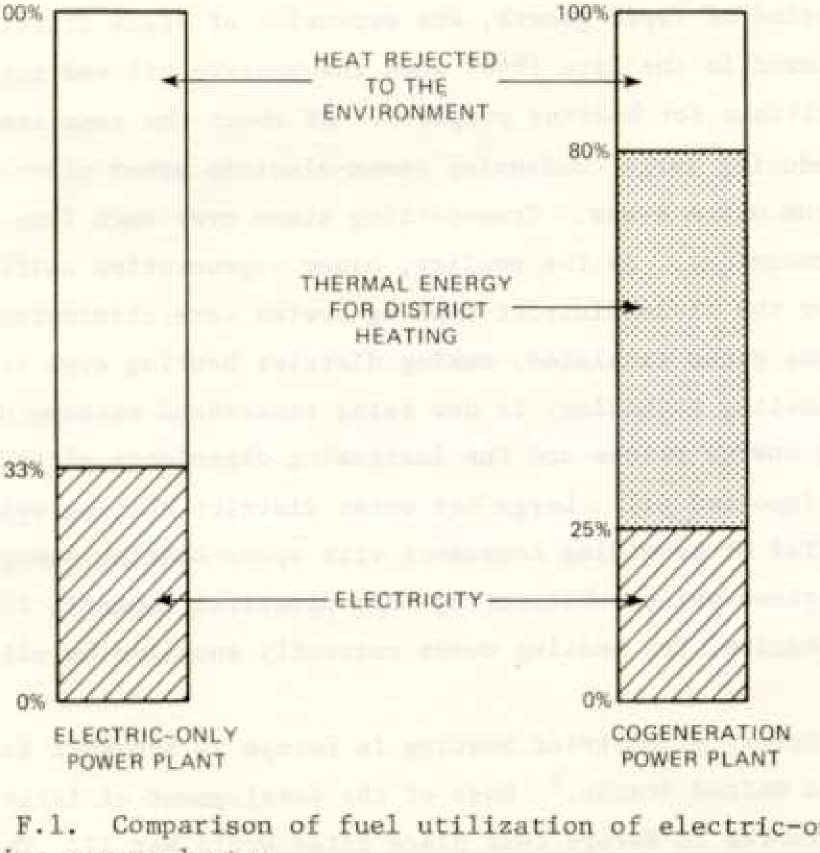

Fig. F.1. Comparison of fuel utilization of electric-only and cogeneration power plants.

systems or cooling towers at about 35 to 40°C. A cogeneration power plant, on the other hand, can operate at an overall efficiency as high as 85%, but this requires some sacrifice in electric output. To supply thermal energy at a temperature level high enough for district heating (e.g., 100°C), steam must be extracted from the power plant's turbine before it has expanded to its full potential. Therefore, there is some reduction in the power output of the turbine which, in turn, reduces the quantity of electricity generated. However, for each unit of electric energy sacrificed, 5 to 10 units of thermal energy are available for district heating.

District heating has been in existence for approximately 100 years. In 1877, a short underground steam pipe was installed in Lockport, New York, to transport thermal energy from a central source to heat a group of buildings.[1] However, it was not until the early part of the twentieth century that cogeneration/district heating systems came into existence. These systems utilized the exhaust steam from small, noncondensing steam-electric power plants to heat buildings in nearby business districts. After a period of rapid growth, the expansion of steam district heating systems slowed in the late 1940s when inexpensive oil and natural gas became available for heating purposes. At about the same time, utilities were introducing large condensing steam-electric power plants remotely located from urban areas. Transporting steam over such long distances was not economical. As the smaller, older cogeneration units were retired, sources for the steam district heating system were eliminated and the cost of supplying steam escalated, making district heating even less attractive. District heating technology is now being reassessed because of rapidly escalating energy prices and the increasing dependence of the United States on imported oil. Large hot water district heating systems have the potential of providing consumers with space-heating energy at competitive prices while substituting more plentiful domestic fuels, such as coal and uranium, for heating needs currently supplied by oil and natural gas.

The history of district heating in Europe is somewhat different than that of the United States.[2] Most of the development of large district heating networks in Europe took place after World War II. This development has been due in large part to high energy prices and a scarcity of alternative heating options, such as natural gas. These factors, although new to the United States, have been strong motivation for the expansion of district heating technology in Scandinavian and other northern European countries. Their district heating technology uses hot water as the distribution media. Hot water was chosen over steam for its flexibility and adaptability to long-distance transport. Over the past 20 years, technology and hardware have been developed that successfully provide large-scale hot water district heating.

TWIN CITIES DISTRICT HEATING STUDIES

Northern States Power Company (NSP), the Department of Energy (DOE), the Minnesota Energy Agency (MEA), the Minnesota Gas Company, the Minneapolis Central Heating Company, the University of Minnesota, and other local governments and private organizations are cooperatively performing an in-depth application study to determine the feasibility of hot water district heating for a large U.S. metropolitan area — namely, Minneapolis-St. Paul, Minnesota. The program to assess district heating for the Twin Cities area consists of several coordinated studies focusing on technical, economic, environmental, and institutional issues. A list of the various studies is given in Table F.1. The stimulus for most of the Twin Cities work has been the Overall Feasibility Study[3] done by Studsvik Energiteknik AB, Sweden.

The objective of Studsvik's analysis was to determine the feasibility of district heating for the Twin Cities, not to develop a detailed step-by-step plan for the network nor to do detailed engineering and economic calculations. The major efforts were concentrated in three areas: (1) assessment of the heating loads that could be connected over a 20-year period, (2) determination of a feasible implementation schedule to connect the loads and to bring cogeneration plants and peak-load boilers on line, and (3) examination of the overall economics based on alternative methods of financing.

Table F.1. Minneapolis-St. Paul district heating studies

Studies	Sponsor
Distribution and building systems	
Studsvik district heating study (overall feasibility study outlining 20-year development)	DOE
Building conversion study (description of conversion techniques and estimation of costs)	DOE
Energy sources studies	
Retrofiting an existing coal plant (description of conversion techniques and costs for High Bridge Power Plant in St. Paul)	NSP and DOE
New coal/cogeneration plant assessment (investigation of the possibility of locating a new coal-cogenerating unit near or in the Twin Cities)	DOE
Institutional issues	
Ownership option and barriers (identification and evaluation of nontechnical issues: ownership, financing, regulation, and marketability)	DOE
Environmental	
Air-quality modeling (prediction of the effect of cogeneration/district heating on Twin Cities air quality)	DOE and EPA

STUDSVIK DISTRICT HEATING STUDY

This study was a joint effort based on current Swedish district heating technology and experience, adopted where necessary to U.S. conditions. Participants in the United States supplied the basic data and economic criteria while Studsvik carried out the analysis. The results presented here are excerpts from the *Executive Summary* of the Overall Feasibility Study.[3]

The Twin Cities Area

The Twin Cities area encompasses two concentrated municipalities about 11 km (7 miles) apart — one in Minneapolis and one in St. Paul (Fig. F.2). These areas are surrounded by a region of industrial sites and residential housing which links the areas into one continuous

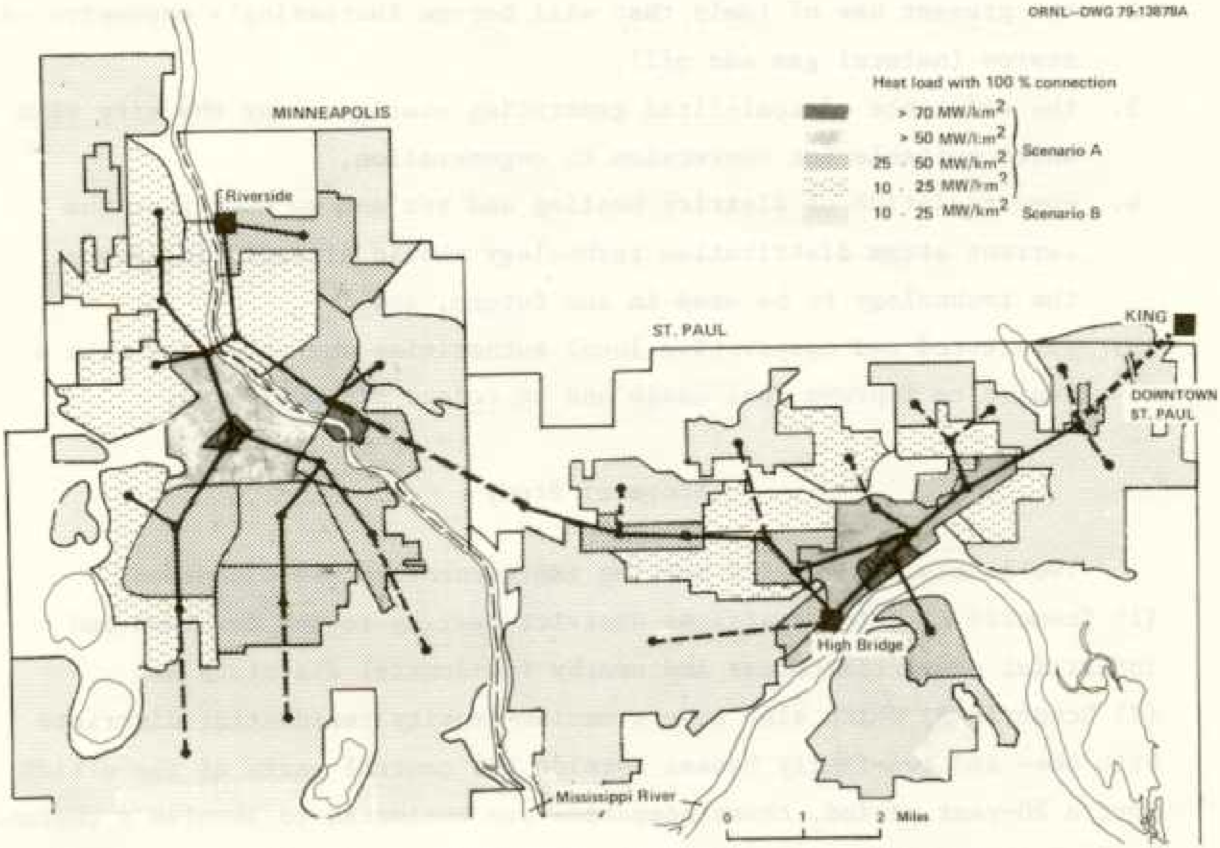

Fig. F.2. Heat-load densities in the Twin Cities area and possible regional piping systems.

metropolitan region. The total metropolitan population of over one million includes 0.8 million within the two city boundaries. This dense population, coupled with the cold climate (>8000 Fahrenheit degree-days), creates a large heat demand.

There are two fairly large coal-fired electric generating stations within the city boundaries — High Bridge for St. Paul and Riverside for Minneapolis (Fig. F.2). A third station, Black Dog, is located about 16 km (10 miles) south of Minneapolis, and several newer coal-fired and nuclear plants outside the metropolitan area exist). The closest of these plants, King [27 km (17 miles) from downtown St. Paul], is also a possible site for another new unit.

The Twin Cities area is a prime candidate for a regional district heating system because of the following attributes:

1. a cold climate and a city structure with a large potential heat load well adapted to district heating,

2. the present use of fuels that will become increasingly expensive and scarce (natural gas and oil),
3. the existence of coal-fired generating stations near the city with units suitable for conversion to cogeneration,
4. some tradition of district heating and yet not so much that the current steam distribution technology should strongly influence the technology to be used in the future, and
5. interested and cooperative local authorities and utilities with a desire to improve fuel usage and to reduce air pollution.

Scope of Study

Two levels of district heating implementation are discussed: (1) Scenario A, which restricts district heating to the downtown and industrial commercial areas and nearby residential districts and (2) Scenario B, which also covers medium-density residential districts with one- and two-family houses outside the central parts of the cities. Over a 20-year period, these scenarios are estimated to involve a thermal load of around 2600 and 4000 MW(t), respectively, for the two scenarios (Fig. F.3).

The 2600 MW(t) for Scenario A excludes the loads of the existing district heating systems in Minneapolis and at the University of Minnesota because more detailed studies on integration of these schemes into the overall scheme are necessary. It also excludes the loads of some large industries that require more study and all loads for new developments within the area. To compensate for the conservatism of these assumptions, it was assumed in the base case that all remaining consumers within the area would subscribe to the service. The influence of a lower effective subscription rate was evaluated separately. For Scenario B, 70% of the potential additional consumers over and above those of Scenario A were assumed to use the service.

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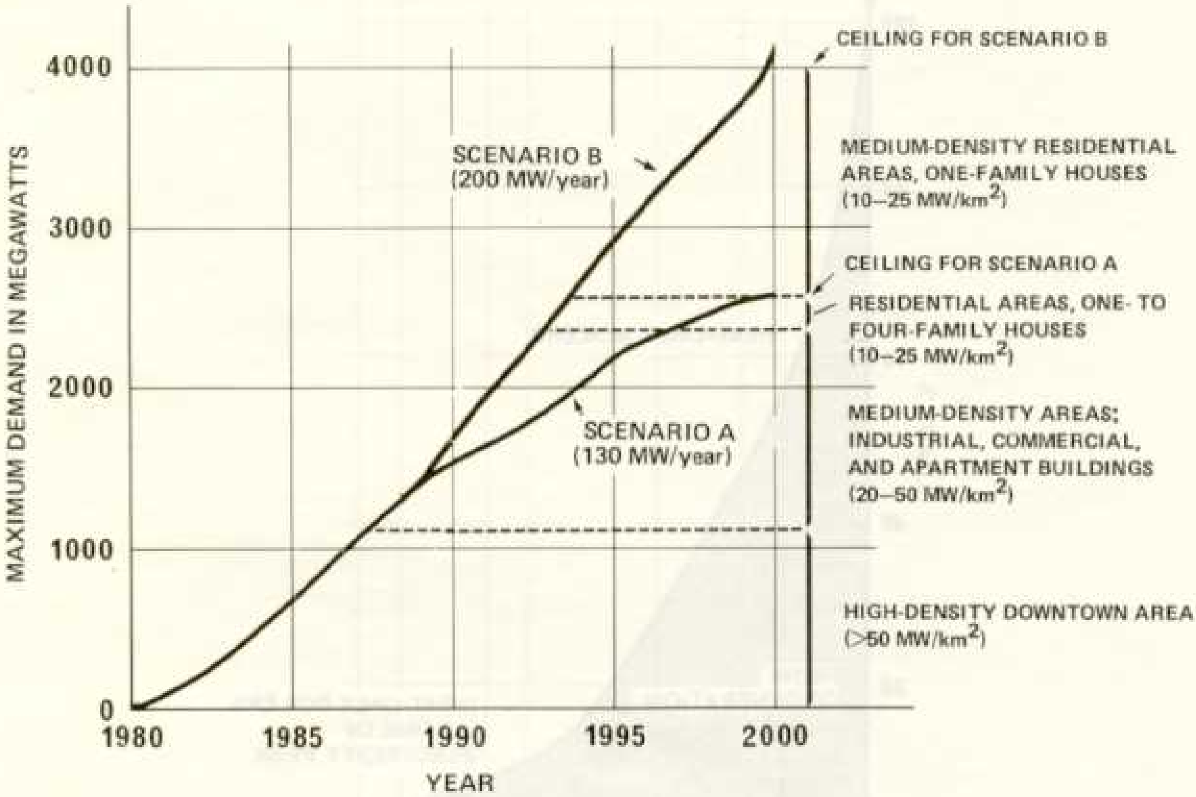

Fig. F.3. Assumed load connection rates for Scenarios A and B.

Principal Features of Proposed Concept

The proposed district heating concept functions as follows:

1. The base load is supplied by cogeneration plants that provide about half the total peak-load capacity but nearly 90% of the annual heat energy (Fig. F.4). Most of the thermal energy from cogeneration units is provided by converting turbogenerators to pass-out machines at two existing power stations — Riverside in Minneapolis and High Bridge in St. Paul. As illustrated in Fig. F.5, this conversion greatly improves fuel utilization. Toward the end of the period, these units would be complemented by new units. A new unit at Riverside is assumed for Scenario A. For Scenario B, two larger units about 27 km (17 miles) from the center of the city area are proposed because it seems impractical to use the existing city

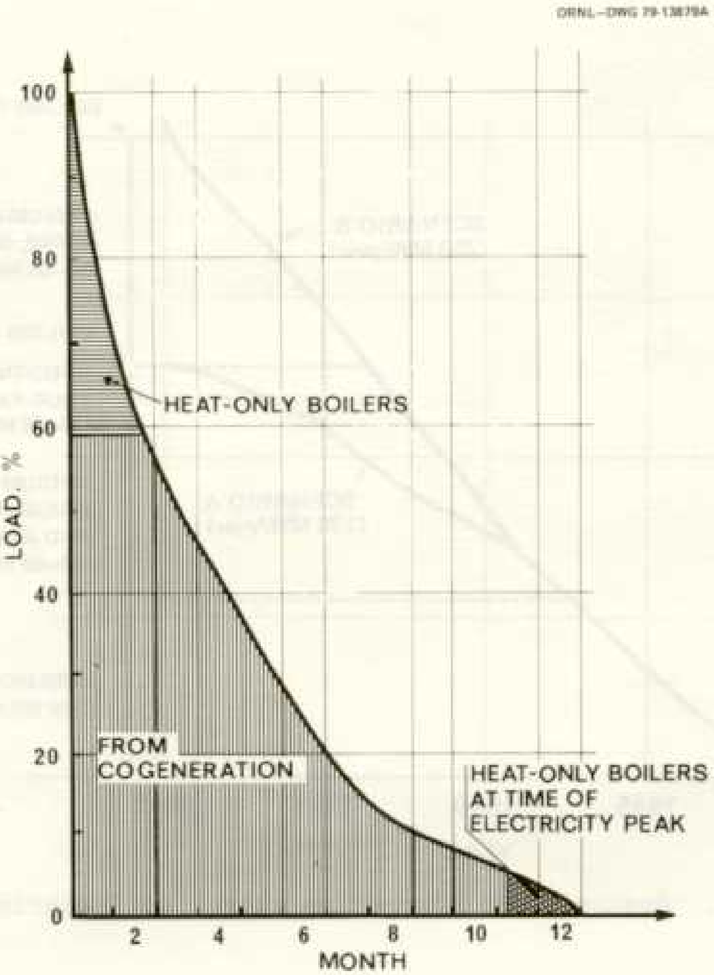

Fig. F.4. Heat-load duration curve and load distribution.

power plants exclusively. The cogeneration plants replace large quantities of oil and gas with small quantities of coal.

2. The peak-load and reserve capacity requirements are supplied by oil-fired, heat-only boilers. These have a large total capacity but supply only a small percentage of the annual heat energy. They are located at various points of the supply area, thus reducing the size of pipes necessary between the central cogeneration plant sites and the supply areas.
3. The heat is transported from the production plants to the various parts of the supply area by hot water mains in accordance with modern European district heating technology. Large pipes run through tunnels for the parts of the area having adequate rock structure. Elsewhere,

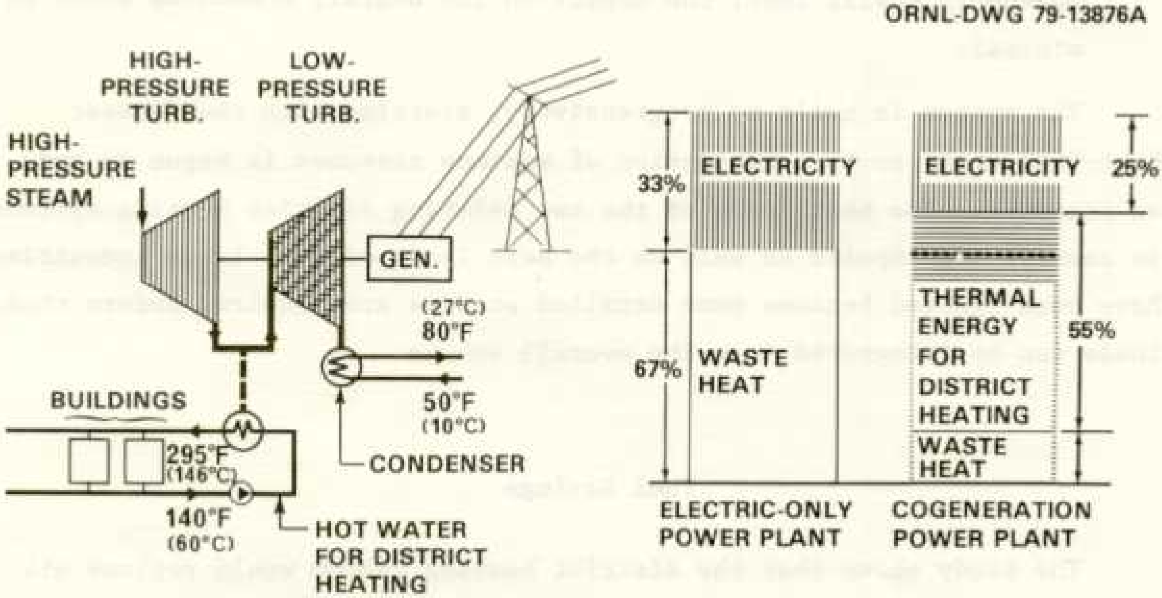

Fig. F.5. Comparison of overall thermal efficiency of electric-only and cogeneration power plants

underground pipes protected by concrete culverts are used. The transport systems are built up separately in Minneapolis and St. Paul initially and then interconnected during the second half of the period.

4. The heat is distributed from the regional system to individual buildings and houses by a hot water distribution system that runs under pavements, under streets, or, where possible, through cellars. Prefabricated pipes complete with insulation and protection ducts are used. For Scenario B, in addition to conventional piping systems, a newer type of piping distribution system for low-heat-density residential areas has been examined.
5. The heating systems of existing buildings are adapted so that they can be connected to the district heating system through heat exchangers. Different conversions are used for buildings and houses currently supplied by hot water, steam, or hot air.
6. The cooling loads were ignored in the analysis. However, in principle, existing absorption chillers could be converted to operate on hot water and could be supplied from the district heating system if certain restrictions are placed on the lowest permissible temperatures for hot water in the summer. The total capacity of such coolers is

presently small; thus, the impact on the overall economics would be minimal.

The system is built up progressively, starting with the densest heat-load areas so that generation of maximum revenues is begun as soon as possible. The heat loads of the two existing district heating systems in central Minneapolis as well as the heat loads of some large industries have been ignored because more detailed studies are required before these loads can be integrated into the overall scheme.

Fuel Savings

The study shows that the district heating system would replace oil and natural gas equivalent to 0.30 and 0.37 EJ (49 and 61 million barrels) of oil for Scenarios A and B, respectively, over the 20-year period studied (Fig. F.6). Without district heating, the amount of fuels used for space heating with respect to the areas for Scenarios A and B is 0.35 and 0.44 EJ (57 and 72 million barrels). After correction for extra coal consumption at the power plants, the net fuel savings are 0.19 and 0.24 EJ (31 and 39 million barrels) of oil respectively. Thus, very substantial contributions to conservation of fuel — particularly the

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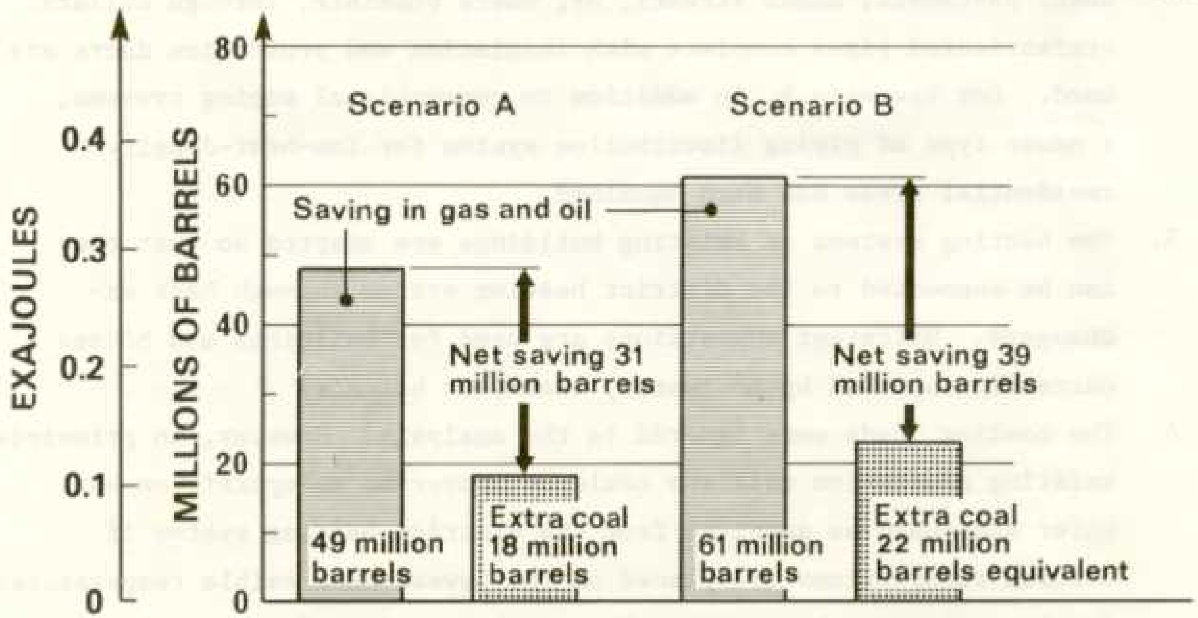

Fig. F.6. Fuel savings realized with district heating, 1980-2000, Scenarios A and B.

scarce fuels — are made. Because the system is developing from "ground zero" during this 20-year period, the fuel savings in the following years will be even greater. Almost as much fuel will be saved in the subsequent 10 years as in the first 20 years.

Economic Results

The total investment, including building conversion, is estimated at 625 million 1978 dollars for Scenario A and 1235 million 1978 dollars for Scenario B. The economic calculation for Scenario A with municipal financing shows that the net savings are negative in the initial years but soon become positive (Fig. F.7). Over the entire period, there is an accumulative net present work savings equivalent to 183 million 1978 dollars. With private utility financing, capital charges are higher, and the accumulated net present worth savings is a negative $77 million over the 20-year period. The sensitivity of the results to changes and assumptions (e.g., fuel costs projections) is also illustrated. With an intermediate financing system, private utility for the production plants, and municipal financing for the piping systems, the net accumulated savings would be only slightly smaller than with municipal financing.

Conclusions

The overall conclusion of the study is that district heating on a regional basis in the Twin Cities area is technically feasible and that large quantities of the potentially scarce and expensive fuels (natural gas and oil) can be saved. The economics are judged to be viable provided a suitable method of financing is used for the transmission and distribution systems.

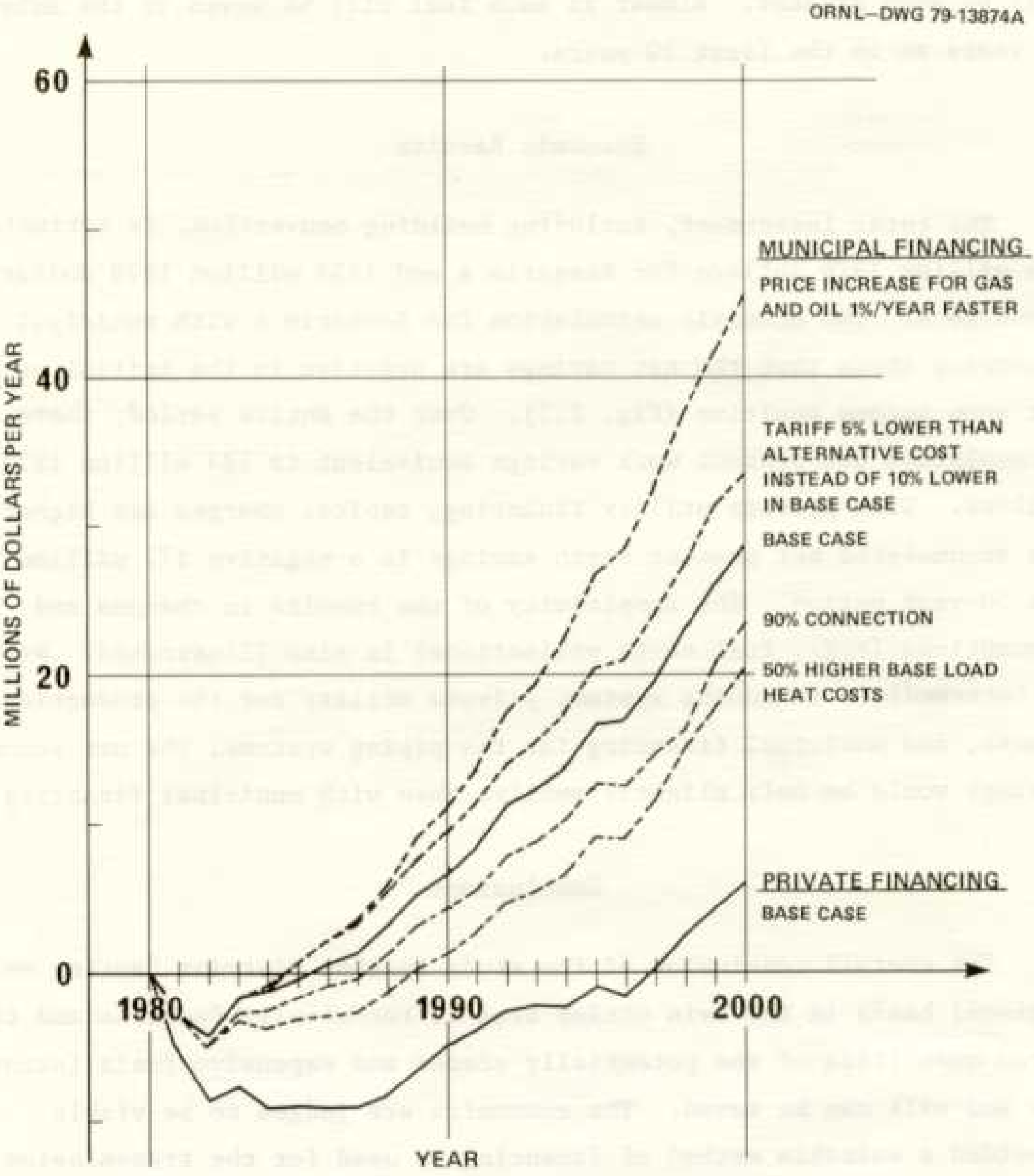

Fig. F.7. Annual net savings in 1978 dollars for Scenario A.

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ABSTRACT

This report presents the results of a study of the costs and techniques required to convert existing buildings in Minneapolis and St. Paul to use 150°C (300°F) hot water district heating. The buildings and heating systems in the high density areas in both downtown Minneapolis and St. Paul were surveyed, and a computer data base was assembled. A total of 280 buildings was surveyed, representing a peak thermal load of about 400 MW. The return-water temperature was selected for minimum cost and maximum power yield at the cogeneration plant.

The cost of converting heating systems in existing buildings to district heating was determined by two separate approaches: theoretical cost studies of heating systems and engineering cost studies of heating systems in existing buildings. In the first approach, cost estimates were generated by designing conversion systems for a range of building sizes for each of the major types of heating systems. In the second approach, engineering cost studies were done for five buildings that were representative of the buildings in the study area. The heating system conversions of the five buildings were designed for three return-water temperatures to determine the effect on conversion costs of varying the water flow rate and the difference between the supply-water temperature and return-water temperature. The conversion costs for the three return-water temperatures can be used to estimate the optimum return-water temperature. Conversion costs were determined from detailed bids submitted by a heating, ventilating, and air conditioning contractor.

1. INTRODUCTION

A study of the costs and techniques required to convert the heating systems in existing buildings in Minneapolis and St. Paul to use 150°C (300°F) hot water district heating was conducted by the Minnesota Energy Agency under contract with the Department of Energy. The objectives of the study were as follow:

- determine the types of heating systems in the study area,
- classify the types of buildings and heating systems in the study area by technical characteristics,
- determine the most economical methods for converting the different types of buildings and heating systems to district heating,
- select specific representative buildings for detailed conversion cost studies and develop engineering specifications and costs for conversion of these buildings to district heating,
- determine the applicability of the general conversion methods to buildings in the city core and to a representative sample of buildings outside the city core,
- provide data on the conversion of existing heating systems and conversion costs to Studsvik Energiteknik (formerly AB Atomenergi) for use in the Twin Cities district heating feasibility study, and
- develop recommendations for future buildings to minimize costs of conversion to district heating systems.

This study will aid in determining the feasibility of a large cogeneration district heating system in the metropolitan Minneapolis and St. Paul area. The feasibility of such a system depends on identifying and defining the major thermal loads. In Minneapolis and St. Paul, the heating loads of the large buildings in the commercial district are most important. Detailed information on the characteristics of existing buildings and their heating and cooling systems is required for this evaluation. Estimates of the cost to convert the different types of heating systems to use district heating are also needed. The conversion of existing buildings from oil- and gas-fired boilers and steam systems to a modern district heating system must be evaluated both technically and economically before building owners will be willing to accept hot water district heating. Standard heating system designs must be developed to minimize the total cost of converting buildings considering the total district heating system.

2. BUILDING AND HEATING SYSTEM CHARACTERISTICS

The design and cost of the systems needed to convert existing building heating systems to use hot water district heating have a direct effect on the economics of the district heating system. There are many different types of heating systems in Twin Cities buildings. Steam is used for heating in most large buildings built before the 1960s. Since the 1960s, many new buildings have been designed with hot water heating. Of course, a hot water heating system is more economical to convert to district heating than is a steam heating system.

A feasibility study must identify the customers who could be connected to the district heating system at reasonable cost. In general, these would be owners of new buildings and existing buildings with hot water or low-pressure steam heating systems. Thus, a thorough survey and study of existing buildings and heating systems was conducted.

2.1 Building Classifications

The heating requirements and energy consumption of a building of a given size are determined both by the activities within the building and the type of construction. The energy use characteristics of buildings can be described by the annual energy use (MWhr or Btu), the peak energy demand or design load (kW or Btu/hr), or the utilization factor (hr/year).

The annual heating energy use is the amount of energy used during a year for space heating, domestic hot water, and process heat. Peak demand is the peak load on the heating system. The utilization factor (U) relates the peak demand to the annual energy use:

$$U = \frac{\text{annual use}}{\text{peak demand}} = \text{hours per year} .$$

Each type of building has a characteristic energy utilization value based on type of use. For this study five categories were considered: industrial (U = 1100 hr), office (U = 1700 hr), hotel (U = 1600 hr), apartment (U = 2000 hr), and others (U = 1700 hr). These utilization hours are typical for Swedish buildings in the same categories. Data from the buildings evaluated as part of this study indicate that buildings in the Minneapolis-St. Paul area have about the same utilization. In many cases, peak-load data is unavailable, and experience must be used to estimate it from boiler capacity or district steam use. The range of utilization values one would expect from a particular class of buildings depends on the type of use. For instance, the utilization value of industrial buildings would depend on the manufacturing operation involved.

2.2 Heating System Classes

Heating systems in existing buildings can be classified by heat source and building internal distribution system (Table 1).

Table 1. Combination of heating systems

Heat source	Building internal distribution system
Hot water boiler	Hot water
Steam boiler	Steam
Steam district heating	Steam
Steam district heating	Hot water
Steam district heating	Forced air
Electric utility	Electric resistance coils and radiators
Furnace gas or oil	Forced air

These seven distinct combinations were useful in developing a method to predict conversion costs and in developing a building and heating system survey. However, many large buildings have more than one type of heating system. For example, some buildings use mainly hot water heating but use steam coils in the ventilation system. As buildings are expanded or renovated, different heating systems are added. In classifying the heating system of a building, it was necessary to consider each of the components. If a building has a steam distribution system, the extent of steam use within the building must be determined: in the boiler room only, in mechanical equipment rooms throughout the building, in all air handling units and induction units, and in the radiators. It must also be determined if steam is used for chilled water generation.

3. BUILDING AND HEATING SYSTEMS SURVEY

The survey portion (Appendix A) of the building conversion study provided detailed information on the characteristics of existing buildings and their heating and cooling systems. A total of 280 buildings in and immediately adjacent to the downtown central business districts of Minneapolis and St. Paul was surveyed. Together, these buildings represent a 400-MW thermal load.

Each building inventoried was classified according to its major use (industrial, office, apartment, hotel, or other). The volume, the number of floors, and the total floor area were also recorded. Building heating systems were classified by type of heating system and by the source of heat. For example, the hot water heating system can have either a hot water or steam boiler or steam district heating system as a heat source. Data were collected on the type and extent of heat distribution systems within the building. To estimate the summer demand for district heating, data were also collected on the size and type of air conditioning equipment in the building.

In Minneapolis, each building surveyed was visited at least once. The building manager or operating engineer was interviewed, and, where possible, the boiler room and mechanical equipment rooms were inspected. Records of fuel and electrical use were used for the survey. In St. Paul, much of this information had already been collected by Northern States Power Company (NSP). Some buildings were visited to confirm the NSP data. The survey was conducted by students majoring in heating, ventilating, and air conditioning (HVAC) from a local vocational technical institute. Before conducting the survey, the students were given instruction in the various types of HVAC equipment commonly found in the buildings surveyed. This instruction included a test by a professional engineer specializing in heating and ventilating equipment, who also accompanied the students on initial surveys of boiler and mechanical equipment in different buildings.

Several unexpected technical and administrative problems were encountered. The technical problems generally related to the complexity of some of the heating systems that had been developed in different stages. Fuel use data in peak periods for domestic hot water heating were difficult to separate from data for space heating and peak period operation. Data for electrical energy used for pumps and resistance heating were frequently difficult to separate from that for the energy used for the general electrical lighting load. Also, many of the buildings have a mixture of air-handling equipment powered by a variety of energy sources.

Administrative problems included delays in getting information, the need to visit several people to get all the necessary information, and multiple visits to a building to get information. In several cases, building managers considered the interview and the information request to be an invasion of privacy by a government agency.

In this survey, buildings were categorized into five classes by use (Table 2). Each building class was divided into seven peak-demand categories. For each peak-demand category, the number of buildings with each type of heating system and average peak loads were determined. The type of air conditioning (electrical or steam absorption) and the average size were identified. Although only 46% of those buildings surveyed had steam heating, they account for nearly 80% of the peak load (Table 3).

Table 2. Building and heating system survey results

Building type and utilization (hr/year)	Peak demand (kW)	Hot air: BDA[a] No.*	Hot air: BDA[a] Average peak	Hot air: BCDA[b] No.	Hot air: BCDA[b] Average peak	District steam: Steam No.	District steam: Steam Average peak	District steam: Hot water No.	District steam: Hot water Average peak	Steam boiler: Steam No.	Steam boiler: Steam Average peak	Steam boiler: Hot water No.	Steam boiler: Hot water Average peak	Hot water boiler No.	Hot water boiler Average peak	Air conditioning: Electric No.	Air conditioning: Electric Average tons	Air conditioning: Steam No.	Air conditioning: Steam Average tons
	4000	1	4,056			2	14,731			2	18,135					5		1	
	3000 to 4000									1	3,857					1			
Industrial	2000 to 3000									1	2,696					1	167		57
	1500 to 2000									1	1,793					1			
(U = 1100 hr)	1000 to 1500					2	1,030			4	1,085					3		1	
	500 to 1000	2	644	1	585					2	744	2	744	2	578	7			
	<500			13	168					3	311					2			
	4000					8	7,997	1	7,997	3	7,587					6		5	
	3000 to 4000					3	3,565			3	3,134					4		1	
Office	2000 to 3000	1	2,436			4	2,440			3	2,188					9			
	1500 to 2000					4	1,660			3	1,782					4	201		135
(U = 1700 hr)	1000 to 1500					5	1,228			5	1,152					8		1	
	500 to 1000			1	514	5	861			3	611	2	611			12			
	<500			15	148	11	226			10	306			1	343	21			
	4000									4	7,455					4			
	3000 to 4000																		
Hotel	2000 to 3000																		
	1500 to 2000																167		
(U = 1600 hr)	1000 to 1500									2	1,205					1			
	500 to 1000			1	583									1	713	1			
	<500	1	390	4	224	1	110			3	318	2	318			4		1	
	4000													1	5,735	1			
	3000 to 4000																		
Apartment	2000 to 3000																397		
	1500 to 2000							1	1,693							1			
(U = 2000 hr)	1000 to 1500			1	1,080									1	1,456				
	500 to 1000			1	540							2	744			2			
	<500			34	222									2	288	2			
	4000	1	9,934			1	4,440			5	8,367					2		2	
	3000 to 4000					1	3,646			2	3,642					4		1	
Other	2000 to 3000	1	2,838									2	2,575	1	2,834	4	340	1	450
	1500 to 2000									3	1,789					3			
(U = 1700 hr)	1000 to 1500			1	1,080											3			
	500 to 1000	1	574	3	605					5	605					2		1	
	<500	3	135	42	172	8	247			7	238	1	238			13		1	
Total		11		117		55		2		75		11		9		128		16	

[a]Buildings in downtown area.

[b]Buildings in or close to downtown area surveyed in less detail.

Table 3. Distribution of types of building heating systems by peak load and number

System category	Load (%)	Number (%)	Peak load (kW) Total	Peak load (kW) Average	Number of buildings
Small buildings					
Air heated	7	42	26,269	224	117
Large buildings					
Air heated	6	4	21,921	1,993	11
Steam heated	79	46	309,643	2,383	130
Hot water heated	8	8	32,725	1,488	22
Total	100	100	390,558		280
Buildings supplied by district steam	39.8	20	155,485	2,728	57

Buildings with air heating systems represent 46% of the buildings surveyed but account for only 13% of the peak load. The number of buildings in each category with each type of heating system varied (Table 4). Only 10% of the buildings surveyed have steam absorption air conditioning. The remainder have electrical or no central air conditioning. There were 117 smaller buildings surveyed. The survey indicated that smaller buildings are heated by air heating units, most of which are gas-fired. Few of these buildings have central air conditioning.

Table 4. Distribution of types of building heating systems for each class of building

Functional category	Air Number	Air Percent	Steam Number	Steam Percent	Hot water Number	Hot water Percent	Total Number	Total Percent
Industrial	17	6.1	18	6.4	4	1.4	39	13.9
Office	17	6.1	70	25.0	4	1.4	91	32.5
Hotel	6	2.1	10	3.6	3	1.1	19	6.8
Apartment	36	12.9			7	2.5	43	15.4
Other	52	15.6	32	11.4	4	1.4	88	31.4
Total	128	45.8	130	46.4	22	7.8	280	100

4. HEATING SYSTEM CONVERSION TECHNIQUES

One of the major concerns in developing the district heating system is proper design of conversion systems for existing buildings. These designs must consider the total district heating system. The importance of designing for as low a return-water temperature as practical is presented in this section along with conversion techniques for each of the types of heating systems. Recommendations of heating system design for future buildings that would be converted to district heating are included (Appendix B). The conversion schematics used were supplied by Erik Wahlman of Theorell & Martin Energikonsulter AB, Sweden (Appendix C).

4.1 Importance of Return-Water Temperature

Each building heating conversion must be designed for the lowest practical return-water temperature. The heat transferred from the district heating water to the building's heating system is proportional to the product of the water flow rate and the difference between the supply-water temperature and return-water temperature. Lower return-water temperatures require lower water flow rates and thus smaller water pipes. Lower return-water temperatures minimize transmission and distribution pipe sizes and maximize power yield at the cogeneration plant. Swedish experience has demonstrated that this principle results in lower overall system costs.

To obtain low return-water temperatures, water from radiator circuits or ventilation units can be used to preheat the cold water to the domestic hot water heat exchanger. If the heating system contains air-handling units, lower return-water temperatures can be achieved by changing the air-handling units. Return-water temperatures from properly selected air-handling units can be as low as 38°C (100°F).

The conversion system must be designed so that all of the hot water passes through the heat exchanger and none of it can bypass to return-water lines. The proper arrangement of valves and bypass is presented in Fig. 1. Water that bypasses the heat exchanger wastes energy.

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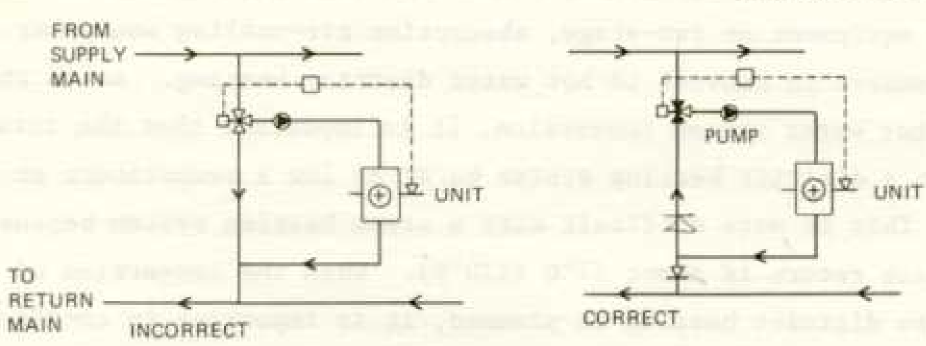

Fig. 1. Flow patterns through building heat exchangers.

4.2 Conversion of Hot Water Heating Systems

The simplest building to convert to hot water district heating is a building with a hot water heating system. It is important to note that the heat supplied to the existing hot water heating system can come either from a steam district heating system or a steam or hot water boiler within the building. The conversion to district heating consists of replacing the heat source with heat exchangers. The flow of hot water from the district heating system is regulated by valves responding to heat requirements in the building heating system.

4.3 Conversion of Steam Heating Systems

District heating water at 150°C (300°F) can produce low-pressure steam in a steam generator at about 135 kPa (5 psig) and 108°C (227°F). Most of the buildings with steam heating systems that were surveyed were designed for low-pressure steam in the heating system. Often the heating systems were designed for steam at a temperature and pressure slightly higher than that produced by a steam generator supplied by 150°C (300°F) water. Frequently, the radiators and air-handling units are oversized, and most will accommodate the heating load when operated at the temperatures and pressures of the steam from a steam generator. An air-handling unit or radiator designed for high-pressure steam must be evaluated to determine if it is oversized. Often, units designed for steam pressures as high as 240 kPa (20 psig) will operate satisfactorily on 135 kPa (5 psig) steam.

Occasionally, high-pressure steam is used for turbine-driven air-cooling equipment or two-stage, absorption air-cooling equipment. These are expensive to convert to hot water district heating. As in the case of the hot water system conversion, it is important that the return water to a district heating system be at as low a temperature as practical. This is more difficult with a steam heating system because the condensate return is about 77°C (170°F). When the conversion of a steam system to district heating is planned, it is important to consider all of the options to reduce the return-water temperature. Lower district heating water temperatures can be obtained by including domestic water heating. Portions of the steam heating system near the equipment rooms often can be economically converted to hot water heating.

The conversion of a typical heating system in a large building to district heating (Fig. 2) requires steam for the air-handling units and hot water for radiators and ventilation units. A steam generator produces steam for the air-handling units, and the return water from the steam generator preheats the water to the domestic hot water heater. Hot water heat exchangers provide hot water for the radiators and ventilation units.

4.4 Conversion of Hot Air Heating Systems

Conversion of existing hot air heating systems can be accomplished by replacing the coils in the air heaters. When district heating becomes common, it is likely that heaters designed to be operated on district heating water will be available and can be substituted for an air heater that operates on natural gas or steam. This use would simplify the conversion and probably reduce the cost.

4.5 Planning for New Buildings

The heating systems of new buildings should be designed so the cost of the eventual conversion to hot water district heating will be minimal (Fig. 3). This can be done by designing a heating system for hot water and sizing each of the components so that they will provide the return-water temperature desired for a district heating system (Table 5).

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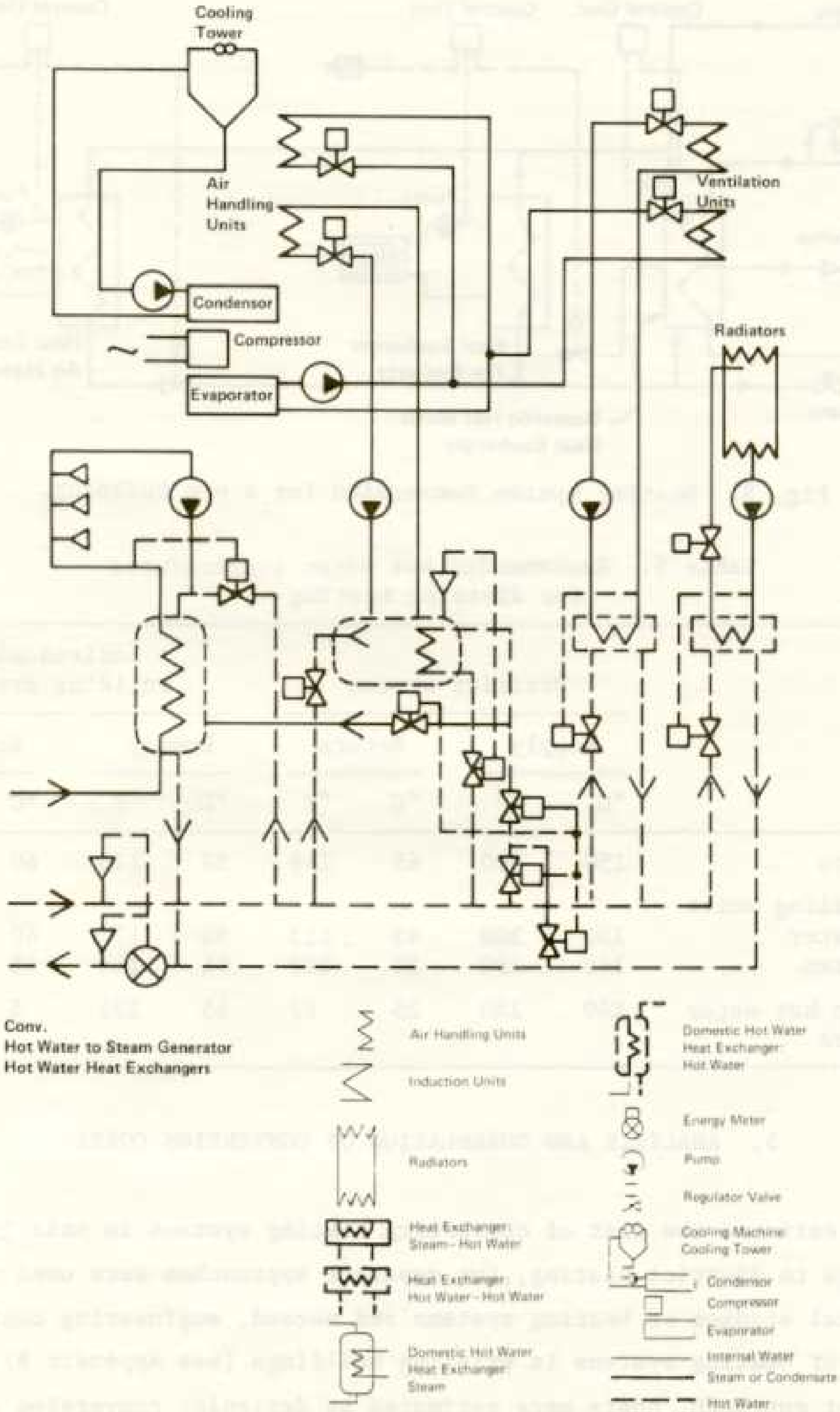


Fig. 2. Building conversion system.

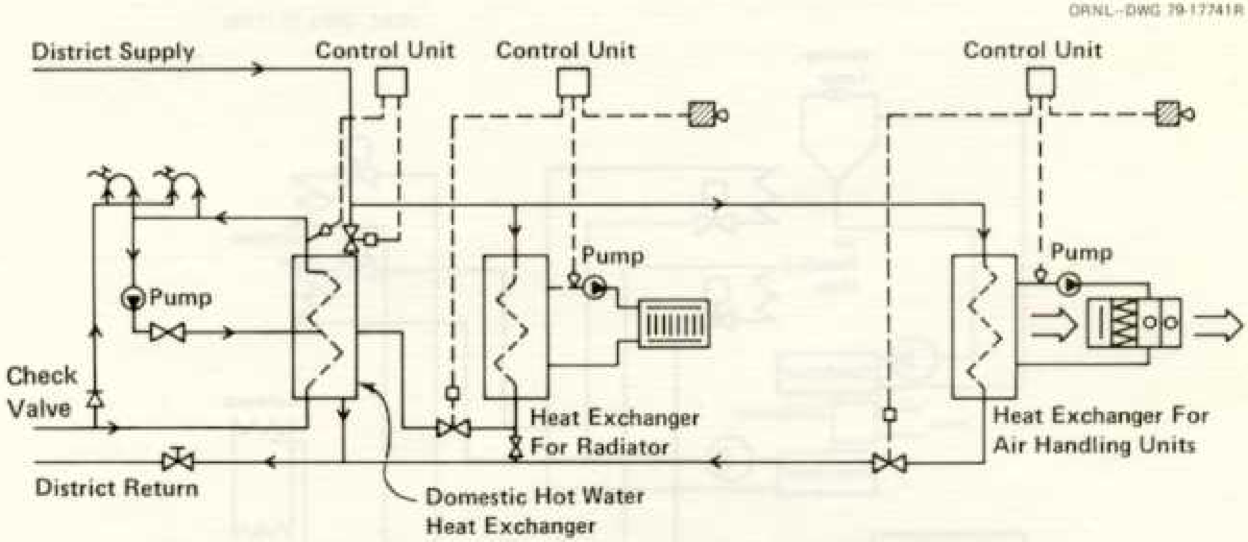


Fig. 3. Heating system conversion for a new building.

Table 5. Recommended hot water temperatures for district heating

	District system				Individual building system			
	Supply		Return		Supply		Return	
	°C	°F	°C	°F	°C	°F	°C	°F
Radiators	150	300	65	149	80	176	60	140
Air-handling units								
Preheater	150	300	45	113	80	176	40	104
Reheater	140	280	50	122	65	144	45	113
Domestic hot water heaters	140	280	25	77	55	131	5	41

5. ANALYSIS AND CORRELATION OF CONVERSION COSTS

To estimate the cost of converting heating systems in existing buildings to district heating, two separate approaches were used — first, analytical studies of heating systems and second, engineering cost studies of heating systems in existing buildings (see Appendix B). In the first approach, costs were estimated by designing conversion systems for a range of building sizes for each of the major types of heating systems. In the second approach, engineering cost studies were done for five buildings that were representative of the buildings in the study area. The results of these two studies were correlated to provide a means of predicting the cost to convert buildings to hot water district heating.

The relation of conversion cost to heating load for the seven heating system schemes (Table 1) was first determined by an analytical study of the heating systems of a hypothetical building. A building configuration was first assumed. The location of a mechanical-equipment room relative to the entrance of district heating supply pipes was considered. The study considered the cost of removing the existing equipment and installing the equipment required for the conversion to district heating. The analysis included piping detail. Cost data was obtained from the reference manual *Means Building Construction Data for 1977* and from equipment manufacturers.

The costs developed in the analytical study are presented as cost per kilowatt of peak load for steam and hot water systems (Fig. 4). Steam heating systems for buildings are basically the same even though they may have different heat sources, so conversion costs are essentially the same. In a similar way different building hot water heating systems are alike enough to have the same conversion costs (Table 1).

Engineering cost studies were done on five representative buildings to better establish conversion costs (Table 6). The buildings were selected by considering the type of heating system, the availability of heating system blueprints, and the size and type of building. Heating system conversions to use 150°C (300°F) hot water from a district heating system were designed for each building, and costs were obtained from bids submitted by HVAC contractors.

The studies of the five buildings were done for three return-water temperatures to determine the effect on conversion costs of varying the water flow rate for the district heating system. The conversion costs for the three return-water temperature levels can be used to estimate the optimum system return-water temperature and the cost penalty for designing to lower return-water temperatures. The three return-water temperatures used were 93, 80, and 60°C (200, 176, and 140°F). For the same heating load, this temperature range between the high and low

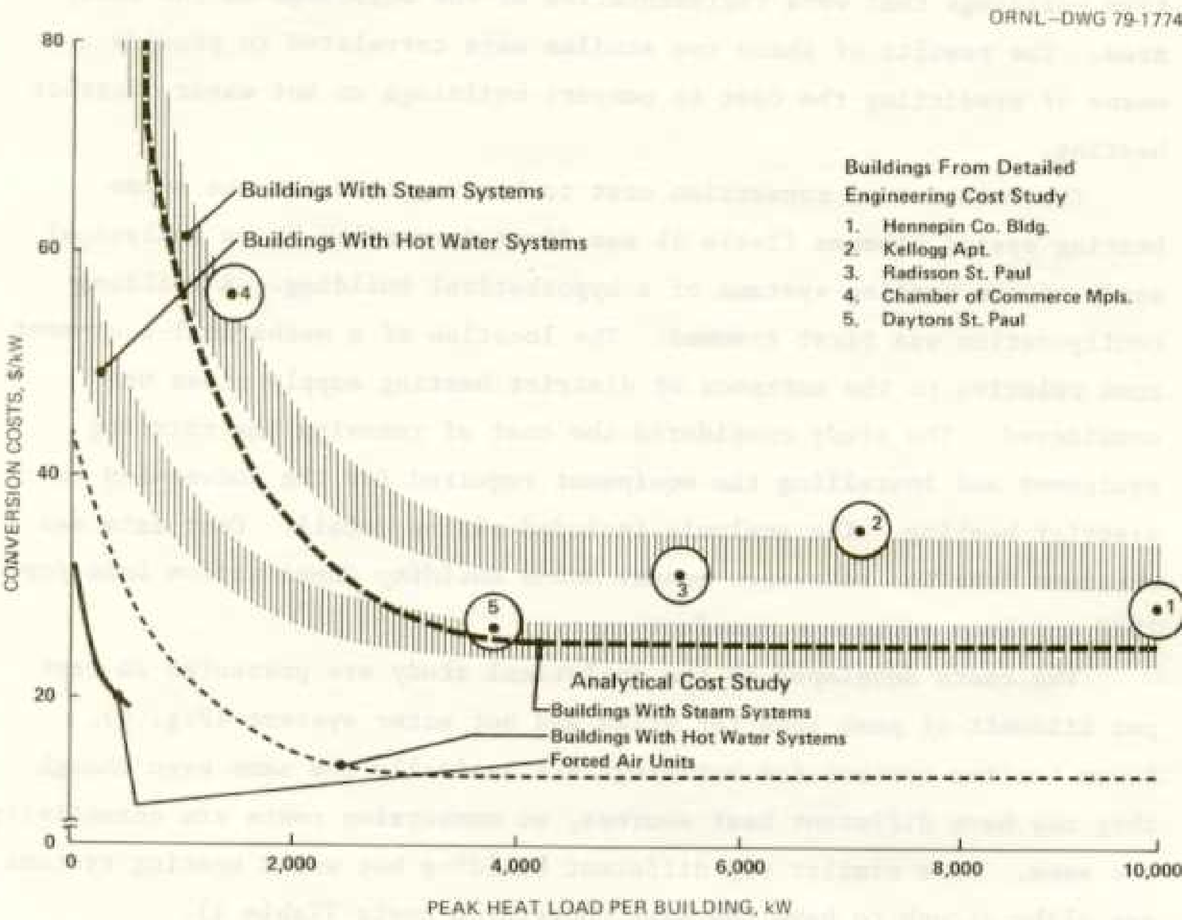


Fig. 4. Heating system conversion cost.

temperatures [93 and 60°C (200 and 140°F)] represents a change of 50% in district-heating-system water flow rate.

6. METHOD TO PREDICT CONVERSION COST

A method to predict the cost to convert existing heating systems to district heating (Fig. 4) was developed by adjusting the trend of conversion costs with building size from the analytical study to the cost levels determined from the engineering cost studies for five representative buildings (Appendix D). A range was established within which it is possible to predict heating system conversion costs for buildings with steam and hot water heating systems (shaded curves on Fig. 4).

Table 6. Heating cost data for five representative buildings

	Building				
	Hennepin County	Kellogg Square	Radisson, St. Paul	Chamber of Commerce	Daytons, St. Paul
Type	Office	Apartment	Hotel	Office	Department store
Heating system	Hot water	Steam[a]	Steam[a]	Steam[a]	Hot water
Gross area, $m^2 \times 10^3$	125	72	113	32	36
($ft^2 \times 10^3$)	(1,350)	(780)	(1,217)	(344)	(388)
Gross volume, $m^3 \times 10^3$	664	400	480	113	154
($ft^3 \times 10^3$)	(23,452)	(14,000)	(17,032)	(4,131)	(5,432)
Annual energy use					
MWhr	16,100	14,360	8,793	2,725	4,400
(Btu $\times 10^6$)	(55,000)	(49,000)	(30,000)	(9,300)	(15,000)
$kWhr/m^2$	128	200	78	85	122
(Btu/ft^2)	(41)	(63)	(25)	(27)	(37)
$kWhr/m^3$	24	35	18	23	28
(Btu/ft^3)	(2.4)	(3.5)	(1.8)	(2.3)	(2.8)
Connected design load					
kW	14,000	10,800	12,000	2,000	5,900
(Btu/hr)	(47.5×10^6)	(37×10^6)	(41×10^6)	(7×10^6)	(20×10^6)
Peak demand					
kW	10,200	7,000	5,400	1,400	3,800
(Btu/hr)	(35×10^6)	(24×10^6)	(18.5×10^6)	(5×10^6)	(13×10^6)
Use, hr	1,570	2,042	1,622	1,860	1,155
Conversion cost estimate[b]					
$\$ \times 10^3$	292	240	171	83.4	102.4
\$/kW	28.51	34.15	31.56	56.92	26.77

[a] Low pressure.

[b] For a 140°F return water.

The costs predicted by the analytical study are lower than the costs from the engineering cost studies for two reasons. First, the analytical study does not include the unique problems encountered in an actual building. Second, the theoretical study was done for a high return-water temperature while the engineering cost studies were done for an optimum return-water temperature of 60°C (140°F).

It is recommended that the data from the analytical study be used to predict conversion costs for buildings heated by hot air systems. An engineering cost study was not done for a building heated by a hot air system. The costs from the analytical study can apply to hot air systems since these systems are the simplest to convert. The buildings heated by hot air systems were only a small part of the heating load surveyed.

Additional data from engineering cost studies of the five representative buildings is presented below.

6.1 Hennepin County Government Center Building

- Office building
- Supplied by district steam
- Hot water in the building
- Peak demand of 10,255 kW
- Annual use of 16,100 MWhr

This county center building is a two-tower structure, 24 stories high, with an open atrium dividing the administrative tower and court tower. The building is used for offices, court rooms, and public service. The present heating requirements include heating domestic water from 4 to 60°C (40 to 140°F) and supplying the ventilation systems with 99°C (210°F) water from a closed-loop circulation system. The water returns at 77°C (170°F). The heat for the hot water heating system is provided by district steam at 1900 kPa (260 psig). Chilled water is supplied for air conditioning from a district distribution system.

6.2 Kellogg Square Building

- Apartment building (554 apartment units, 19 townhouses, and some commercial spaces)

- Steam boiler
- Steam heating system
- Peak demand of 7030 kW
- Annual use of 14,360 MWhr

This 32-story apartment-townhouse complex, located in St. Paul, has 554 one- and two-bedroom apartments and 19 townhouses. The total area of the building is 72,000 m^2 (780,000 ft^2). The lower three floors are used for commercial and office space.

The building is heated by low-pressure steam supplied from two 450 kW (600-hp) boilers in the main boiler room. The steam is distributed to various parts of the building from the main steam header. It services blast unit heaters for entrances, preheat ventilation coils, heating coils, domestic hot water heat exchangers, and steam-to-water heat exchangers for radiation reheat and fan-coil systems. The summer load is principally domestic hot water and reheat. Two centrifugal electric chillers located in the boiler and equipment room generate 4700 kW (1340 tons) of refrigeration. Chilled water is distributed to central air units and fan coils.

6.3 Radisson St. Paul

- Hotel
- Supplied by district steam
- Steam system
- Peak demand of 8793 kW
- Annual use of 5,240 MWhr

This 23-story hotel, located in St. Paul, has a floor area of 113,000 m^2 (1,220,000 ft^2) in a total building volume of 480,000 m^3 (17,000,000 ft^3). Five percent of the floor area is below grade. The present heating system is low-pressure steam supplied to indirect hot water heating exchangers, domestic water, and ventilation air units. The building uses steam at 240 kPa (20 psig) and 127°C (260°F) from the St. Paul district steam distribution system.

6.4 Chamber of Commerce

- Office building
- Supplied by district steam
- Steam heating system
- Peak demand of 1465 kW
- Annual consumption 2,795 MWhr

This 12-story office building, located in Minneapolis, has 32,000 m^2 (344,000 ft^2) of floor area and a volume of 113,000 m^3 (4,000,000 ft^3). Three floors are below grade. The building is a typical small office structure. The original construction, started in 1923, has been modified continually including conversion to a district heating steam system in 1954. An indirect hot water system supplies 32°C (90°F) water to ventilation units. Three high-velocity air-handling systems supply conditioned air to the basement and first five floors. These systems receive steam, hot water, or chilled water. The sixth through twelfth floors have individual equipment rooms housing multizone fan units. Each unit receives chilled or hot water depending on seasonal demand.

6.5 Daytons St. Paul

- Department store
- Hot water boiler
- Hot water system
- Peak demand of 3823 kW
- Annual consumption of 4,400 MWhr

This five-story merchandising department store has 36,000 m^2 (390,000 ft^2) of area and a volume of 154,000 m^3 (5,440,000 ft^3). The main mechanical equipment room is a penthouse. It houses two 400-hp hot water boilers, each with a capacity of 2.5 m^3/min (664 gal/min). The penthouse equipment room also houses air-handling units, and domestic water and snow-melting equipment.

6.6 Discussion of Conversion Systems

Both the Hennepin County building and the Daytons St. Paul building use hot water in their existing systems. In the design study, the boilers in these two buildings were replaced with heat exchangers. The design study was done for three return-water temperatures: 93, 80, and 60°C (200, 176, and 140°F). In the Hennepin County building it would not be practical to reduce the return-water temperature below 60°C (140°F), because that would require changing the coils in more than 100 air-handling units. This probably could not be economically justified. The snow-melting system in the Daytons building is designed to operate with 54°C (130°F) inlet water and a return-water temperature of about 43°C (110°F). A more thorough study would determine if this system could be operated at a lower return-water temperature without interfering with the snow-melting operation.

The Kellogg Square, Radisson, and Chamber of Commerce buildings are now heated with low-pressure steam. The conversion systems designed for these buildings used a steam generator. The steam produced from the steam generator is at about 135 kPa (5 psig) and 108°C (227°F). Some of the air-handling units at the Radisson Hotel are designed for 240 kPa (20 psig) steam at 125°C (257°F). These air-handling units are oversized and would provide the required heat load at the lower temperature. For instance, the connected design load at the Radisson is about 12 MW (40×10^6 Btu/hr), and the peak demand is only about 6 MW (20×10^6 Btu/hr).

The conversion costs (Table 7), in the case of the Hennepin County building, for a larger heat exchanger required for lowering return-water temperature to 60°C (140°F) is more than compensated for by the lower cost for piping. The cost penalty paid for converting to the lowest return-water temperature is small in all five cases (Table 7).

Heat exchangers used in the design study are American made. These heat exchangers are probably not sized and designed specifically for district heating applications. It has been determined that Swedish heat exchangers could be used at about half the price. When hot water district heating becomes established in the United States, heat exchangers designed for district heating should be available.

Table 7. Conversion costs ($/kW) for major cost categories in five representative buildings from the Twin Cities areas

	Building									
	Hennepin Company building (10,255)[a]		Kellogg Square (7,030)[a]		Radisson (5,420)[a]		Chamber of Commerce (1,465)[a]		Daytons (3,823)[a]	
Return water, °C (°F)	100 212	60 140	100 212	75 168	100 212	72 162	100 212	74 166	100 212	60 140
Labor	3.64	3.96	6.54	7.17	2.15	4.10	8.40	7.38	5.92	5.02
Heat exchangers	3.66	7.96	15.05	9.62	10.00	7.79	10.36	11.20	4.13	4.18
Piping	7.16	4.34	3.29	3.91	5.55	7.47	15.59	12.35	4.76	4.34
Demolition	1.32	1.33	1.71	1.84	.28	.98	8.63	8.63	3.14	3.14
Insulation	2.92	2.92	2.84	3.10	1.14	1.94	4.78	3.75	3.14	3.09
Temperature control	5.18	4.43	4.78	5.41	3.83	5.60	8.60	7.51	4.33	3.51
Total	23.88	24.94	34.21	31.05	22.95	27.89	56.37	50.82	25.42	23.28
Mark up	3.47	3.57	3.41	3.10	2.75	3.67	6.76	6.10	3.82	3.49
Total price	27.35	28.51	37.62	34.15	25.70	31.56	63	56.92	29.25	26.77
New heat exchangers sized from Swedish experience		4.00		5.00		4.00		6.00		2.20
Total price-adjusted heat exchangers sized from Swedish experience		24.50		29.53		27.77		51.72		24.79

[a]Peak heating load (kW).

7. CONCLUSIONS

These studies indicate that a building heated by steam is more expensive to convert to district heating than a building heated by hot water. New buildings that will eventually be converted to district heating should be designed for hot water heating systems. These heating systems should be designed for as low a return-water temperature as practical.

The design and cost studies of five representative buildings provided a significant amount of information on the cost and methods for conversion to district heating. However, a larger sample is needed over a larger range of building sizes and heating systems to substantiate cost predictions.

Appendix A

BUILDING HEATING SURVEY FORM

MINNESOTA ENERGY AGENCY

DISTRICT HEATING SURVEY

Date ____________________ Interviewer ____________________

Firm or owner ____________________ Phone ____________________

Address of facility surveyed ____________________

Person Interviewed ____________________

A. Building Data

1. Type of Building ____________%
   a. Office Building ____________%
   b. Industrial ____________%
   c. Shopping Center ____________%
   d. Storage ____________%
   e. Library ____________%
   f. Parking ____________%
   g. Schools ____________%
   h. Post Office ____________%
   i. Hospital ____________%
   j. Hotel ____________%
   k. Other ____________ ____________%

2. Floor area ____________
3. Length ____________ Width ____________
4. Volume ____________
5. # of Stories ____________
6. % Building Below Grade ____________
7. % Surface glass (Normal 30%) ____________
8. Double pane ____________
   Single pane ____________

CODE NO. ____________________

Domestic Hot Water Heaters | Capacity In

1. Steam ____________
2. Hot water ____________
3. Gas fired ____________
4. Electric ____________
5. Oil fired ____________

Name ______________________ Serial # ____________________________

Air Conditioning | Size in Tons

1. Direct expansion reciprocating compressor ____________
2. Water chiller (reciprocating compressor) ____________
3. Steam Absorption water chiller ____________
4. Hot water absorption water chiller ____________
5. Electric centrifugal water chiller ____________

If unable to get size what is Model # and Manufacturer

Heating ____

____

____

Air Conditioner ____

____

____

Hot Water ____

____

____

Air Handling Equip. ____

____

____

A. Type of Fuel

	Annual Consumption 1976	Annual Consumption 1977	Max. Hourly Consumption
Oil Fuel #______	______	______	______
Steam	______	______	______
Gas	______	______	______
Electrical	______	______	______

B. Any other large uses for power which could be converted to District Heating

____

____

Amount and Temp. needed ______________________ Degree (f^{o})__________

C. At what temp. are the present boilers producing steam of hot water

______________________________ Degree F^{o}

D. Is there an outdoor temp. correction control? ____________________

E. Is there presently an energy conservation program or one planned?

____

F. Is any major remodeling planned?______________________________

II. Present Heating System (Please circle and fill in size. If combination, put % of each).

A. Air System — Size (Btu)

1. Gas fired furnace (inside) ________
2. Oil fired furnace (inside) ________
3. Roof top unit (gas fired) ________
4. Roof top unit (oil fired) ________
5. Roof top unit (electric coil) ________
6. Roof top unit (steam coil) ________
7. Roof top unit (hot water coil) ________
8. Air handling units (inside with steam coil) ________
9. Air handling units (inside with hot water oil) ________
10. Air handling units (inside with electric coil) ________

B. Steam System

1. Steam Boilers — Boiler (H.P.) ________
   a. gas fired — # of boilers ________
   b. gas fired — Pressure (P.S.I.) ________
   c. combination gas, oil fired
2. Steam Boilers Converted to Hot Water Boiler (H.P.) ________
   for Radiation and Coils in Air — # of boilers ________
   Handling Units — Pressure (P.S.I.) ________
3. Steam Boilers Converted to Hot Water Boiler (H.P.) ________
   for Radiation but using Steam in — # of boilers ________
   Coils for Air Handling Unit — Pressure (P.S.I) ________
4. Steam Boilers using Steam for Radiation Boiler (H.P.) ________
   and Steam Coils for Air Handling Units # of boilers ________
   Pressure (P.S.I.) ________

C. Hot Water System

1. Hot Water Boiler using Hot Water — Boiler (H.P.) ________
   # of boilers ________
   Pressure (P.S.I.) ________

D. District Steam System

1. Used Direct for Steam Radiation and Coils in Air Handling Units ________
2. Converted to Hot Water for Radiators and Coils in Air Handling Unit ________
3. Converted to Hot Water for Radiation but using Steam for Coils in Air Handling Units ________

Appendix B

A THEORETICAL STUDY OF DISTRICT HEATING CONVERSION METHODS AND COSTS FOR EXISTING BUILDINGS

A THEORETICAL STUDY OF DISTRICT HEATING CONVERSION METHODS AND COSTS FOR EXISTING BUILDINGS

PART I: HEATING SYSTEM CONVERSION TECHNIQUES

I hereby certify that this plan, specification or report was prepared by me or under my direct supervision and that I am a duly Registered Professional Engineer under the laws of the State of Minnesota.

V. E. Stelmack

Date: 2-10-78 Reg. No. 3774

Heating System Classification

Heating systems have been classified by existing heat source, type of existing heating system, type of existing air conditioning system, and type of existing domestic hot water heating equipment, as follows:

CL.	HEAT SOURCE	HEATING SYSTEM	DOMESTIC HOT WATER EQUIPMENT	AIR CONDITIONING EQUIPMENT
1	Hot water boiler	Hot water	Hot water heat exchanger Gas Electric	Hot water absorption water chiller Electric water chiller Electric direct expansion
2	Steam boiler	Steam	Steam heat exchanger Gas Electric	Steam absorption watter chiller Electric water chiller Electric direct expansion
3	Steam district heating	Steam	Steam heat exchanger Gas Electric	Steam absorption water chiller Electric water chiller Electric direct expansion
4	Steam district heating	Hot water	Steam heat exchanger Gas Electric	Steam absorption water chiller Electric water chiller Electric direct expansion
5	Steam district heating	Forced air	Steam heat exchanger Gas Electric	Steam absorption water chiller Electric water chiller Electric direct expansion
6	Electric utility	Elec. resist coils and rads	Electric Gas	Electric chilled water Electric direct expansion
7	Furnace Gas or Oil	Forced air	Electric Gas Oil	Electric direct expansion

METHODS OF CONVERSION 260°F hot water (Minimum Cost to Building Owner)
Classification #1
Remove existing hot water heating boiler and install new water to water heat exchanger or exchangers with connections to district high temperature water system.

Heating system conversion (260°F Hot Water)
The existing hot water heating circulation system shall be utilized with connections made to the low temperature side of the heat exchanger. A water temperature control on the heat exchanger is to be provided to maintain water temperature consistent with the existing system. If the existing circulation system has more than one zone, the temperature of the heat exchanger shall be maintained at a fixed temperature high enough to satisfy all zones. Individual zone water temperatures are to be controlled by use of three-way mixing valves. In all cases, for fail safe provisions, the control valves on the high temperature water and low temperature water shall normally be closed to prevent overheating in the low temperature water system in the event of central control air or electricity failure. Also, to prevent overheating, a high limit control should be located in the low temperature water system to bleed off the control air line to the normally closed valves. In either single zone or multiple zone systems, the low temperature water zones shall be provided with variable temperature controls which respond to outdoor temperature which varies the low temperature water inversely with the outdoor temperature in accordance with a set schedule.

Domestic water heater conversion (260°F Hot Water)
The existing gas fired or electric domestic water heaters are to be removed and replaced with a water to water heat exchanger, directly connected to the district high temperature water system. Temperature control of domestic hot water shall be maintained at the desired temperature by the use of a remote bulb transmitter located inside the drum of the heat exchanger, connected the controlling receiver which in turn is connected to a normally closed control valve on the district high temperature water supply.

In the event the domestic hot water is now heated by a water to water heat exchanger, it probably can be reused with the addition of controls as explained above.

Air conditioning conversion (260°F Hot Water)
Conversion of an existing hot water absorption water chiller can be accomplished by disconnecting the hot water supply to the absorption unit and reconnecting directly to the district high temperature water supply. The existing controls would be reused. The existing cooling tower will continue to be used.

Conversion of an existing electric water chiller will require complete removal of chiller and a new hot water absorption unit installed in its place connected directly to district high temperature water supply along with new controls on the hot water side. The existing chilled water circulation system will be maintained and connected to the chilled water side of the hot water absorption unit. The controls on the chilled water side are to be changed so as to be compatable with the absorption unit control system. The existing cooling tower and condenser water piping shall be removed and a new cooling tower and condenser water piping of the capacity required for the absorption unit along with the new condenser water pump and controls shall be installed.

Conversion of an electric direct expansion air conditioning system will require the removal of the refrigeration compressor unit or units, the direct expansion cooling coils, the air cooled condenser or cooling tower. A new hot water absorption unit will be installed and connected to the district high temperature water supply system. New chilled water coils will be installed in place of the direct expansion cooling coils connected to the new absorption unit by a new chilled water circulation system including circulating pump and controls. A new cooling tower, condenser water piping, pump and controls will be installed.

Classification #2 (260°F Hot Water)
Remove existing steam heating boiler and install new water to steam heat exchanger or exchangers with connections to district high temperature water system. It should be noted that the maximum steam pressure obtained when using 260°F water in the exchanger will be approximately 3 P.S.I.G.

Heating system conversion (260°F Hot Water)
The existing steam heating piping system and radiation shall be utilized with a steam connection made to the steam supply connection on the heat exchanger. The condensate return connection to the heat exchanger shall be made from the existing condensate pump. Pressure control shall be provided to maintain the proper steam pressure at heat exchanger. The existing temperature control system for the building can be used without any change. Control valves installed on the district high temperature water system will be of the normally closed type to prevent overheating in the event of central control air or electricity failure.

In some cases the 3 P.S.I.G. steam pressure will not be high enough to provide the proper amount of steam to the radiation and steam coils in the ventilation system. If higher pressure steam (5 P.S.I.G. to 12 P.S.I.G.) is required, a steam pressure booster pump shall be provided in the steam supply system.

Domestic water heater conversion (260°F Hot Water)
If the existing domestic water heater uses steam as the water heating medium of a pressure compatible with the new water to steam heat exchanger, it shall be reused with the steam connection made to new heat exchanger. The existing steam regulating valve controlling domestic water temperature will also be reused.

In the event that gas fired or electric water heaters are now used for domestic hot water, they shall be removed and replaced with a water to water heat exchanger, directly connected to the district high temperature water system. The controls for maintaining domestic water temperature are to be as explained under Classification #1.

Air conditioning conversion (260°F Hot Water)
If the existing water chiller for the air conditioning system is a steam absorption water chiller, the water chiller cannot operate on 3 P.S.I.G. steam as provided by the water to steam heat exchanger. The existing steam absorption water chiller would have to be converted to a hot water absorption unit. This conversion would be accomplished by certain modifications to the chiller and then directly connected to the district high temperature water system, complete with proper controls on the incoming hot water supply. The existing cooling tower and pump will continue to be used. An alternate to the conversion above would be to install a steam pressure booster pump to provide the proper steam pressure required for the operation of the steam absorption unit.

Conversion of an existing electric water chiller or electric direct expansion air conditioning system will be accomplished as explained under Classification #1.

Classification #3 (260°F Hot Water)
Conversion of a steam heated building served by a district high pressure steam system can be accomplished by removing the existing steam pressure reducing valve assembly and converting the system to the system explained under Classification #2 utilizing the existing condensate return pumps to return the condensate to the new water to steam heat exchanger.

Domestic hot water conversion and air conditioning conversion shall be accomplished as explained in Classification #2.

Classification #4 (260°F Hot Water)
Conversion of a building heated by hot water served by a district high temperature steam system can be accomplished by removing the existing steam pressure reducing valve assembly, condensate pump and steam to hot water convertor, and converting the system as discribed in Classification #1.

In some cases in a building served by district steam and heated by hot water, the coils in the ventilation system are supplied with low pressure steam. In this case, a water to steam heat exchanger shall be installed adjacent to the heat exchanger serving the hot water heating system. The existing steam condensate pump can be reused in this system to return the condensate to the new water to steam heat exchanger. If steam at 3 P.S.I.G. does not have the necessary pressure to provide the coils with enough steam capacity, a steam pressure booster pump shall be provided in the steam supply system.

Domestic hot water conversion and air conditioning conversion shall be accomplished as described in Classification #1.

Classification #5 (260°F Hot Water)
Conversion of a building heated by forced air with coils in the system supplied by a district high pressure steam system can be accomplished by removing the pressure reducing valve assembly and provided with a water to steam heat exchanger as described under Classification #2.

Domestic hot water conversion and air conditioning conversion shall be accomplished as described in Classification #2.

Classification #6 (260°F Hot Water)
Conversion of an all electric heating system using electric resistance type radiation and electric resistance type coils in the ventilation system to a system using a district high temperature water system requires a complete change of the heating and temperature control system.

All existing electric resistance type radiation shall be removed and replaced with hot water type radiation and a completely new hot water heating piping system with circulating pumps and appropriate temperature control.

Classification #7 (260°F Hot Water)
Remove existing gas or oil fired furnace and install new air handling unit with hot water heating coil, blower, filters, etc., with connections to district high temperature water system.

Heating system conversion (260°F Hot Water)
The air duct system shall be utilized with duct connections made to new air handling unit. The existing temperature controls to the removed and new controls installed controlling new hot water heating coil and blower.

Domestic water heater conversion (260°F Hot Water)
The existing gas fired, oil fired or electric water heaters shall be removed and replaced with a water to water heat exchanger complete with controls as explained under Classification #1.

Air conditioning conversion (260°F Hot Water)
The air conditioning systems in this classification are probably in the range of 2 to 25 ton capacity and utilizing direct expansion condensing units and direct expansion coils. Under this classification, the direct expansion condensing unit would be continued in use and existing direct expansion coils removed from existing furnace and installed in new air handling unit.

METHODS OF CONVERSION 200°F Hot Water (Minimum cost to building owner)
Classification #1 (200°F Hot Water)
Remove existing hot water heating boiler and install new water to water heat exchanger or exchangers with connections to district high temperature water system.

Heating System Conversion
The existing hot water heating circulation system shall be utilized with connections made to the low temperature side of the heat exchanger. A water temperature control on the heat exchanger is to be provided to maintain water temperature consistent with the existing system. If the existing circulation system has more than one zone, the temperature of the heat exchanger shall be maintained at a fixed temperature high enough to satisfy all zones. Individual zone water temperatures are to be controlled by use of three-way mixing valves. In all cases, for fail safe provisions, the control valves on the high temperature water and low temperature water shall normally be closed to prevent overheating in the low temperature water system in the event of central control air or electricity failure. Also, to prevent overheating, a high limit control should be located in the low temperature water system to bleed off the control air line to the normally closed valves. In either single zone or multiple zone systems, the low temperature water zones shall be provided with variable temperature controls which respond to outdoor temperature which varies the low temperature water inversely with the outdoor temperature in accordance with a set schedule.

Domestic Water Heater Conversion (200°F Hot Water)
The existing gas fired or electric domestic water heaters are to be removed and replaced with a water to water heat exchanger, directly connected to the district high temperature water system. Temperature of domestic hot water shall be maintained at the desired temperature by the use of a remote bulb transmitter located inside the drum of the heat exchanger, connected to the controlling receiver which in turn is connected to a normally closed control valve on the district high temperature water supply.

In the event the domestic hot water is now heated by a water to water heat exchanger, it probably can be reused with the addition of controls as explained above.

Air Conditioning Conversion (200°F Hot Water)
Conversion of an existing hot water absorption water chiller with an entering water temperature of 190° F can be accomplished by disconnecting the existing hot water supply to the absorption unit and reconnecting directly to the district heating water supply. The existing controls would be reused. The existing cooling tower will continue to be used.

Conversion of an existing electric water chiller will require complete removal of the chiller and a new hot water absorption unit installed in its place connected directly to district heating water supply along with new controls on the hot water side. The existing chilled water circulation system will be maintained and connected to the chilled water side of the hot water absorption unit. The controls on the chilled water side are to be changed so as to be compatible with the absorption unit control system. The existing cooling tower and condenser water piping shall be removed and a new cooling tower and condenser water piping of the capacity required for the absorption unit along with the new condenser water pump and controls shall be installed.

Conversion of an electric direct expansion air conditioning system will require the removal of the refrigeration compressor unit or units, the direct expansion cooling coils, the air cooled condenser or cooling tower. A new hot water absorption unit will be installed and connected to the district hot water supply system. New chilled water coils will be installed in place of the direct expansion cooling coils connected to the new absorption unit by a new chilled water circulation system including circulating pump and controls. A new cooling tower condenser water piping, pump and controls will be installed.

<u>Classification #4</u> (200°F Hot Water)
Conversion of a building heated by hot water served by a district high temperature steam system can be accomplished by removing the existing steam pressure reducing valve assembly, condensate pump and steam to hot water convertor, and converting the system as described in Classification #1.

<u>Domestic Water Heater Conversion</u> (200°F Hot Water)
The existing steam, electric or gas fired domestic water heaters are to be removed and replaced with a water to water heat exchanger, directly connected to the district hot water heating system. Temperature of domestic hot water shall be maintained by the use of a remote bulb transmitter located inside the drum of the heat exchanger, connected to the controlling receiver which in turn is connected to a normally closed control valve on the district hot water heating supply.

<u>Air Conditioning Conversion</u> (200°F Hot Water)
If the existing water chiller for the air conditioning system is a steam absorption water chiller, the chiller shall be converted to a water absorption chiller using an inlet water temperature of 190°F and a leaving temperature of 183°F. Use of water at these temperatures derates the capacity of the existing chiller approximately 57%. A new water absorption chiller shall be installed adjacent to the existing chiller of a capacity to make up for the 57% of the cooling capacity of the steam absorption chiller lost in converting it to a hot water absorption unit.

The conversion of the steam absorption chiller would be accomplished by certain modifications to the chiller and then directly connected to the district hot water supply.

The existing chilled water circulation system will continue to be used with piping modifications to connect the new and existing chiller in a parallel configuration.

The existing cooling tower and condenser water piping will continue to be used. The existing condenser water pump shall be removed and two (2) new pumps installed with a pumping capacity compatible with the cooling capacity of the two chillers. Each chiller to be provided with its own condenser water pump.

Conversion of an existing electric centrifugal water chiller or an electric direct expansion air conditioning system will be accomplished as described under Classification #1.

<u>Classification #5</u> (200°F Hot Water)
Conversion of a building heated by forced air with coils in the system supplied with low pressure steam. Steam supplied by a district high pressure steam distribution system with steam pressure reduced to 10 PSI in the building.

<u>Heating System Conversion</u> (200°F Hot Water)
The existing pressure reducing station, steam piping, condensate return piping and steam coils shall be removed. A new water to water heat exchanger shall be installed and connected to the district hot water distribution system. A new hot water circulation system shall be installed along with new circulating pump to provide a heat source for new water coils installed in the system replacing the existing steam coils.

Controls for the water to water heat exchanger to be as described under Classification #1. Control of each new water coil shall be accomplished with the use of a secondary pump and circulation system circulating water to the coil through a three-way mixing valve.

<u>Domestic Water Heater Conversion</u> (200°F Hot Water)
The existing gas fired, electric or steam heat exchanger type water heaters are to be removed and replaced with a water to water heat exchanger, directly connected to the district hot water heating system. Temperature control of domestic hot water will be as described under Classification #1.

__Air Conditioning Conversion__ (200°F Hot Water)
The air conditioning conversion shall be accomplished as described under Classification #1 for existing electric centrifugal water chillers and electric direct expansion systems. Conversion of a steam absorption unit shall be done as described under Classification #2.

__Classification #7-__ (200°F Hot Water)
Remove existing gas or oil fired furnace and install new air handling unit with hot water heating coil, blower, filters, etc., with connections to district high temperature water system.

__Heating System Conversion__ (200°F Hot Water)
The air duct system shall be utilized with duct connections made to new air handling unit. The existing temperature controls to be removed and new controls installed controlling new hot water heating coil and blower.

__Domestic Water Heater Conversion__ (200°F Hot Water)
The existing gas fired, oil fired or electric water heaters shall be removed and replaced with a water to water heat exchanger complete with controls as explained under Classification #1.

__Air Conditioning Conversion__ (200°F Hot Water)
The air conditioning systems in this classification are probably in the range of 2 to 25 ton capacity and utilizing direct expansion condensing units and direct expansion coils. Under this classification, the direct expansion condensing unit would be continued in use and existing direct expansion coils removed from existing furnace and installed in new air handling unit.

__NOTE__
Buildings with a steam heating system or an electric heating system have not been classified for conversion or priced out. These two systems require a complete new redesign and installation and would be impractical to convert.

A THEORETICAL STUDY OF
DISTRICT HEATING CONVERSION
METHODS AND COSTS
FOR
EXISTING BUILDINGS

PART II: ESTIMATED CONVERSION COSTS

I hereby certify that this plan, specification or report was prepared by me or under my direct supervision and that I am a duly Registered Professional Engineer under the laws of the State of Minnesota.

V. E. Stelmack

Date: 2-10-78 Reg. No. 3774

Classification #1 (Minimum Cost to Building Owner)

Cost Estimate

260°F Hot Water

Conversion of heating system in a building with existing hot water boiler and using the existing piping and circulation system costs include profit and overhead.

Load in MBH	GPM Circ.	Removal of Exist. Equip.	Convertor Cost	Labor, Piping & Insul. Cost	Control Cost	Misc. Costs Mounting Etc.	Total Cost
100	10	$ 125	$ 350	$ 845	$ 175	$ 150	$ 1645
200	20	150	500	1149	500	230	2529
300	30	250	750	1149	500	265	2914
400	40	500	1120	2705	500	483	5308
800	80	850	1220	3210	800	608	6688
1000	100	1100	1400	3210	800	651	7161
1500	150	1500	1700	5356	800	935	10291
2500	250	2000	2300	5356	1300	1095	12051
5000	500	2200	3700	7578	1300	1478	16256
7500	750	3000	4400	7578	1500	1648	18126
10000	1000	4000	6000	7578	(2) 3000	2058	22636
12500	1250	5000	7200	10910	(2) 4000	2711	29821
15000	1500	6500	(2) 8800	16000	(2) 4000	3530	38830
20000	2000	7500	(2) 12000	16000	(2) 7500	4300	47300

Classification #2 (Minimum Cost to Building Owner)
Cost Estimate
260°F Hot Water

Conversion of heating system in a building with existing low pressure steam boiler and using existing steam piping system and condensate return system including condensate return pumps costs include profit and overhead.

Load in LBS/HR	Removal of Exist. Equip.	Steam Gen. Cost	Labor, Piping & Insul. Cost	Control Cost	Misc. Costs	Total Cost
250#	$ 250	$12000	$ 1175	Cost	$1343	$14768
500#	550	15500	3100	of	1915	21065
1000#	1100	19000	3300	Control	2340	25740
1500#	1500	22400	5500	Included	2940	32340
2000#	1900	25800	5600	in	3330	36630
3000#	2000	29300	5600	Cost	3690	40590
4000#	2100	32800	6700	of	4160	45760
5000#	2200	36200	7700	Steam	4610	50710
7500#	3000	39700	10500	Generation	5320	58520
10000#	4000	43100	10500		5760	63360
12500#	5000	46600	14100		6570	72270
15000#	6500	50000	19500		7600	83600

Classification #3 (Minimum Cost to Building Owner)

Cost Estimate

260°F Hot Water

Conversion of heating system in a building supplied by a district high pressure steam system and using the existing steam piping system, condensate return system including condensate pumps. Costs include profit and overhead.

Load in LBS/HR	Removal of Exist. Equip.	Steam Gen. Cost	Labor, Piping & Insul. Cost	Control Cost	Misc. Costs	Total Cost
250#	$ 150	$12000	$ 1175	Cost	$1333	$14658
500#	250	15500	3100	of	1885	20735
1000#	300	19000	3300	Control	2260	24860
1500#	450	22400	5500	Included	2835	31185
2000#	500	25800	5600	in	3190	35090
3000#	500	29300	5600	Cost	3540	38940
4000#	700	32800	6700	of	4020	44220
5000#	700	36200	7700	Steam	4460	49060
7500#	900	39700	10500	Generation	5110	56210
10000#	900	43100	10500		5450	59950
12500#	1100	46600	14100		6180	67980
15000#	1100	50000	19500		7060	77660

Classification #4 (Minimum Cost to Building Owner)
Cost Estimate
260°F Hot Water

Conversion of heating system in building supplied by a district high pressure steam system and installing a new water to water convertor and using existing hot water circulation system and pumps. Costs include profit and overhead.

Load in MBH	GPM Circ.	Removal of Exist. Equip.	Convertor Cost	Labor, Piping & Insul. Cost	Control Cost	Misc. Costs Mounting Etc.	Total Cost
100	10	$ 125	$ 350	$ 845	$ 175	$ 150	$ 1645
200	20	150	500	1149	500	230	2529
300	30	200	750	1149	500	260	2859
400	40	250	1120	2705	500	458	5033
800	80	300	1220	3210	800	553	6083
1000	100	300	1400	3210	800	571	6281
1500	150	450	1700	5356	800	831	9137
2500	250	450	2300	5356	1300	940	10346
5000	500	700	3700	7578	1300	1328	14606
7500	750	700	4400	7578	1500	1418	15596
10000	1000	700	6000	7578	(2) 3000	1728	19006
12500	1250	900	7200	10910	(2) 4000	2300	25310
15000	1500	900	(2) 8800	16000	(2) 4000	2970	32670
20000	2000	900	(2) 12000	16000	(2) 7500	3640	40040

Classification Nos. 2, 3, 4 and 5 (Minimum Cost to Building Owner)
Cost Estimate
260°F Hot Water

Cost of steam pressure booster pump required for buildings that require steam pressures more than 3 PSIG, but not more than 12 PSIG. Costs include: booster pump, base, motor, drives, intake and discharge mufflers, pressure gauges, thermometers, motor starters, and pressure switch.

Load in LBs/HR	Motor HP	Booster Pump Cost	Piping, Labor & Insul. Cost	Electrical Cost	Misc. Costs	Total Cost
250	8.5	$ 4100	$ 2965	$ 400	$ 747	$ 8218
500	15.5	4600	3950	520	907	9977
1000	29.5	6600	5775	660	1304	14339
1500	41.0	8500	7780	780	1706	18765
			Duplex Units			
2000	(2) 29.5	13200	11550	1320	2607	28677
3000	(2) 41.0	17000	12600	1560	3116	34276
4000	(2) 53.0	21100	13400	1920	3642	40062
5000	(2) 71.0	31400	15400	2360	4916	54076
7500	(2) 95.0	34100	18600	2730	5543	60973
10000	(2) 125.0	47500	19500	2930	6993	76923
12500	(2) 155.0	54200	26200	5260	8566	94226
15000	(2) 180.0	55300	29600	5400	9030	99330

Classification Nos. 1, 2, 3, 4, 5 & 6 (Minimum Cost to Building Owner)
Cost Estimate
260°F Hot Water

Conversion of existing domestic hot water heaters 40° to 140° using existing domestic hot water piping system and district hot water system.

Load in GPH	Load in MBH	Removal of Exist. Equip.	New Heater Cost	Labor, Piping & Insul. Cost	Control Cost	Misc. Costs	Total Cost
30	25	$ 25	$ 150	$ 150	$125	$ 45	$ 495
60	50	35	175	200	125	53	588
90	75	100	300	200	175	77	852
120	100	150	500	425	500	158	1733
300	250	300	1000	725	500	252	2777
600	500	375	2150	1149		366	4022
900	750	450	3553	2705	Included	671	7379
1200	1000	600	4370	2705	in	768	8443
1800	1500	700	5120	3210	Cost	903	9933
3000	2500	800	5717	3450	of	997	10964
7500	6250	1000	7675	5356	Heater	1403	15434
9000	7500	1200	10400	7578		1918	21096
12000	10000	1400	13195	7578		2217	24390

Classification Nos. 1, 2, 3, 4, 5 and 6 (Minimum Cost to Building Owner)
Cost Estimate
260°F Hot Water

Conversion of air conditioning systems of 100 tons cooling or over by replacing the electric water chillers with hot water absorption units, replacing the existing cooling tower, piping and condenser water pump and using the existing chilled water piping and circulation system costs includes profit and overhead.

Load in Tons	Removal of Exist. Chiller & Cooling Twr.	Chiller Cost	Cooling Tower Cost	Condenser Pump Cost	Labor, Piping & Insul. Cost	Electric Cost Incl. Starter	Misc. Cost	Total Cost
100	$2400	$ 24200	$ 4070	$ 3345	$ 19360	$ 3200	$ 5655	$ 65430
200	2800	37400	8140	3515	29920	3400	8520	93695
300	3200	42900	12210	4775	34320	4050	10145	111600
400	3600	53680	16280	4995	42940	5400	12690	139585
500	4000	63250	20350	7125	50600	7150	15250	167725
600	4400	75900	24420	7235	60720	7300	17995	197970
700	4800	84700	28490	7850	67760	7600	20120	221320
800	5200	92400	32560	9250	73920	9200	22250	244780
900	5600	99000	36630	9250	79200	9700	23940	263320
1000	6000	110000	40700	9250	88000	11330	26530	291810
1250	6800	130625	50875	9804	104500	12600	31520	346724
1500	7400	156750	61050	15390	125400	14300	38030	418320

Classification Nos. 2, 3, 4 and 5 (Minimum Cost to Building Owner)
Cost Estimate
260°F Hot Water

Conversion of air conditioning systems with steam absorption water chillers to hot water absorption water chillers.

Chiller Size in Tons	Conversion Cost
100 to 500 Tons	$ 7000
550 to 1000 Tons	10000
1050 to 1500 Tons	12500

Classification #7 (Minimum Cost to Building Owner)

Cost Estimate

260°F Hot Water

Conversion of heating system in a building with an existing forced air furnace and air duct system and using existing supply, return and fresh air duct system. Costs include profit and overhead.

Load in BTUs/HR	% FA	CFM Circ.	Removal of Exist. Equip.	Air Handling Unit Cost	Labor, Ductwork Piping, Insul.	Control Cost	Misc. Costs	Total Cost
80000	--	800	$ 50	$ 350	$ 325	$140	$ 87	$ 952
10000	--	1000	50	400	350	140	94	1039
140000	--	1500	75	750	460	160	145	1590
170000	20	2000	75	1000	700	320	210	2305
240000	20	3000	100	1100	770	360	233	2563
320000	20	4000	100	1200	890	360	255	2805
400000	20	5000	150	1300	975	360	279	3064
480000	20	6000	150	1500	1325	360	334	3669
680000	20	8500	200	1870	1540	440	405	4455
800000	20	1000	200	2100	1730	440	447	4917

CLASSIFICATION #1 (Minimum Cost to Building Owner)

COST ESTIMATE

200°F Hot Water

Conversion of a heating system in a building heated with hot water supplied by a hot water boiler and reusing the existing hot water circulation system. Costs include Profit and overhead.

Load In MBH	Pipe Size	GPM Circ	Removal Of Exist Equip.	Heat Exchanger Cost	Labor, Piping & Insul. Cost	Control Cost	Misc. Costs Mounting Etc.	Total Cost
100	1 1/2	10	$125	$975	$930	$500	$255	$2785
200	2	20	150	1020	1265	500	295	3230
300	2	30	250	1200	1265	500	295	3540
400	2 1/2	40	50	1345	2975	500	535	5855
800	3	80	850	1638	3530	800	685	7503
1000	3	100	1100	1805	3530	800	725	7960
1500	4	150	1500	2409	5890	800	1060	11659
2500	4	250	2000	3014	5890	1300	1220	13924
5000	6	500	2200	4700	8336	1300	1655	18191
7500	6	750	3000	5695	8336	1500	1855	20386
10000	6	1000	4000	7328	8336	(2)3000	2265	24929
12500	8	1250	5000	8900	12000	(2)4000	2990	32890
15000	8	1500	6500	(2)11390	17600	(2)4000	3950	43440
20000	8	2000	7500	(2)14655	17500	(2)7500	4725	51980

CLASSIFICATION #7 (Minimum Cost to Building Owner)

200°F Hot Water

Conversion of a heating system in a building with an existing forced air furnace and air duct system and using the existing supply, return and fresh air duct system. Costs include profit and overhead.

Load In MBH	% F.A.	CFM Circ	Removal Of Exist Equip.	Air Handling Unit Cost	Labor, Ductwork Piping & Insul.	Control Cost	Misc. Cost	Total Cost
80	--	800	50	350	325	140	87	952
100	--	1000	50	400	350	140	94	1039
140	--	1500	75	750	460	160	145	1590
170	20	2000	75	1000	700	320	210	2305
240	20	3000	100	1100	770	360	233	2563
320	20	4000	100	1200	890	360	255	2805
400	20	5000	150	1300	975	360	279	3064
480	20	6000	150	1500	1325	360	334	3669
680	20	8500	200	1870	1540	440	405	4455
800	20	10000	200	2100	1730	4400	447	4917

CLASSIFICATION #5 (Minimum Cost to Building Owner)

200°F Hot Water

Conversion of a heating system in a building heated by forced air and supplied with high pressure steam by a district high pressure steam system. Cost includes profit and overhead.

Load In MBH	COILS	Pipe Size	GPM Circ	Removal Of Exist Equip.	Heat Exchanger Cost	Circ Pump Cost	Labor, Piping & Insul. Cost Incl. Coils	Elec. Cost	Control Cost	Misc. Cost	Total Cost
100	1	1 1/2	10	$461	$975	$169	$1120	$75	$390	$319	$3509
200	1	2	20	570	975	403	1684	350	870	485	5337
300	2	2	30	620	1200	403	2199	350	1140	591	6503
400	2	2 1/2	40	754	1345	498	4425	425	1140	859	9446
800	3	3	80	1308	1638	653	6835	618	1770	1282	14104
1000	3	3	100	1812	1805	940	7610	668	2040	1488	16363
1500	4	4	150	3466	2409	960	12456	718	2400	2241	24650
2500	5	4	250	3660	3014	1145	14856	767	3360	2677	29449
5000	5	4	500	3724	4700	1680	20220	1020	4560	3591	39503
7500	6	6	750	4732	5695	2965	22778	1020	7200	4439	48829
10000	7	6	1000	5740	7328	4370	27178	1450	9900	5597	61563
12500	8	8	1250	7620	8900	4770	36010	2852	10200	7035	77387
15000	9	8	1500	8292	(2)11390	5165	44000	2852	13440	8514	93653
20000	10	8	2000	8964	(2)14656	5465	48900	2952	18000	9894	108831

CLASSIFICATION #4 (Minimum Cost to Building Owners)

COST ESTIMATE

$200^{o}F$ Hot Water

Conversion of a heating system in a building heated with hot water converted from steam supplied by a district high pressure steam system and using the existing hot water circulation system. Costs include profit and overhead.

Load In MBH	Pipe Size	GPM Circ	Removal Of Exist Equip.	Heat Exchanger Cost	Labor, Piping & Insul. Cost	Control Cost	Misc. Costs Mounting Etc.	Total Cost
100	1 1/2	10	$125	$975	$930	$500	$253	$2783
200	2	20	150	1020	1265	500	295	3230
400	2 1/2	40	250	1345	2975	500	507	5577
800	3	80	300	1638	3530	800	627	6895
1000	3	100	300	1805	3530	800	645	7080
1500	4	150	450	2409	5890	800	955	10504
2500	4	150	450	3014	5890	1300	1065	11719
5000	6	500	700	4700	8336	1300	1504	16540
7500	6	750	700	5695	8336	1500	1623	17854
10000	6	1000	700	7328	8336	(2)3000	1936	21300
12500	8	1250	900	8900	12000	(2)4000	2580	28380
15000	8	1500	900	(2)11390	17600	(2)4000	3389	37279
20000	8	2000	900	(2)14655	17600	(2)7500	4065	44720

CLASSIFICATION NO's 1 - 4 - 5

Conversion of air conditioning systems of 100 tons cooling or over by replacing the electric water chillers with hot water absorption units, replacing the existing cooling tower, piping and condenser water pump and using the existing chilled water piping and circulation system. Costs include profit and overhead.

Load In Tons	Removal Of Exist Chiller & Cooling Twr.	Chiller Cost	Cooling Tower Cost	Condenser Pump Cost	Labor, Piping & Insul. Cost	Elec. Cost Inc'. Startor	Misc. Cost	Total Cost
100	$2400	$39790	$4070	$3345	$61620	$3200	$11443	$125868
200	2800	63100	8140	3515	98436	3400	17940	197331
300	3200	91600	12210	4775	120744	4050	23658	260237
400	3600	98300	16280	4994	153348	5400	28192	310115
500	4000	124300	20350	7125	193908	7150	35683	392516
600	4400	146000	24420	7235	227760	7300	41712	458827
700	4800	171800	28490	7850	268008	7600	48855	537403
800	5200	(2)196600	32560	(2)9990	306696	10000	56180	618031
900	5600	(2)223800	36630	(2)14250	349128	12400	54180	705988
1000	6000	(2)248600	40700	(2)14250	387816	14300	71655	783321
1250	6800	(2)343600	50875	(2)15696	536016	14900	96790	1064677

CLASSIFICATION NO's 4 - 5

Conversion of air conditioning systems of 100 tons cooling or over by converting the existing steam absorption water chiller to a hot water absorption unit and adding a new water absorption water chiller of capacity sufficient to make up the cooling load required as a result of converting the existing steam absorption unit to a hot water absorption unit using 190°F entering water. The existing cooling tower, condenser water piping, condenser water pump, chilled water circulation system will remain in use. Cost includes profit and overhead.

Load In Tons	Conv. Of Exist Chiller Cost	Cap. Of Exist Chiller After Conv In Tons	New Chiller Capacity In Tons	New Chiller Cost	Labor, Piping & Insul. Cond. Pumps. Cost	Electrical Cost	Misc. Cost	Total Cost
100	$7000	43	57	$29200	$37960	$3840	$7800	$85800
200	7000	86	114	39500	51350	4080	10193	112123
300	7000	129	171	51600	67080	4860	13054	143594
400	7000	172	228	63100	82030	6480	15861	174471
500	7000	215	285	77400	100620	8500	19360	212960
600	10000	258	342	91600	119080	8760	22945	252385
700	10000	361	399	98300	127790	9120	24520	269730
800	10000	344	456	111900	145470	11040	27840	306250
900	10000	387	513	124300	161590	11640	30750	338280
1000	10000	430	570	146000	189800	13500	35930	395035
1250	12500	537	712	171800	223340	15120	92275	465035
1500	12500	645	855	(2)223800	290940	20020	54725	601985

CLASSIFICATION NO's 1 - 4 - 5 - 7

Conversion of existing domestic water heaters 40° to 140° using district hot water ranging in temperature from 190°F to 240°F. The existing domestic hot water piping system will continue in use. Costs include profit and overhead.

Load In GPH	Load In MBH	Removal Of Exist Equip.	New Heater Cost	Labor, Piping & Insul. Cost	Control Cost	Misc. Cost	Total Cost
30	25	$ 25	1275	425	150	188	2063
60	50	35	2760	425	200	342	3762
90	75	100	4250	550	200	510	5610
120	100	150	5478	720	Included	635	6983
300	250	300	5680	1075	In	705	7760
600	500	375	5975	1375	Cost	773	8498
900	750	450	6350	3246	Of	1005	11051
1200	1000	600	7638	3340	Heater	1158	12736
1800	1500	700	10481	3852		1503	16536
3000	2500	800	12550	4140		1749	19239
7500	6250	1000	22137	6427		2956	32520
9000	7500	1200	24760	9094		3505	38559
12000	10000	1400	28650	10340		4040	44420

Appendix C

HEATING SYSTEM CONVERSION METHODS — OPTIMUM RETURN WATER TEMPERATURE

CONVERSION OF HEATING SYSTEMS IN U.S. BUILDINGS

by Erik Wahlman, M.Sc.Mech.Eng. Theorell & Martin Energikonsulter AB, Sweden.

District heating hot water system has many good prepequistes for profitable economy. One of the elements which have great influence of the economy is the converting costs of the heating systems in existing buildings. The heating system must be well adopted to the district heating hot water system, otherwise the function of the system could fail.

In US-buildings compared to European, the heating systems have great variations in both the heating media and the regulating systems. In Swedish buildings e.g. the heating systems since the beginning of 1920 are pure hot water used for both airconditioning, radiators and domestic hot water heaters. Because of that there are usually no problems and no large costs to connect Swedish buildings to the district heating network. From investigations it seems that many of the US buildings especially those who are built before the mid of 1960 require considerable conversions of their heating systems.

To get rapid start with good economy of a new district heating systems one needs customers who are willing to be connected to the central system at reasonable energy rates. These will probable be represented by owners of new buildings and those existing buildings with hot water systems which do not need any great conversions. To find those buildings, a very thorough survey of all buildings should be made in the areas considered for district heating to get them classified regarding to the conversion costs to the d.h. system.

SURVEY

The survey of the buildings shall itemize the HVAC system, to get an opinion of the HVAC-type and condition in the investigated buildings. Following items about the system are of interest.

A Steam distribution system
- in boiler room only
- to mechanical equipment rooms throughout the building
- to all air handling units and induction units
- to radiators

B Hot water system to heating coils

C Hot water radiation system

D Type of chilled water generation

To be able to evaluate the systems, interviews with the owners must be performed. An example of an interview checklist may look like fig. 1.

That list will give the system and conditions of the buildings heating and cooling facilities. Together with that list and schemes over different HVAC-system shown in exhibit 1 a classification and estimation of the conversion costs could be performed of the surveyed buildings as shown later on.

SCHEMES

The schemes in exhibit 1 illustrate eight different common HVAC-systems and their conversion from steam heating to district heating hot water system. The schemes are made for different type and age of buildings.

They only show the principles of connecting the heating system via heat exchanger to the d.h. system and the idea of regulating the heating air units, induction units and radiators. The principle is that no hot water can be returned without passing a user. Otherwise the return temperature to the heatexchanger will be too high and the return temperature of the primary d.h. hot water will also be too high and that will spoil the economy in the cogeneration plant. The return water temperature still will vary by different use of the hotwater and improper regulation.
No notice is taken if the steam is produced in the building´s boiler room or in a centralized steam boiler plant.

Scheme 1

Users: large modern offices, hotels and stores.

Steam to hot water heaters for air handling and induction units, radiators and domestic hot water.

Conversion: Replacement of steam/hot water heatexchanger and new energy meter.

Supply temperature various to outdoor temperature 145°C (290 F), 80°C (176 F). Return temperature will be calculated in three levels 100° (212 F), 80°C (176 F) and 60°C (140 F) due to the achievement of the heating units and their regulating systems.

Scheme 2

Users: large offices, hotels and stores.

Steam for air handling units, hot water exchangers for induction units, radiators and domestic hot water.

Conversion: Replacement of air handling units or enlarging their surface so they will fit to hot water, new pipes for hot water, new heat exchanger for hw/hw to air units, induction units, radiators and domestic hot waters.

Supply temperature varies as in scheme 1 to the outdoor temperature 145°C (290 F) to 80°C (176 F). Return temperature will be set in three different levels as in scheme 1.

Scheme 3

Users: large offices, hotels and stores. Scheme 3 is equal to scheme 2 but the cooling machine is a steam driven one-effect absorption chiller.

Conversion: Replacement of air handling units or enlarging their surface so they will fit to hot water, new hot water pipes and new heatexchangers and energy meter as in scheme 2. Conversion of the steam coils to bigger hot water coils in the apsorption engine.

The supply temperature must be constant 145°C (290 F) to provide enough heat to the absorption machine. The return temperature after the absorption chiller is fairly high about 125°C (257 F). That return water should go into the supply water pipe to the other heatexchangers, but when there is a small heat demand the return water enters into the d.h. return water pipe. Return temperatures of 120°C (248 F), 100°C (212 F) and 80°C (176 F) should be calculated. Special attention must be paid to the regulating valves of the heatexchangers. Their volume range will be very large because the d.h. supply water does not vary the temperature when the energy demand decreases.

Scheme 4

Users: offices, hotels and small hospitals.

Scheme 4 is equal to scheme 2 except that the steam systems to the air handling units are preserved. The d.h. hot water shall generate steam by a steam-generator. This system can be used if the ordinary steampressure is up to 2 bar (29 psi) and the steam demand to the air units and eventually also steam for kitchen and washing machines is not too great.

Conversion: New heatexchangers for hw/hw to induction units, radiators and domestic hot water, new energy meter and a steam generator with a design pressure of 3,2 bar (46 psi) and a working pressure up to 2 bar (29 psi).

The supply temperature will be high, about 135°C (275 F). The return water, when there is a demand at the other heatexchangers, will go into the supply d.h. water pipe otherwise directly into the d.h. return pipe.
Return temperature levels will be set to 130°C (266 F) and 100°C (212 F).

Special attention must be paid to the dimension of the regulating valves of the heatexchangers such as in scheme 3.

<u>Scheme 5</u>

Users: old offices, hotels, shops and stores.

Steam is used directly for all air handling and eventually induction units. Steam is heatexchanged to hot water for the radiators and domestic hot water.

Conversion: Replacement of all air handling and induction units or enlarging their surface so they will fit to hot water, new pipes for hot water, new heat exchangers for hw/hw to ventilating systems, radiators and domestic hot water, new energy meter.

Supply temperature varies to outdoor temperature 145°C (290 F) to 80°C (176 F). Return temperature can be set to 80°C (176 F) and 60°C (140 F). This low temperature can be reached when a new and well designed system is introduced.

Scheme 6

Users: old offices, hotels, shops, appartment buildings and stores.

The whole building is steamheated by radiators and probable some small ventilation systems.

Conversion: Replacement of the ventilating units or enlarging their surface so they will fit to hot water, new pipes for hot water, new heatexchanger for the heating systems and the domestic hot water, new energy meter. The radiators can usually be used for hot water.

Supply temperature 145°C (290 F) to 80°C (176 F)

Return temperature 80°C (176 F) to 60°C (140 F)

as in scheme 5.

Scheme 7

Users: small offices, shops, appartment buildings, multi and single family houses.

The whole building is heated by hot air heated by steam air handling units.

Conversion: Replacement of all air handling units or enlarging their surface so they will fit to hot water, new pipes for hot water, new heatexchanger for the heating system and the domestic hot water, new energy meter.

Supply temperature 145°C (290 F) to 80°C (176 F). Return temperature can be set lower to 60°C (140 F) due to the airheating coils can be designed for a lower temperature.

Scheme 8

Users: small offices, shops, multy or single family houses.

The whole building is heated by air, heated by natural gas.

Conversion: The gas airheaters are replaced by waterheating units, new hot water pipes, new heatexchangers for heating system and domestic hot water, new energy meter.

Supply temperature 145°C 8290 F) to 80°C (176 F)
Return temperature 60°C (140 F) and 40°C (104 F)
the same system as in scheme 7.

Conversion costs

The different type of buildings which are represented by the eight schemes can be grouped in three sizes of their heat demand like this matrix.

Scheme	Building heat demand		
nr	5 MW	0,5- 5 MW	0,5 MW
1	x	x	-
2	x	x	-
3	x	x	-
4	x	x	-
5	x	x	x
6	-	x	x
7	-	-	x
8	-	-	x

Of each system there are about three variations of the return temperature. This will give about 45 different cases to calculate. To minimize the calculation work an evaluation has to be done from the survey. Buildings of three different sizes and representing the most commom schemes should be calculated due to the conversion costs and three different return temperature levels.

The conversion cost should be split up in the following items, then these figures can be used for similar buildings and systems in other areas.

Cost items expressed in \$ and \$/kW (\$/MBtu/hr)
- Replacement or enlarging of the heating surface of the air handling units.
- New hot water pipes in the building.
- Heatexchanger for hw/hw to ventilating systems and radiators.
- Domestic hot water heatexchanger.

- Conversion of one-stage absorption chillers
- Steamgenerator
- Regulating systems
- Piping in the heatexchanger room
- Energy meter
- Demolishing of steam boilers and stem/condensate piping system

The conversion cost should also be figured out in $/MWh ($MBtu) based on the capital costs at a depreciation time of 15 years and common U.S. interest and the annual energy consumption. This energy cost shall be added to the energy cost given from the district heating company. The difference between this sum and the actual energy cost in existing situation, including labor cost in the boiler room, maintenance, spare parts, sweeping, costs for water, water treatment, etc. shall be as high as possible to the benefit of the district heating system.

CLASSIFICATION

Based on the survey, the schemes and the conversion costs the buildings can be classified to their life expectancy and their suitability for conversion. They can be classified to

A Building suitable for conversion without big system changes

B Building suitable for conversion after remodelling.

C Building unsuitable for conversion

As a result, different buildings can be grouped together according to their conversion suitability. Together with these estimations, regional building expansion plans must be studied. These shall show the changes to the existing situation like demolishing, remodelling and/or new development areas. All these information will help the planning of a d.h. system so the d.h. network can be laid in those areas where connection of existing and new buildings can be made most favourable.

Firm or Owner ....

Adress ....

Person interviewed ....

BUILDING HVAC SYSTEM SURVEY

SIC code or type of establishment ....

Age of building ....

	EXISTING/ NOT EXISTING	TEMP. PRESSURE	CAPACITY MBTU/HR	ANNUAL DEMAND MBtu	YEAR INSTALLED	YEARS TO RETIREMENT	REMARKS
Connected to central steam distribution system	Yes/No			-			
Steam/boiler	Yes/No						
HW boiler	Yes/No						
Steam distribution system:	-	-	-	-	-	-	
- in boiler room only	Yes/No						
- to mechanical rooms throughout building	Yes/No						
- to radiation system	Yes/No						
HW system to heating coils	Yes/No						
HW radiation system	Yes/No						
Induction unit/fan coil unit system	Yes/No						
Central chilled water generation:	-				-	-	
- Reciprocating	Yes/No						
- Centrifugal/screw	Yes/No						
- One/two stage absorption	Yes/No						
DX - cooling	Yes/No						
Gas fired ventialtion units	Yes/No						
Steam/HW/gas/electric dom. hot water heater							

Note: When systems have been installed in phases, define data for each phase.

Interviewr´s name ....

Date ....

Fig. 1.

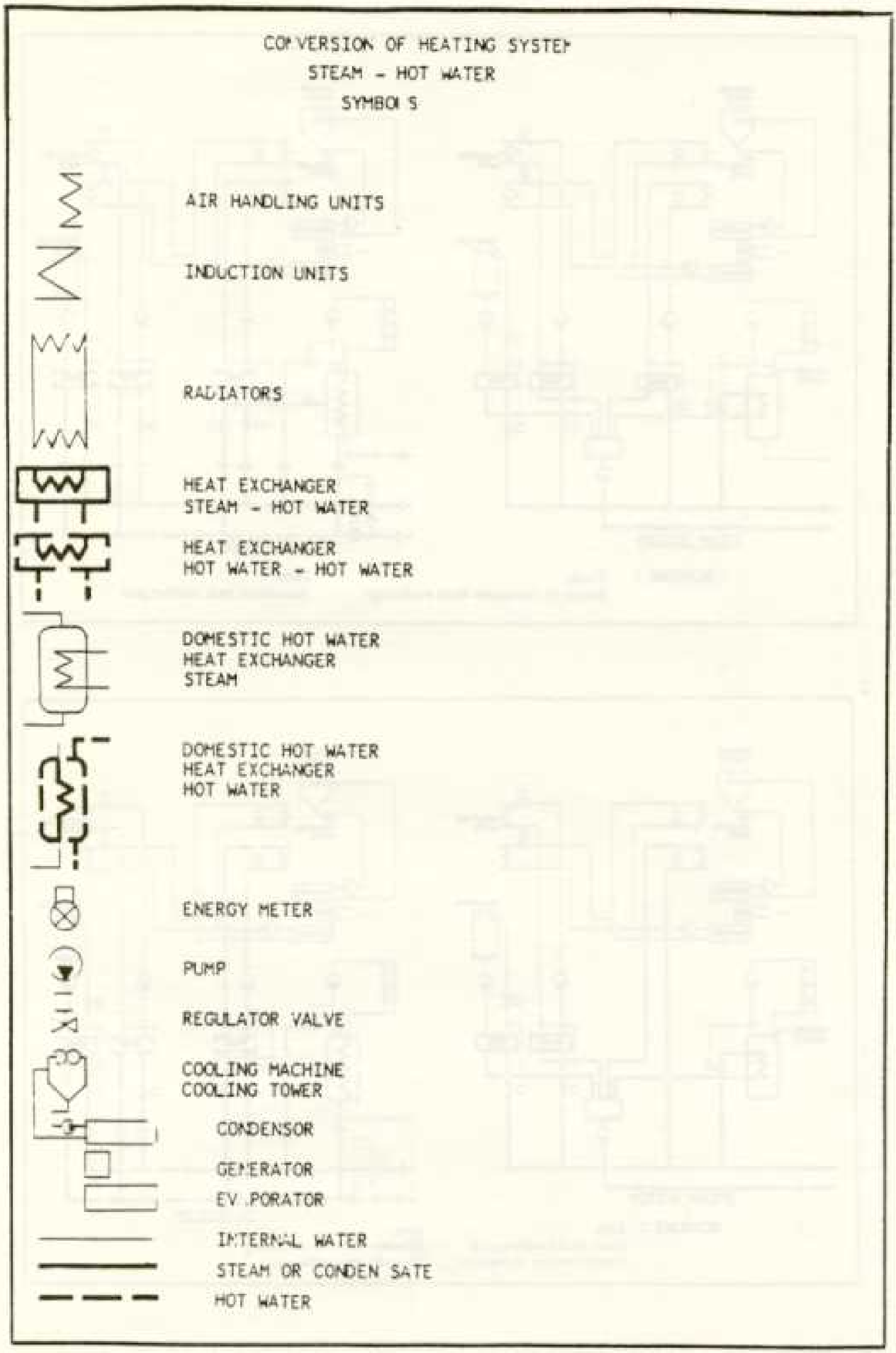
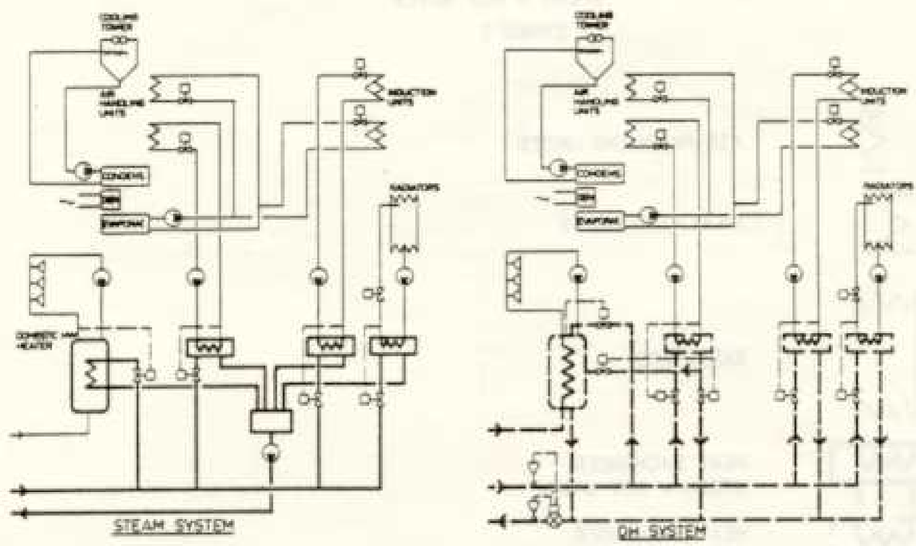
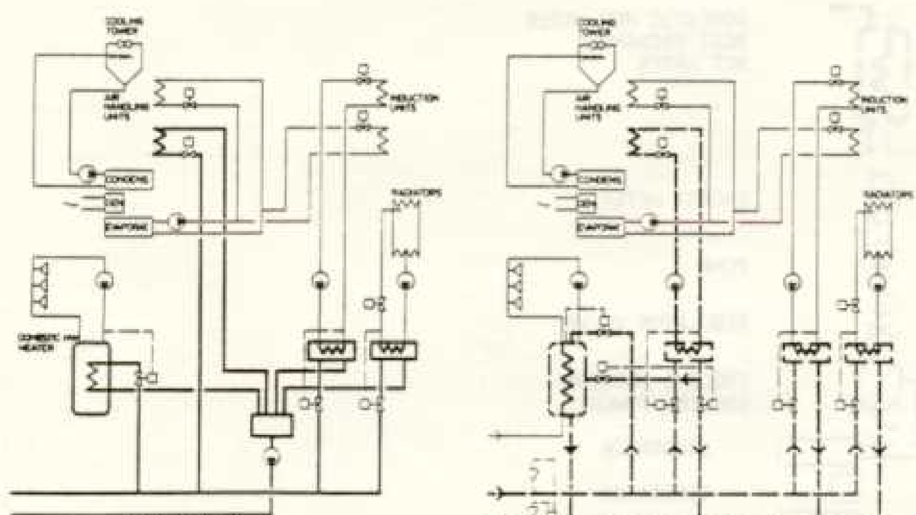

CONVERSION OF HEATING SYSTEM
STEAM - HOT WATER
SYMBOLS
AIR HANDLING UNITS
INDUCTION UNITS
RADIATORS
HEAT EXCHANGER
STEAM - HOT WATER
HEAT EXCHANGER
HOT WATER - HOT WATER
DOMESTIC HOT WATER
HEAT EXCHANGER
STEAM
DOMESTIC HOT WATER
HEAT EXCHANGER
HOT WATER
ENERGY METER
PUMP
REGULATOR VALVE
COOLING MACHINE
COOLING TOWER
CONDENSOR
GENERATOR
EVAPORATOR
INTERNAL WATER
STEAM OR CONDENSATE
HOT WATER

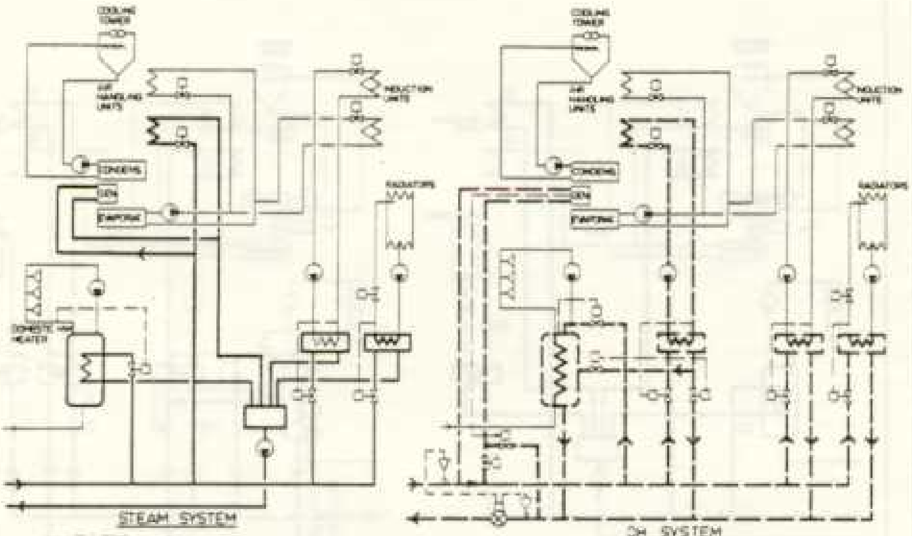
EXHIBIT 1



SCHEME 1 Exist: Steam to hotwater heat exchanger — Conv. Hotwater heat exchangers

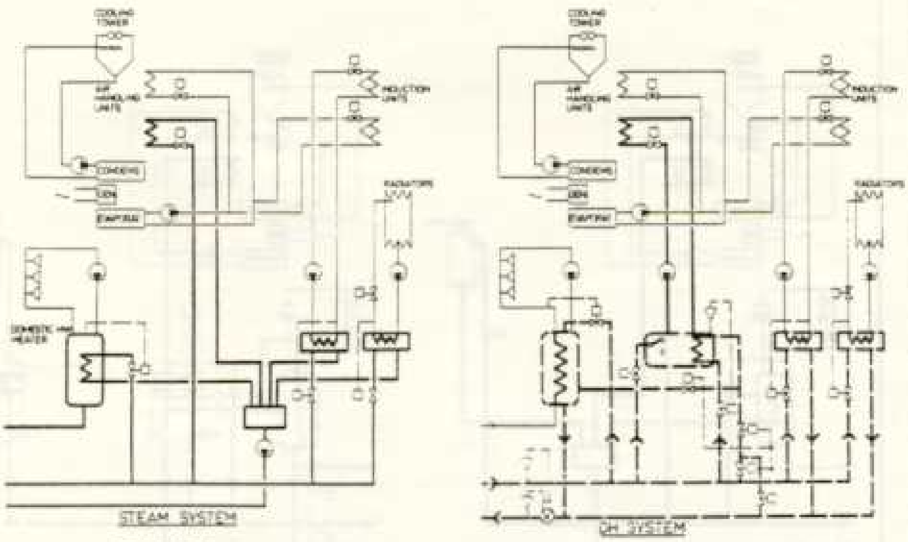


SCHEME 2 Exist. Steam to air handling units; Steam/hotwater to radiators — Conv. Hotwater to air handling units; Hotwater heat exchangers



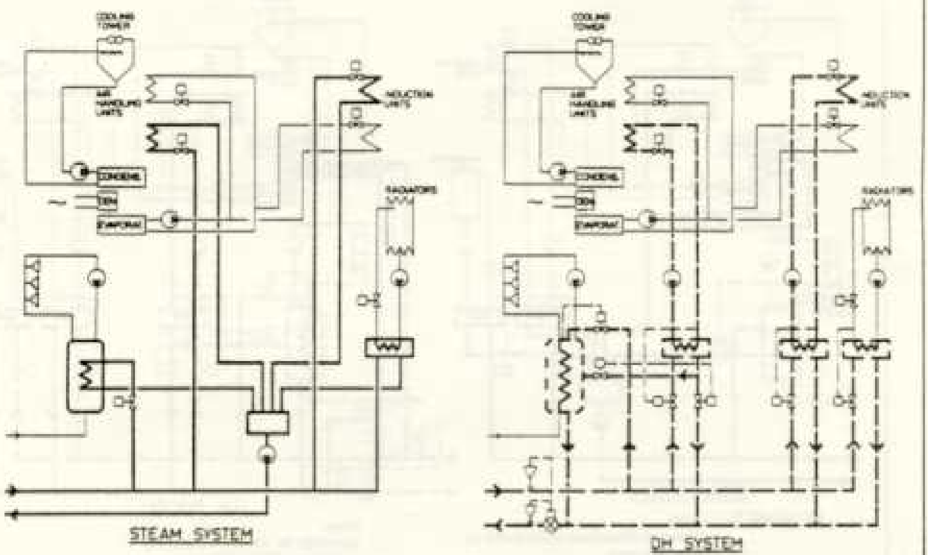
SCHEME 3 Exist.
Steam to absorption chillers and air handling units.
Steam/ hotwater to radiators

Conv.
Hotwater to absorption chillers and air handling units
Hotwater heat exchangers



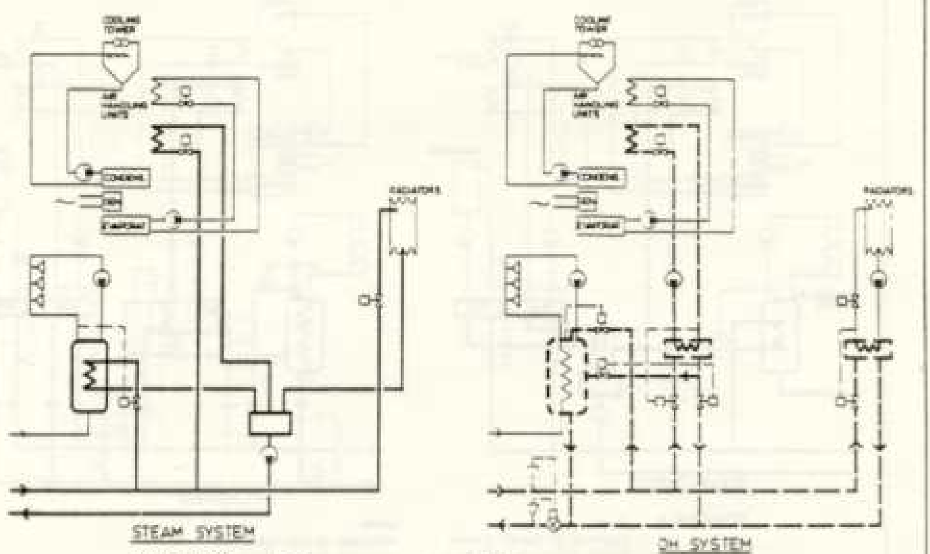
SCHEME 4 Exist.
Steam to air handling units
Steam/ Hotwater to radiators

Conv.
Hotwater to steamgenerator
Hotwater heat exchangers



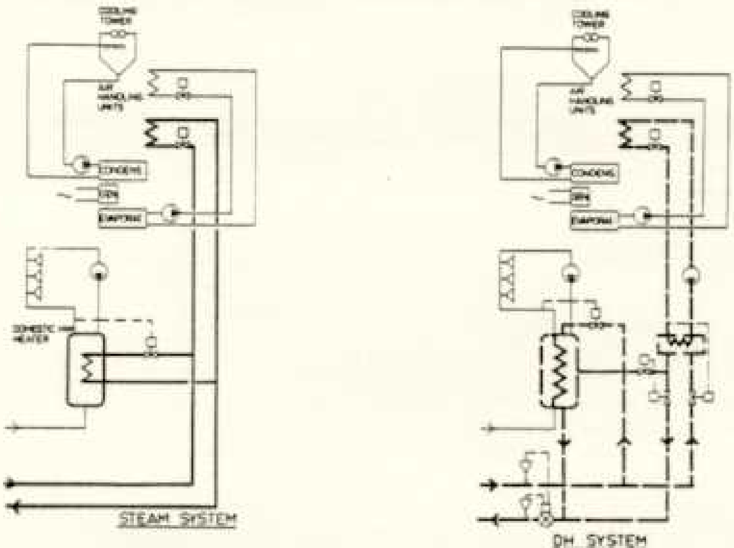
SCHEME 5 Exist.
Steam to ventilating systems
Steam/hotwater to radiators

Conv.
Hotwater to ventilating systems
Hotwater heat exchangers



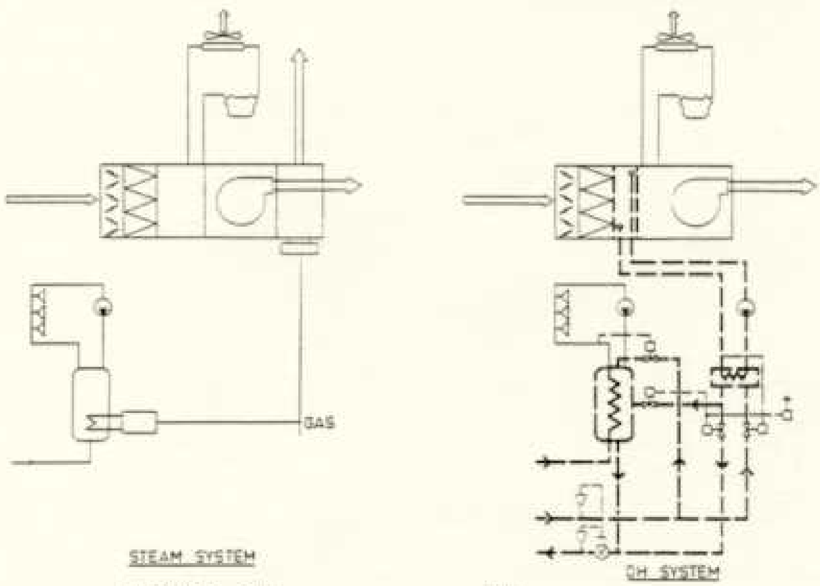
SCHEME 6 Exist.
Steam to radiators

Conv.
Hotwater to radiators
Hotwaters heat exchangers



SCHEME 7 Exist.
Steam to hotair-heaters

Conv.
Hotwater to hotair-heaters
Hotwater heat exchangers



SCHEME 8 Exist.
Air heaters heated by natural gas

Conv.
Hotwater to new airheaters
Hotwater heat exchangers

Appendix D

BUILDING CONVERSION COST STUDY FOR
FIVE EXITING BUILDINGS

BUILDING CONVERSION COST STUDIES
RELATING TO
DISTRICT HEATING
FOR
FIVE EXISTING BUILDINGS

MINNESOTA ENERGY AGENCY
720 AMERICAN CENTER BUILDING
150 EAST KELLOGG BOULEVARD
ST. PAUL, MINNESOTA 55101

PREPARED BY

MICHAUD, COOLEY, HALLBERG, ERICKSON & ASSOC., INC.
310 PLYMOUTH BUILDING
MINNEAPOLIS, MINNESOTA 55402

I HEREBY CERTIFY THAT THIS PLAN, SPECIFICATION OR REPORT WAS PREPARED BY ME OR UNDER MY DIRECT SUPERVISION AND THAT I AM A DULY REGISTERED PROFESSIONAL ENGINEER UNDER THE LAWS OF THE STATE OF MINNESOTA.

DATE ________ REG. NO. 4039

HENNEPIN COUNTY GOVERNMENT CENTER

This County Center building is a two tower structure, 24 floors high with an open atrium dividing the administrative tower and court tower. The principle type of occupancy is offices, court rooms and public service on the lower four floors.

Steam at 265 psig and chilled water is piped to the structure from a street tunnel distribution system and a district power plant approximately three blocks away. Since the Government Center does not have it own chillers within its structure, the need for steam is for heating, ventilating system, and domestic water systems.

Three mechanical rooms serve the building, one sub grade lower level, and one each at the top of the tower sections. Steam pressure is reduced to 100 psig to serve heat exchangers for heating and domestic water at the lower level and upper level mechanical rooms. Generally, the existing direct steam radiation reduced at the PRV station to 10 psig steam, has been disconnected or out of service because of need. Consideration has been given to new heat exchangers serving only the ventilation and domestic water systems.

The original design criteria includes heating domestic water from 40° to 140° F and supplying the ventilation systems with 210°F water from a closed loop circulating system and 170° F return water temperature. Preheat coils have a separate secondary "run-around" cycle pump circulating piping; reheat generally piped directly from the primary 210° F. water is controlled through automatic three way and modulating pneumatic controls.

Cost data is for converting the existing systems from high pressure steam to district heating high temperature hot water supplies at an assumed 300° F. Return mixed water has been considered at three separate temperatures: 212° F, 176° F. and 140° F. with controls designed to approach these selective conditions.

Reference is made to the schematic sketch, SH-1, showing the three equipment room systems, using district high temperature hot water in series with heating and ventilating heat exchanges and domestic water exchangers. Duplicate exchangers, piping and controls are included in the conversion cost estimate, from a practical design, duplicate equipment serve only as standby. Existing piping has been used where feasible; the high pressure steam and condensate return mains could serve as the carrying circuits in high temperature hot water. Demolition costs included in this building have been kept to minimum values. It is assumed that the insulation thickness of existing steam and condensate return piping used for district heating water would be adequate, but not necessarily meeting Minnesota Energy Code requirements for new piping. All new piping connections and heat exchangers would have the required insulation thickness and "U" values.

Reference is made to Sketches 3, 4, and 5, showing the control and series piping required for each system. The tabulated data for the lower level and two upper level systems include the pipe size, temperature, heat exchanger size and the pre-determined mixed return water temperature. Cost estimating includes the variable sizes for control pipes and heat exchangers. Additional cost breakdown is presented in the appendix.

The composite total costs are summarized as follows:

212° F. System	$280,546
176° F. System	$281,650
140° F. System	$292,400

The sequence of controls is described in basic control system and used to limit the predetermined return water temperature (212°, 176°, 140°F.) In actual practice, the supply water temperature to the heating coils and pre-heat coils can be varied and reset from outdoor temperature, the current L.W.T. is set for 210° F. at -20° F outdoor temperature. When the return water temperature to the district heating plant is set for 140° F., a condition may occur when the demand for domestic water is minimal resulting in a limited supply of D.H. water to the heating water exchanger due to the high limit sensor located in the D.H. water return line. An alternate solution to this problem would be to change all pre-heat coils, heating coils, fan coils and unit heater.

The coils designated in the existing system schematic as preheat (PH) or heating coils (H) all in banks or row or multiple settings. The proximity of adjacent bank of coils for each air handling system would not lend itself to removing and replacing new and larger coils having a greater surface area in the form of tube row depth. Because of the numerous quantities and space limitation, it is impractical to change coils.

HENNEPIN COUNTY GOVERNMENT CENTER

Date	Steam Demands Temperature	Lbs./Hr.
1/10/77	-19	28,000
1/11/77	-26	27,500
1/17/77	-21	25,000
1/18/77	-2	22,500
12/6/77	-10	24,600
12/7/77	-10	28,500
12/9/77	-12	26,700
12/26/77	-3	27,600
12/27/77	-10	28,800

PURCHASED STEAM

1976

Month	M Lbs.
January	14151
February	9085
March	7403
April	3796
May	3219
June	2278
July	2048
August	2095
September	2562
October	4543
November	5226
December	8952
Total	65358

1977

January	10863
February	6787
March	3863
April	1911
May	947
June	1068
July	1037
August	1117
September	1410
October	3553
November	5684
December	9204
Total	47444

SEQUENCE OF CONTROL OPERATION

Instrument supply line to ventilation air equipment maintains 210° F. modulates valve V_2.

Instrument in supply line in domestic water maintains 140° F. by modulating valves V_3 and V_4 in sequence; V_3 open first on call for heat, V_4 open only after V_3 is fully open.

Instrument sensor in main return to central heat plant will prevent temperature from rising above (212, 176, 140) by modulating V_1 directly, and through reversing relay modulating valve V_3.

V_1 closes V_3 opens. Modulation of V_3 from instrument in domestic water line will override modulation of V_3 from instrument in main return line.

COST ESTIMATE

Lower Level 212°	$109,346	
Admin. Tower 212°	85,600	
Court Tower 212°	85,600	
		$280,546
Lower Level 176°	104,250	
Admin. Tower 176°	88,700	
Court Tower 176°	88,700	
		$281,650
Lower Level 140°	112,400	
Admin. Tower 140°	90,000	
Court Tower 140°	90,000	
		$292,400

The above totals include the following:

	Demolition	Controls and Insulation
212 L.L.	4,000	30,000
Admin.	4,800	26,560
Court	4,800	26,560
176 L.L.	4,000	27,300
Admin.	4,800	26,560
Court	4,800	26,560
140 L.L.	4,000	28,700
Admin.	4,800	23,400
Court	4,800	23,400

The following is a breakdown requested by your office for Hennepin County Civic Center.

LOWER LEVEL 212'	
Labor	$ 15,428.00
Heat Exchangers	15,527.00
Piping	31,391.00
Demo	4,000.00
Insul	10,000.00
Temp Control	20,000.00
Total	96,346.00
Mark Up	13,000.00
Total Price	$109,346.00

ADMINISTRATIVE TOWER 212'	COURT TOWER 212' - SAME
Labor	$ 10,944.00
Heat Exchanger	10,993.00
Piping	21,023.00
Demo	4,800.00
Insul	10,000.00
Temp Control	16,560.00
Total	74,320.00
Mark Up	11,280.00
Total Price	85,600.00

LOWER LEVEL 140'

Labor	$ 10,200.00
Heat Exchangers	42,600.00
Piping	13,300.00
Demo	4,000.00
Insul	10,000.00
Temp Control	18,700.00
Total	98,800.00
Mark Up	13,600.00
Total Price	$112,400.00

ADMINISTRATIVE TOWER 140'

COURT TOWER 140' - SAME

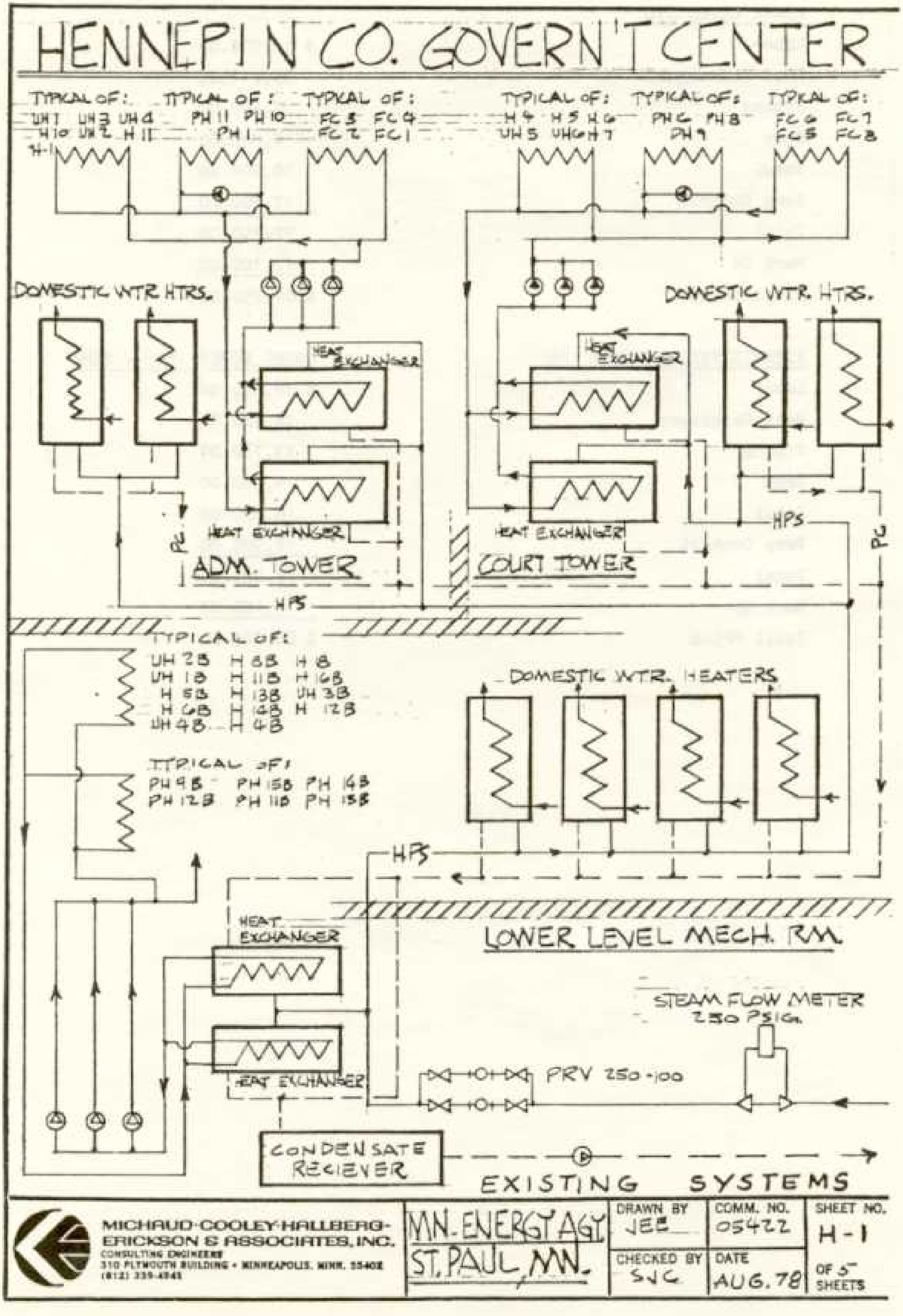
Labor	$ 15,200.00
Heat Exchangers	19,500.00
Piping	15,600.00
Demo	4,800.00
Insul	10,000.00
Temp Control	13,400.00
Total	78,500.00
Mark Up	11,500.00
Total Price	$ 90,000.00

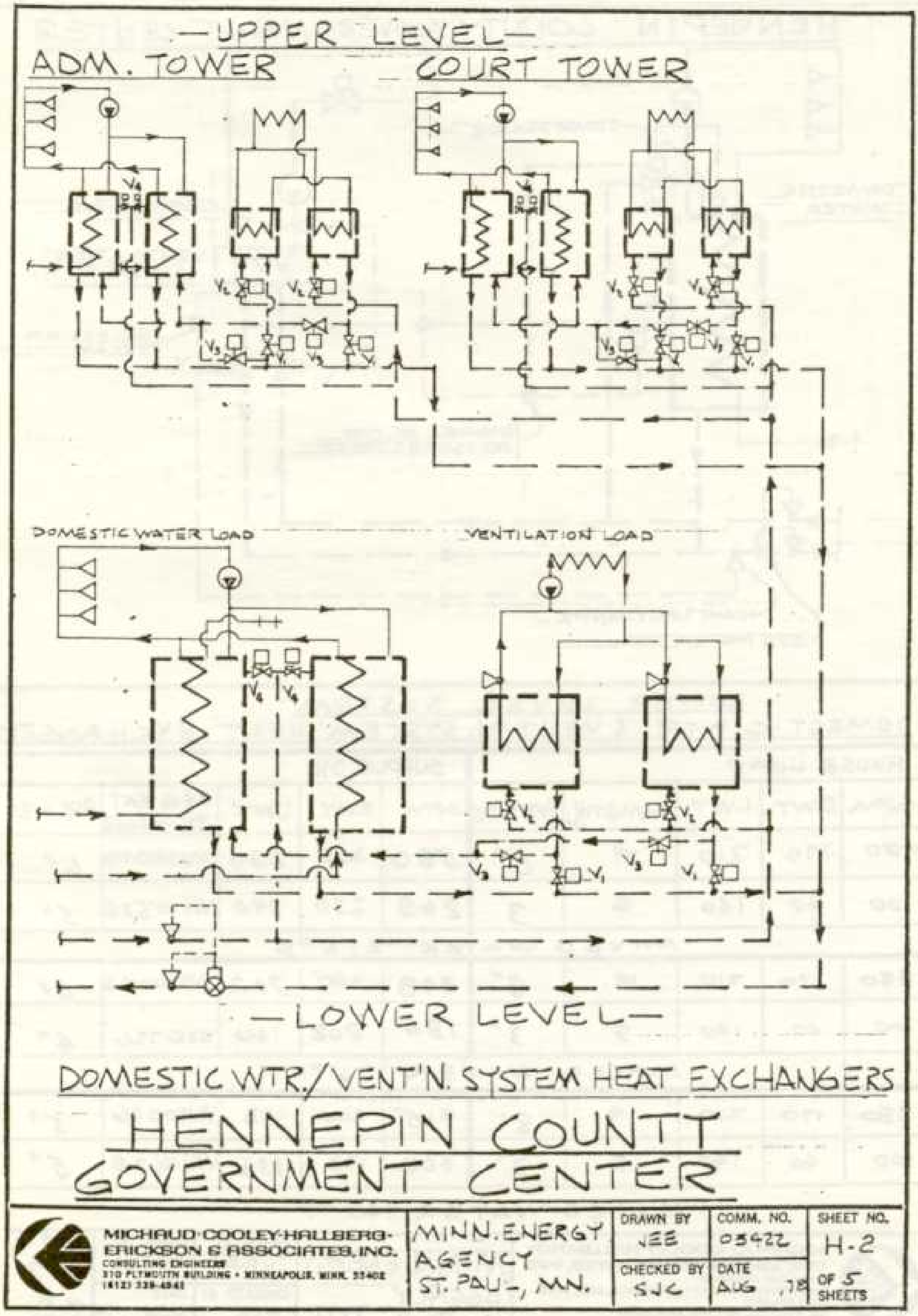
HENNEPIN COUNTY BUILDING SUMMARY

	140°		212°	
Labor	40,600	3.96	37,316	3.64
Heat Exchangers	81,600	7.96	37,513	3.66
Piping	44,500	4.34	73,437	7.16
Demo	13,600	1.33	13,600	1.32
Insul	30,000	2.92	30,000	2.92
Temp Control	45,500	4.43	53,120	5.18
Total	255,800	24.94	244,986	23.88
Mark Up	36,600	3,57	35,560	3,47
Total	292,400	28.51	280,546	27.35

LOWER LEVEL 176'	
Labor	$ 10,039.00
Heat Exchangers	35,711.00
Piping	15,100.00
Demo	4,000.00
Insul	10,000.00
Temp Control	17,300.00
Total	92,150.00
Mark Up	12,100.00
Total Price	$104,250.00

ADMINISTRATIVE TOWER 176'	COURT TOWER 176' - SAME
Labor	$ 18,650.00
Heat Exchanger	14,130.00
Piping	13,160.00
Demo	4,800.00
Insul	10,000.00
Temp Control	16,500.00
Total	77,240.00
Mark Up	11,460.00
Total Price	$ 88,700.00


HENNEPIN CO. GOVERN'T CENTER
DOMESTIC WTR. HTRS.
HEAT EXCHANGER
ADM. TOWER
COURT TOWER
HPS
PC
TYPICAL OF:
DOMESTIC WTR. HEATERS
LOWER LEVEL MECH. RM.
STEAM FLOW METER
250 PSIG
PRV 250-100
CONDENSATE
RECIEVER
EXISTING SYSTEMS
MICHAUD-COOLEY-HALLBERG-
ERICKSON & ASSOCIATES, INC.
CONSULTING ENGINEERS
MN. ENERGY AGY
ST. PAUL, MN.
DRAWN BY
JEE
CHECKED BY
SJC
COMM. NO.
05422
DATE
AUG. 78
SHEET NO.
H-1
OF 5 SHEETS


—UPPER LEVEL—
ADM. TOWER
COURT TOWER
DOMESTIC WATER LOAD
VENTILATION LOAD
—LOWER LEVEL—
DOMESTIC WTR./VENT'N. SYSTEM HEAT EXCHANGERS
HENNEPIN COUNTY
GOVERNMENT CENTER
MICHAUD-COOLEY-HALLBERG-ERICKSON & ASSOCIATES, INC.
CONSULTING ENGINEERS
MINN. ENERGY AGENCY
ST. PAUL, MN.
DRAWN BY
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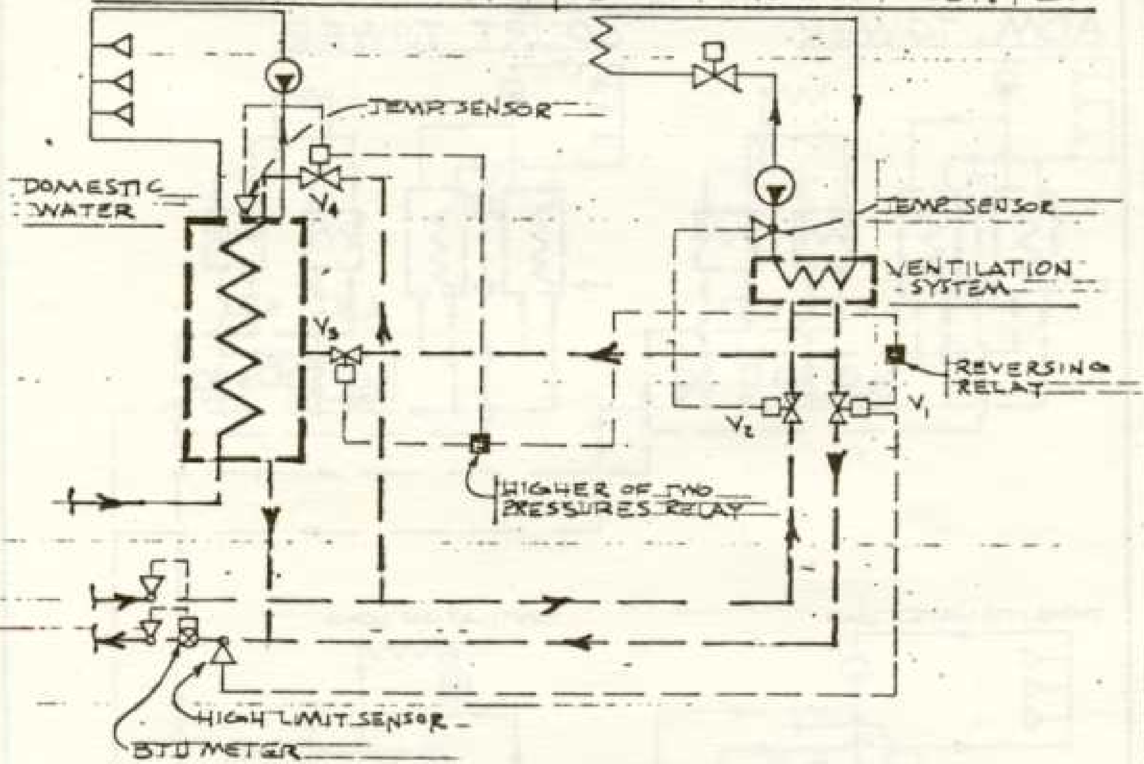
COMM. NO.
03422
SHEET NO.
H-2
CHECKED BY
SJC
DATE
AUG. '78
OF 5 SHEETS

HENNEPIN COUNTY GOVERNMENT CENTER



LOWER LEVEL SYSTEM
DOMESTIC WTR. & VENT'N. SYSTEM HEAT EXCHANGERS

HOUSE LOAD					SUPPLY DH.				
GPM	EWT	LWT	MMBTU/H	PIPE SIZE	GPM	EWT	LWT	B&G HEAT EXCHANGER	PIPE SIZE
950	170	210	19	8"	580	300	230	WU240-210	6"
100	40	140	5	3	263	230	190	WU10528	5"
MIXED WATER 212°F									
950	170	210	19.	8"	408	300	242	WU30104G	6"
100	40	140	5	3"	185	202	140	WU10726	4"
MIXED WATER 176°F									
950	170	210	19	8"	315	300	173	WU30104G	5"
100	40	140	.5	3"	302	173	138	WU12628	5"
MIXED WATER 140°F									

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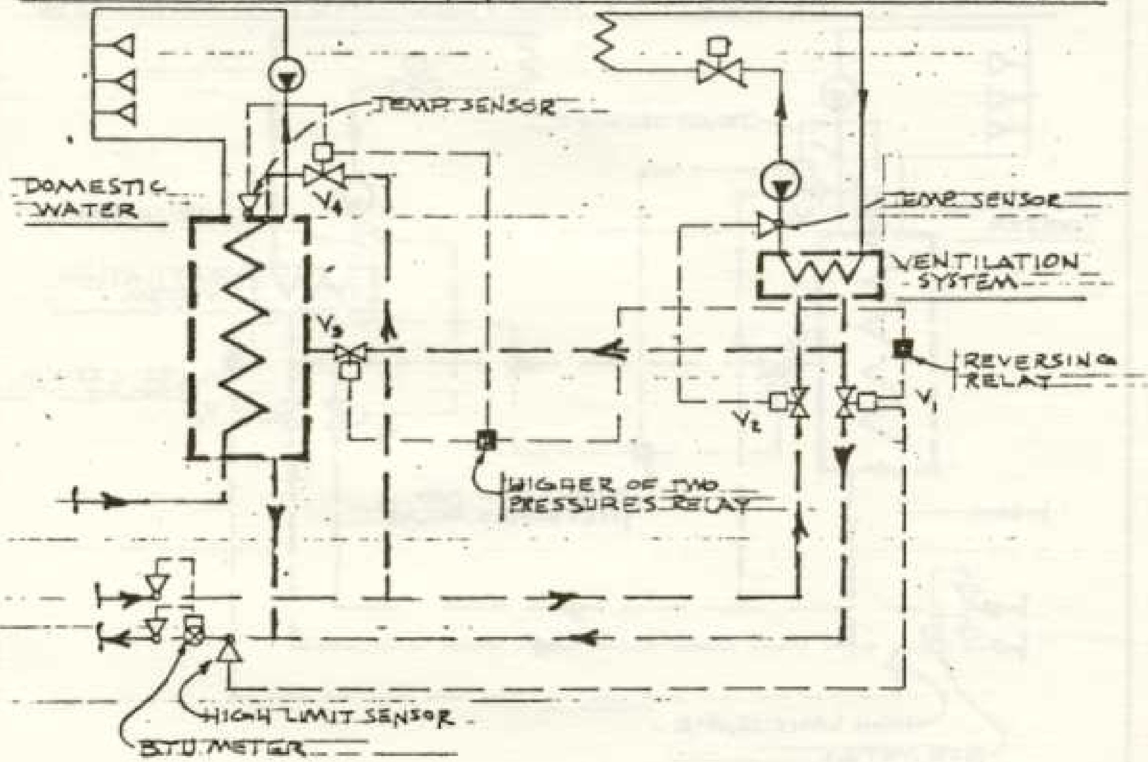
		CHECKED BY SJC	DATE AUG. '73	OF 5 SHEETS

HENNEPIN COUNTY GOVERNMENT CENTER



UPPER LEVEL ADMINISTRATION TOWER DOMESTIC WTR. & VENT'N. SYSTEM HEAT EXCHANGERS

HOUSE LOAD					SUPPLY DISTRICT HEAT				
GPM	EWT	LWT	MMBTU/HR	PIPE SIZE	GPM	EWT	LWT	BIG HEAT EXCHANGER	PIPE SIZE
425	170	210	8.5	6"	265	300	231	WU 18846	5"
50	40	140	2.5	2½	128	231	190	WU 10424	4"
MIXED WATER 212°F									
425	170	210	8.5	6"	188	300	203	WU 20 1044	4"
50	40	140	2.5	2½	99	203	150	WU 8744	3
MIXED WATER 176°F									
425	170	210	8.5	6"	146	300	175	WU 22 845	4"
50	40	140	2.5	2½	142	175	138	WU 10625	4"
MIXED WATER 140°F									

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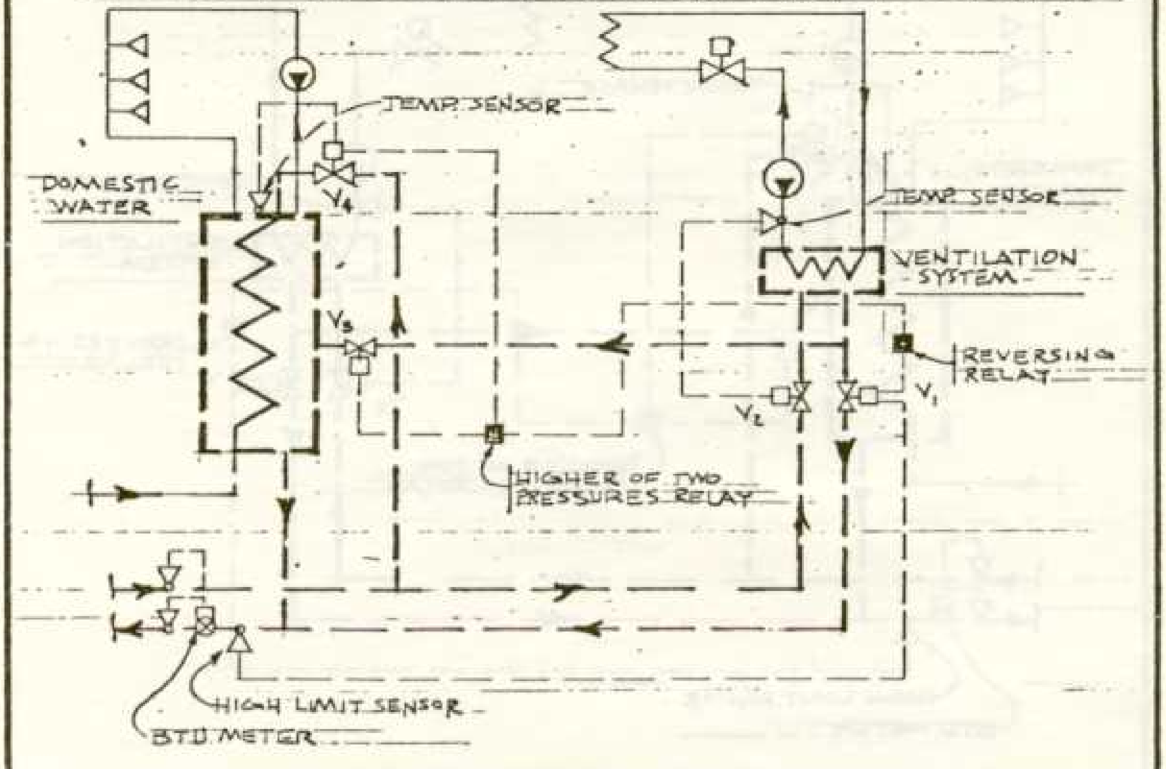
HENNEPIN COUNTY GOVERNMENT CENTER



UPPER LEVEL COURT TOWER
DOMESTIC WTR. & VENT'N. SYSTEM HEAT EXCHANGERS

HOUSE LOAD					SUPPLY DISTRICT HEATING				
GPM	EWT	LWT	MMBTU/HR	PIPE SIZE	GPM	EWT	LWT	B&G HEAT EXCHANGER	PIPE SIZE
500	170	210	10	6"	302	300	229	WU1894 B	5"
50	40	140	2.5	2½"	132	229	197	WU 10424	4"
MIXED WATER 212°F									
500	170	210	10	6"	214	300	200	WU2010C 4	4"
50	50	140	2.5	2½	105	200	150	WU 8745	3"
MIXED WATER 176°F									
500	170	210	10	6"	166	300	173	WU22045	4"
50	40	140	2.5	2½	150	173	138	WU10625	4"
MIXED WATER 140°F									

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KELLOGG SQUARE

This town house, apartment complex is located in St. Paul, Minnesota and consists of 779,580 sq. ft. of floor area and 13,983,840 cu. ft. total volume. The 554 apartment section of the building is a structure 32 floors in height serving one and two bedroom tenant type apartments. The 19 unit town house portion of this structure totals 5 floors. Generally, the lower three floors consist of commercial and office space.

The main boiler room houses the two 600 H.P. low pressure steam boilers which are combination gas/oil fired. Steam is distributed to various parts of the building from the main steam header, which serves blast unit heaters for entrances, preheat ventilation coils, heating coils, domestic water heat exchanges, steam to water heat exchangers serving radiation, reheat and fan coil systems.

The boiler room equipment includes two domestic water heat exchangers which deliver water to the town house units and the lower floors of the apartment tower section. One steam to water heat exchanger serves radiation for the lower three floors. Steam from the boiler room header also distributes steam to the town house heat exchangers and air ventilation units.

The town house heat exchangers are used for reheat air systems and fan coil heating units.

The 24th floor equipment rooms house the ventilation units, domestic water and heat exchanger equipment. Steam is distributed to the air units and heat exchangers.

The summer load is principally domestic hot water and reheat. Two centrifugal electric refrigeration chillers located in the boiler and equipment room generate 1340 tons of refrigeration. Chilled water is distributed to central air units and fan coils.

ANNUAL CONSUMPTION - FUEL(S)

MONTHS DATES FROM/TO	* FUEL TYPE & UNIT Quantity Used MCF	** FUEL TYPE Quantity Used Gallons
10-20-76		
9-21-76	4565	100
8-20-76	3559	0
7-26-76	2557	0
6-22-76	3507	0
5-21-76	3720	0
4-22-76	4070	350
3-23-76	4600	500
2-23-76	2480	24,450
1-27-76	3390	29,995
12-22-75	50	68,750
11-21-75	1200	49,350
10-21-75	3610	67,750
TOTAL	37,308	241,245

* Natural Gas 1000 BTU/Cu. Ft.

** Oil 150,000 BTU/Gal.

KELLOGG SQUARE

Summary of Existing Connected Load

Steam	MBH	
Preheat Coils	8,781	
Heating Coils	9,535	
Cabinet Unit Heater	427	
Blast Unit Heater	690	
	19,433	19,433

Steam to Hot Water Converters

Boiler Room	MBH	
Domestic Water	1,800	
Domestic Water	1,800	
(Radiation H.W. SL216120	3,760	
	7,360	
Town House		
Reheat H.W. SL41660	2,050	
Fan Coil H.W. B & G SU1062	1,800	
	3,850	
24th Floor		
Domestic Water	1,800	
Domestic Water	1,800	
Reheat H.W. SL41460	1,290	
Fan Coil H.W. SL41260	1,030	
Total	5,920	17,130
		36,563

Maximum Daily Consumption - 3,000 Gallons #4 Oil

	1976	1977
#4 Oil Consumption (Gallons)	206,583	151,034
Natural Gas Consumption (Cu. Ft.)	41,311,000	46,178,000

SEQUENCE OF CONTROL OPERATION

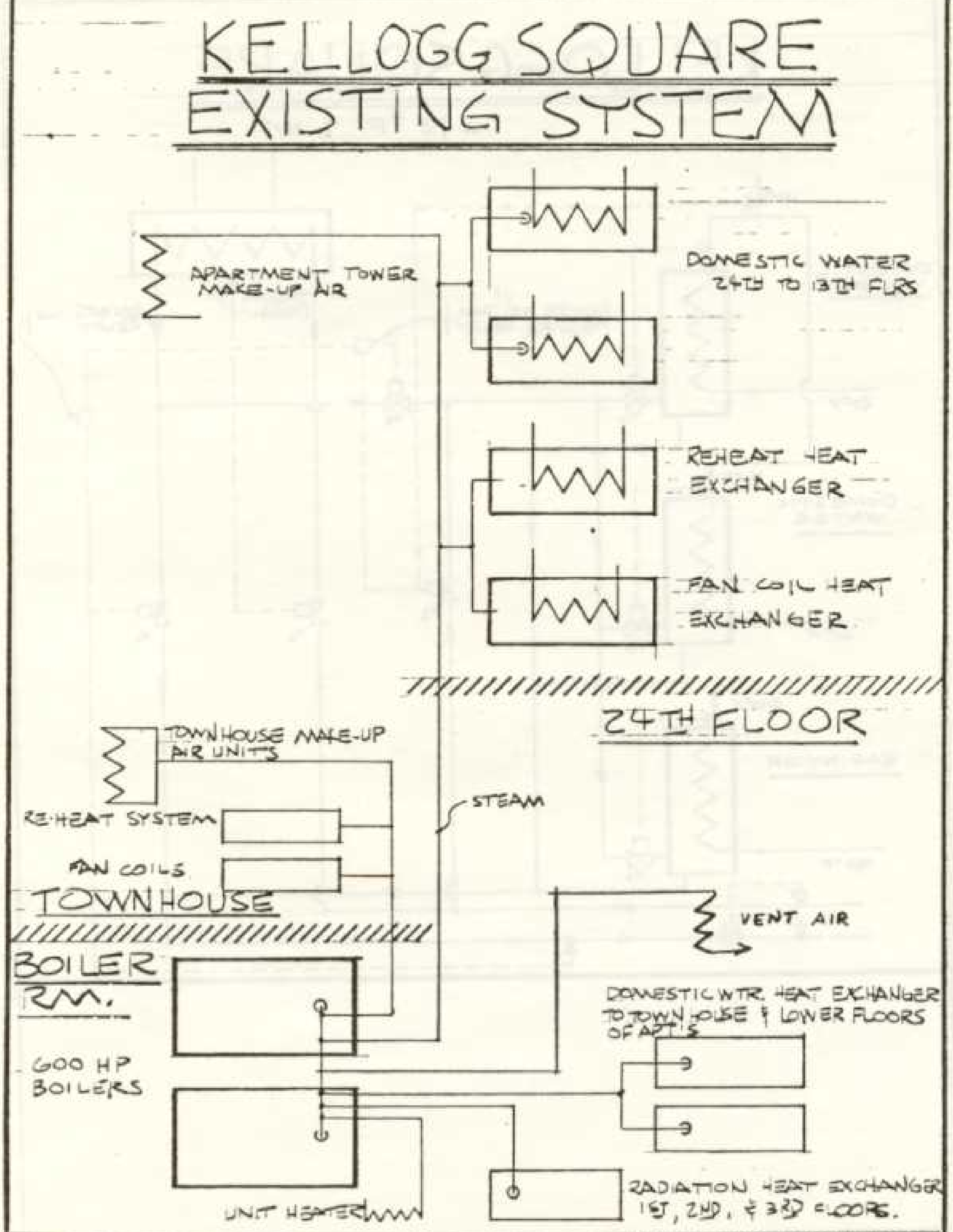
Instrument supply line to ventilation air equipment and heat exchangers maintains 5 psig steam at 227° F., modulates valve V_2.

Instrument in supply line in domestic water maintains 140° F. by modulating valves V_3 and V_4 in sequence; V_3 open first on call for heat, V_4 open only after V_3 is fully open.

Instrument sensor in main return to central heat plant will prevent temperature from rising above (212, 176, 140) by modulating V_1 directly, and through reversing relay modulating valve V_3.

V_1 closes, V_3 opens. Modulation of V_3 from instrument in domestic water line will override modulation of V_3 from instrument in main return line.

Valves V_a, V_b, etc. act independently through their respective sensor instrument in the leaving water side for domestic water and heat exchanger equipment.



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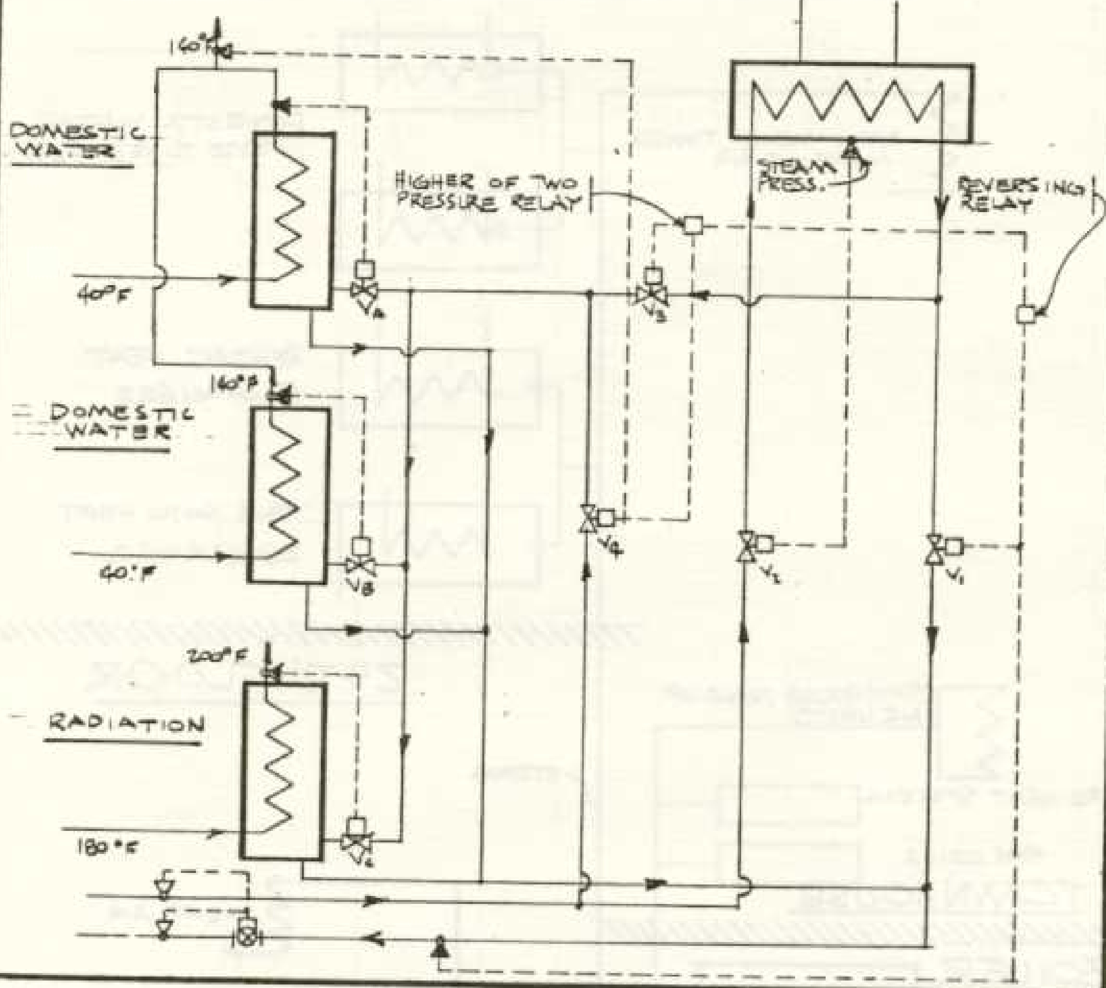
310 PLYMOUTH BUILDING • MINNEAPOLIS, MINN. 55402
(612) 339-4941

MN. ENERGY AGY. ST. PAUL, MN	DRAWN BY JEE	COMM. NO. 05422	SHEET NO. K-1
	CHECKED BY SJC	DATE AUG. 78	OF 4 SHEETS

KELLOGG SQUARE

212 °F. L.W.T.



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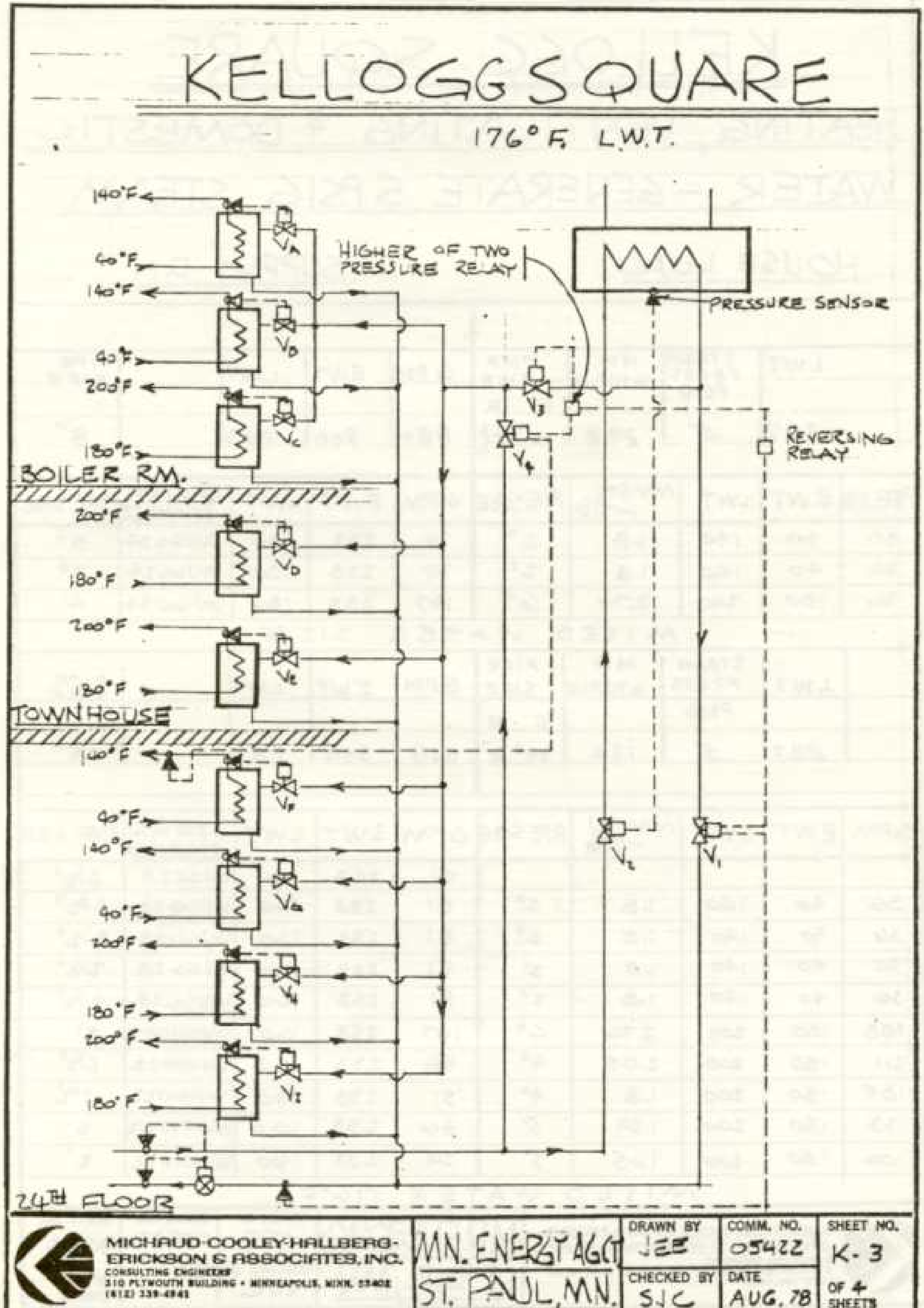
KELLOGG SQUARE
176° F. L.W.T.
140°F
40°F
200°F
180°F
VA
VB
VC
VD
VE
VF
VG
VH
VI
V1
V2
V3
V4
HIGHER OF TWO PRESSURE RELAY
PRESSURE SENSOR
REVERSING RELAY
BOILER RM.
TOWNHOUSE
24TH FLOOR
MICHAUD-COOLEY-HALLBERG-ERICKSON & ASSOCIATES, INC.
CONSULTING ENGINEERS
310 PLYMOUTH BUILDING • MINNEAPOLIS, MINN. 55402
(612) 339-4941
MN. ENERGY AGCY
ST. PAUL, MN.
DRAWN BY
JEE
CHECKED BY
SJC
COMM. NO.
05422
DATE
AUG. 78
SHEET NO.
K-3
OF 4 SHEETS

KELLOGG SQUARE

HEATING, VENTILATING & DOMESTIC WATER – GENERATE 5 PSIG STEAM

HOUSE LOAD — SUPPLY D.H

	LWT	STEAM PRESS PSIG	MM BTU/HR	PIPE SIZE S R	GPM	EWT	LWT		PIPE SIZE
	227	5	29.2	12" 2½	884	300	233		8"

PIPE SIZE	EWT	LWT	MMBTU/HR	PIPE SIZE	GPM	EWT	LWT	B&G HEAT EXCHANGER	PIPE SIZE
36	40	140	1.8	2"	70	233	180	WU6624	3"
36	40	140	1.8	2'	70	233	180	WU6624	3'
36	180	200	3.76	6"	147	233	180	WU61044	4'

MIXED WATER 212°F

	LWT	STEAM PRESS PSIG	MM BTU/HR	PIPE SIZE S R	GPM	EWT	LWT		PIPE SIZE
	227	5	19.4	10" 2"	619	300	233		6"

GPM	EWT	LWT	MMBTU/HR	PIPE SIZE	GPM	EWT	LWT	B&G HEAT EXCHANGER	PIPE SIZE
					51	233	160	WU6623	2½"
36	40	140	1.8	2"	51	233	160	WU6623	2½"
36	40	140	1.8	2"	51	233	160	WU6623	2½"
36	40	140	1.8	2'	51	233	160	WU6623	2½"
36	40	140	1.8	2"	51	233	160	WU6623	2½"
388	180	200	3.76	6"	107	233	160	WU61044	3"
211	180	200	2.05	4"	58	233	160	WU101022	2½"
185	180	200	1.8	4"	51	233	160	WU101022	2½"
133	180	200	1.29	3"	36	233	160	WU101022	2"
106	180	200	1.03	3"	29	233	160	WU101022	2"

MIXED WATER 176°F

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CONSULTING ENGINEERS
310 PLYMOUTH BUILDING • MINNEAPOLIS, MINN. 55402
(612) 339-4941

MN. ENERGY AGY	DRAWN BY: JEE	COMM. NO.: 03422	SHEET NO.: K-4
ST. PAUL, MN.	CHECKED BY: SJC	DATE:	OF 4 SHEETS

COST ESTIMATE

KELLOGG SQUARE, ST. PAUL

212 System

Labor	$	46,000
Heat Exchangers		105,800
Piping		23,100
Demo		12,000
Insulation		20,000
Temp. Control		33,600
Total		240,500
Mark Up		24,000
Total Price		264,500

176 System

Labor	$	47,700
Heat Exchangers		65,800
Piping		26,300
Demo		12,000
Insulation		21,000
Temp. Control		36,400
Total		209,200
Mark Up		20,900
Total Price		230,100

COST ESTIMATE

KELLOGG SQUARE - ST. PAUL, MINNESOTA

168° F. System

Labor	$ 50,416
Heat Exchangers & Coils	67,600
Piping & Valves	27,521
Demo	12,900
Insulation	21,800
Temp. Controls	38,030
	218,267
Mark Up	21,828
	240,095

RADISSON HOTEL

This hotel located in St. Paul, Minnesota is a 23 story structure with 5% of floor area below grade. The steam at 20 psig and 260°F. is supplied to the building from a public utility from underground tunnel distribution laterials in the street. The condensate is not returned to the utility grid system. The floor area is 1,216,608 sq. ft. and the total building volume is 17,032,512 cu. ft.

The heating load is principally the indirect hot water heat exchangers, domestic water and ventilation air units. The peak monthly demand 6810 M lbs. steam, reference is made to the annual steam consumption.

Refrigeration machines for cooling are two machines, each 242 tons, direct drive electric centrifugal, well water 252 tons and DX units 145 tons.

The kitchens utilize approx. 3000 MCF/year natural gas for cooking.

RADISSON HOTEL

ST. PAUL MINNESOTA

CONNECTED DESIGN LOAD

	LBS/HR.
Zone Reheat Coils	1,532
Entrance and Unit Heaters	215
Ballroom Floor Heat Exchanger	5,000
Ballroom Floor Heat Exchanger	5,000
Lobby Direct Radiation Heat Exchanger	60
Penthouse Direct Radiation Heat Exchanger	40
Preheat Coils (air handling Units)	9,990
Reheat Coils (air handling units)	9,520
Domestic Water Heater	5,000
	36,657
Kitchen	4,000
	40,657

SEQUENCE OF CONTROL OPERATION

Instrument supply line to ventilation air equipment and heat exchangers maintains 5 psig steam at 227°F., modulates valve V_2.

Instrument in supply line in water maintains 180°F. by modulating valves V_3 and V_4 in sequence; V_3 open first on call for heat, V_4 open only after V_3 is fully open.

Instrument sensor in main return to central heat plant will prevent temperature from rising above (212) by modulating V_1 directly, and through reversing relay modulating valve V_3.

V_1 closes, V_3 opens. Modulation of V_3 from instrument in domestic water line will override modulation of V_3 from instrument in main return line.

Valves V_a, V_b, act independently through their respective sensor instrument in the leaving water side for domestic water and heat exchanger equipment.

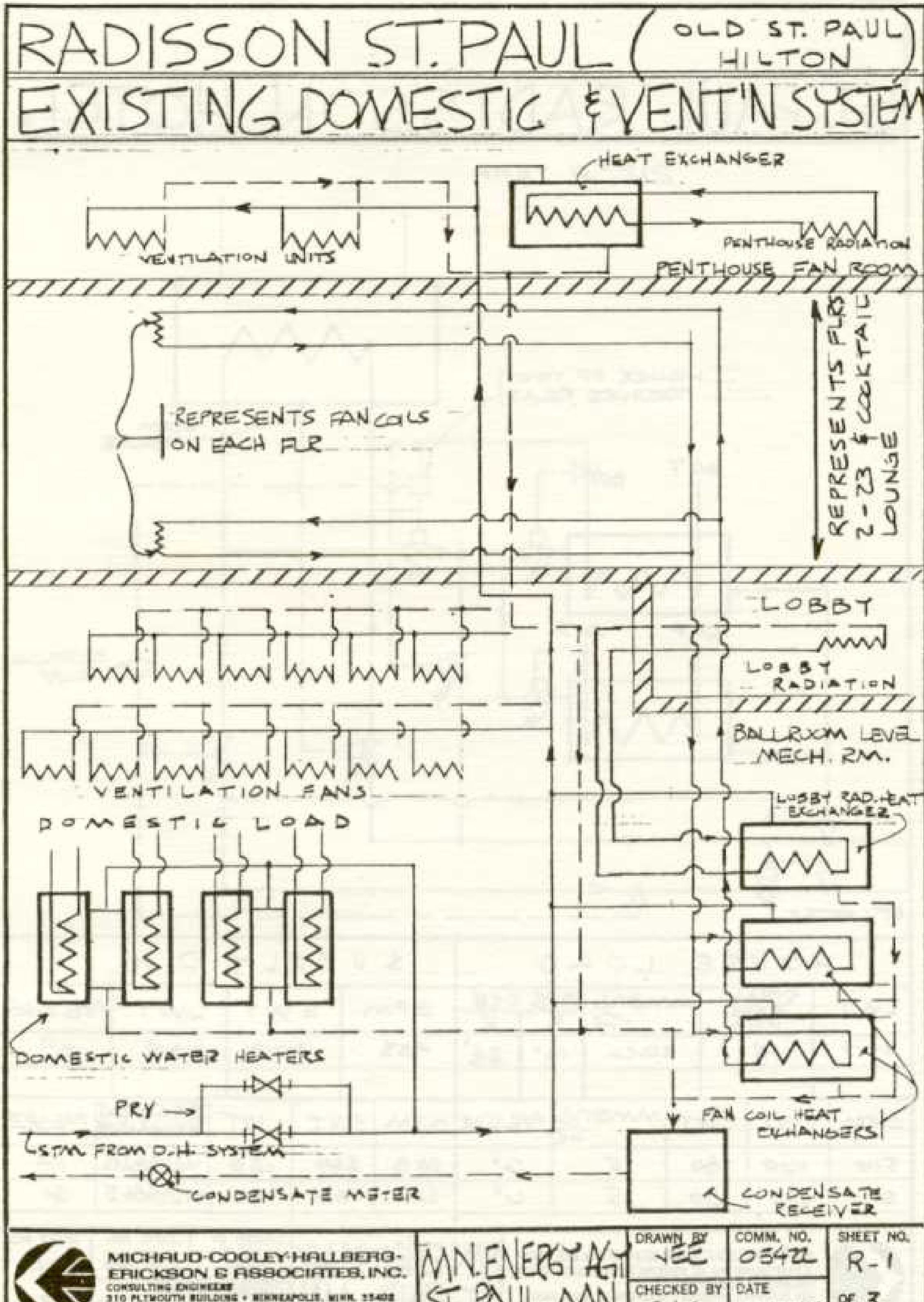
RADISSON HOTEL

ST. PAUL, MINNESOTA

ANNUAL STEAM CONSUMPTION

M-LB STEAM

	1976	1977	1978
January	5,190	6,810	4,220
February	1,550	4,020	4,440
March	3,240	2,890	3,720
April	2,950	1,780	1,990
May	1,260	570	1,190
June	590	370	
July	340	420	
August	330	380	
September	590	320	
October	1,030	960	
November	1,950	1,390	
December	3,980	4,460	
	25,490	24,370	15,560


RADISSON ST. PAUL (OLD ST. PAUL HILTON)
EXISTING DOMESTIC & VENT'N SYSTEM
HEAT EXCHANGER
VENTILATION UNITS
PENTHOUSE RADIATION
PENTHOUSE FAN ROOM
REPRESENTS FAN COILS ON EACH FLR
REPRESENTS FLRS 2-23 & COCKTAIL LOUNGE
LOBBY
LOBBY RADIATION
BALLROOM LEVEL MECH. RM.
VENTILATION FANS
DOMESTIC LOAD
LOBBY RAD. HEAT EXCHANGER
DOMESTIC WATER HEATERS
PRV
STM FROM D.H. SYSTEM
FAN COIL HEAT EXCHANGERS
CONDENSATE METER
CONDENSATE RECEIVER
MICHAUD-COOLEY-HALLBERG-ERICKSON & ASSOCIATES, INC.
CONSULTING ENGINEERS
310 PLYMOUTH BUILDING • MINNEAPOLIS, MINN. 55402
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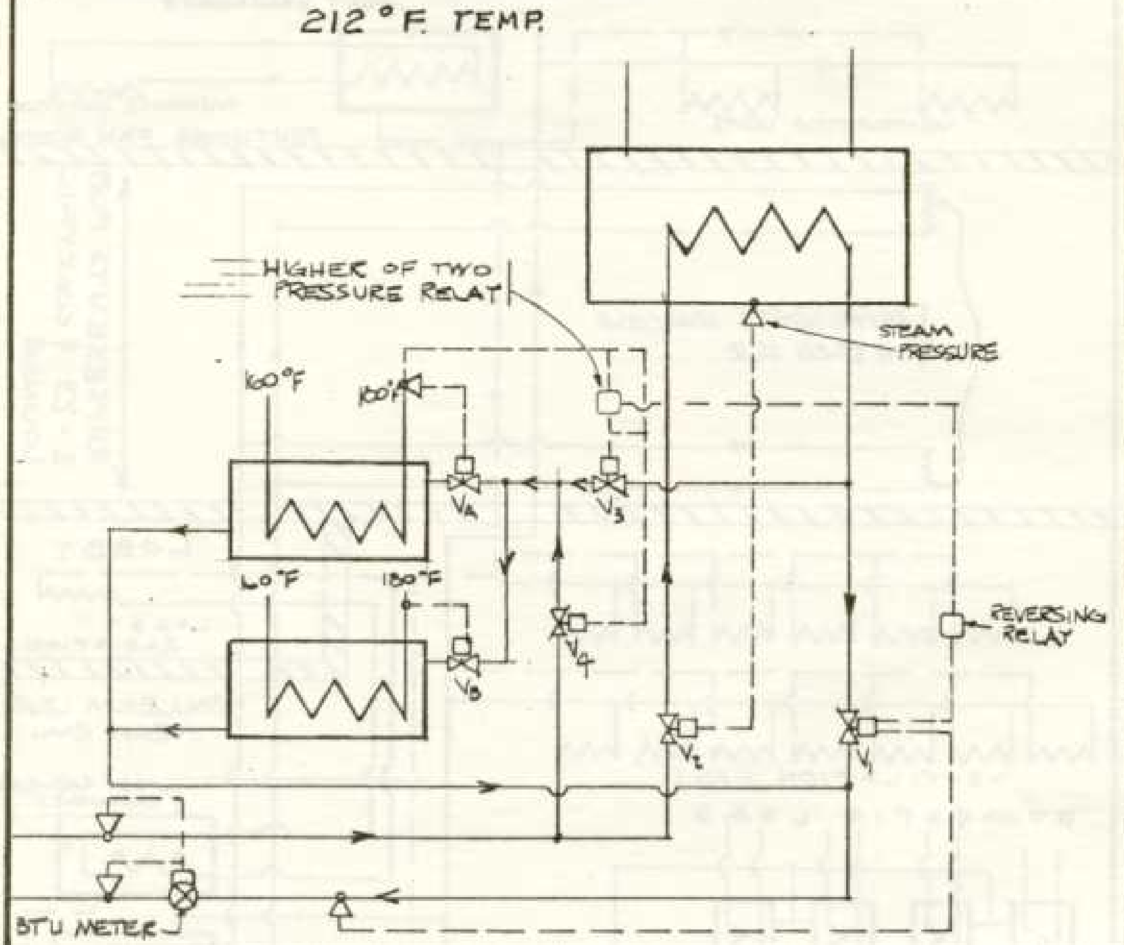
ST. PAUL RADISSON HOTEL



HOUSE LOAD					SUPPLY D.H.			
LWT	STEAM PRESS. PSIG	MMBTU/HR	PIPE SIZE S	PIPE SIZE R	GPM	EWT	LWT	PIPE SIZE
227	5	30.6	12"	2½"	983	300	235	8"

GPM	EWT	LWT	MMBTU/HR	PIPE SIZE	GPM	EWT	LWT	B & G HEAT EXCHANGER	PIPE SIZE
516	160	180	5	6"	203	235	185	WU13325	41
516	160	180	5	6"	208	235	185	WU13325	41

MICHAUD-COOLEY-HALLBERG-ERICKSON & ASSOCIATES, INC.
CONSULTING ENGINEERS
310 PLYMOUTH BUILDING • MINNEAPOLIS, MINN. 55402
(612) 339-4941

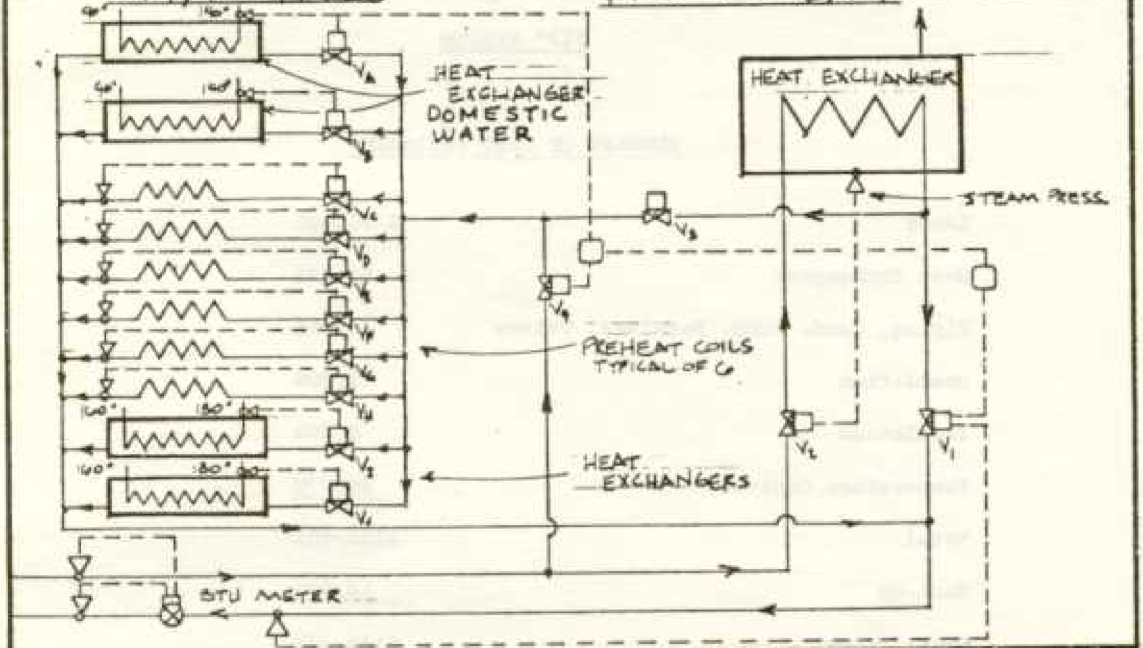
MN. ENERGY AGY.
ST. PAUL, MN

DRAWN BY	COMM. NO.	SHEET NO.
JEE	05422	R-2
CHECKED BY	DATE	OF 3 SHEETS
SJC	AUG. 78	

RADISSON HOTEL

ST. PAUL, MN

176 °F TEMP.



HOUSE LOAD					SUPPLY D.H.			
LWT	STEAM PRESS PSIG	MMBTU/HR	PIPE SIZE S	R	GPM	EWT	LWT	PIPE SIZE
227	5	1977	10	2½	697	300	241	

GPM	EWT	LWT	MMBTU/HR	PIPE SIZE	GPM	EWT	LWT	HEAT EXC.	PIPE SIZE
516	160	180	5	6"	208	241	160	WU18825	
516	160	180	5	6"	208	241	160	WU18825	
50	40	140	2.5	2½"	62	241	160	WU10842	3"
50	40	140	2.5	2½"	62	241	160	WU10842	3"

CFM	EAT	LAT	MMBTU/HR	EXISTING DUCTS	GPM	EWT	LWT	HEAT EXCHANGER	PIPE SIZE
14,000	50	80	.48		12	241	160	AIR COIL	1½"
35,000	40	130	3.4		87	241	160	AIR COIL	4"
11,200	40	80	.48		12	241	160	AIR COIL	1½"
21,600	55	105	1.17		30	241	160	AIR COIL	2"
23,000	50	90	1.0		26	241	160	AIR COIL	2"
6,750	50	100	.35		9	241	160	AIR COIL	1¼"

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MN. ENERGY AGT.
ST. PAUL, MN.

DRAWN BY	COMM. NO.	SHEET NO.
JEE	05422	R-3
CHECKED BY	DATE	OF 3 SHEETS
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RADISSON HOTEL

OLD ST. PAUL HILTON

212° SYSTEM

SUMMARY OF COST ESTIMATES

Labor	$ 11,640
Heat Exchangers	54,226
Piping, Cond. Pump, Receiver, Valves	30,066
Demolition	1,500
Insulation	6,200
Temperature Control	20,770
Total	$124,402
Mark-Up	14,900
Total Price	$139,302

RADISSON HOTEL
OLD ST. PAUL HILTON

176°F System

SUMMARY OF COST ESTIMATE

Labor	$ 22,240
Heat Exchangers	42,226
Piping, Cond. Pump	40,506
Demolition	5,300
Insulation	10,500
Temperature Control	30,370
Sub Total	151,142
Mark Up	19,900
Total	$ 171,042

CHAMBER OF COMMERCE BUILDING

This office building has 344,250 sq. ft. and a volume of 4,131,000 cu. ft. It is contained in a typical small office structure 12 floors above grade plus a penthouse, and 3 floors below grade. The original construction was started in 1923 with modification made continuously to date including converting to a D.H. type steam system in 1954. The original building was operated from 2 low pressure steam boilers. There is an existing total connected load of 7000 MBH, of which the direct connected steam load is approximately 56% of the total load.

An indirect hot water system supplies 90°F water to ventilation units. Three high velocity air handling system supply conditioned air to the basement and first five floors. The units receive steam, hot water or chilled water.

The 6th through 12th floors have individual equipment rooms housing multizone fan units. Each unit will receive chilled or hot water depending on seasonal demand. The conversion of chilled water to hot water is presently accomplished through manual valve changes which can be automated.

(OLD N.S.P.) CHAMBER OF COMMERCE BUILDING

MINNEAPOLIS, MINNESOTA

	Design Chilled Water GPM	Design Hot Water GPM
12th Floor N.E. Zone	45	22.5
12th Floor S.W. Zone	35	17.5
11th Floor	60	30.0
10th Floor	50	25.0
9th Floor N.E. Zone	45	22.5
9th Floor S.W. Zone	5	2.5
8th Floor	50	25.0
7th Floor N.E. Zone	41	20.5
7th Floor S.W. Zone	9	4.5
6th Floor	40	20.0
High Velocity N.E. and S.E.	80	40.0
High Velocity S.W. and N.W.	90	45.0
High Velocity Internal	170	85.0
1st Floor	80	40.0
Cafe and Auditorium	60	30.0
Vaults	29	14.5
Home Service	11	5.5
Total	900	450.0

CHAMBER OF COMMERCE

POUNDS OF STEAM

	1976-1977	1977-1978
September	324,600	62,300
October	902,700	492,600
November	1,496,700	1,026,800
December	2,085,700	1,779,600
January	2,181,800	1,670,900
February	1,211,200	1,635,900
March	862,400	952,000
April	386,600	725,400
May	125,100	251,400
June	67,600	126,500
July	75,700	73,100
August	85,600	69,300
Total	9,805,700	8,865,800

(OLD N.S.P.) CHAMBER OF COMMERCE BUILDING

MINNEAPOLIS, MINNESOTA

EXISTING DESIGN

SUMMARY OF CONNECTED LOAD

	Water MBH	Direct Steam MBH	
Sub-Basement Units	1,263.6		
Rest and Auditorium	182.0	167.0	
Vaults	77.5	212.0	
Home Service	48.6		
Upper Floors Unit (6 to 12)	1,471.0		
	3,042.7	379.0	379.0
Perimeter Radiation			3,421.0
Domestic Hot Water			165.0
Total	3,042.7		3,965.0

SEQUENCE OF CONTROL OPERATION

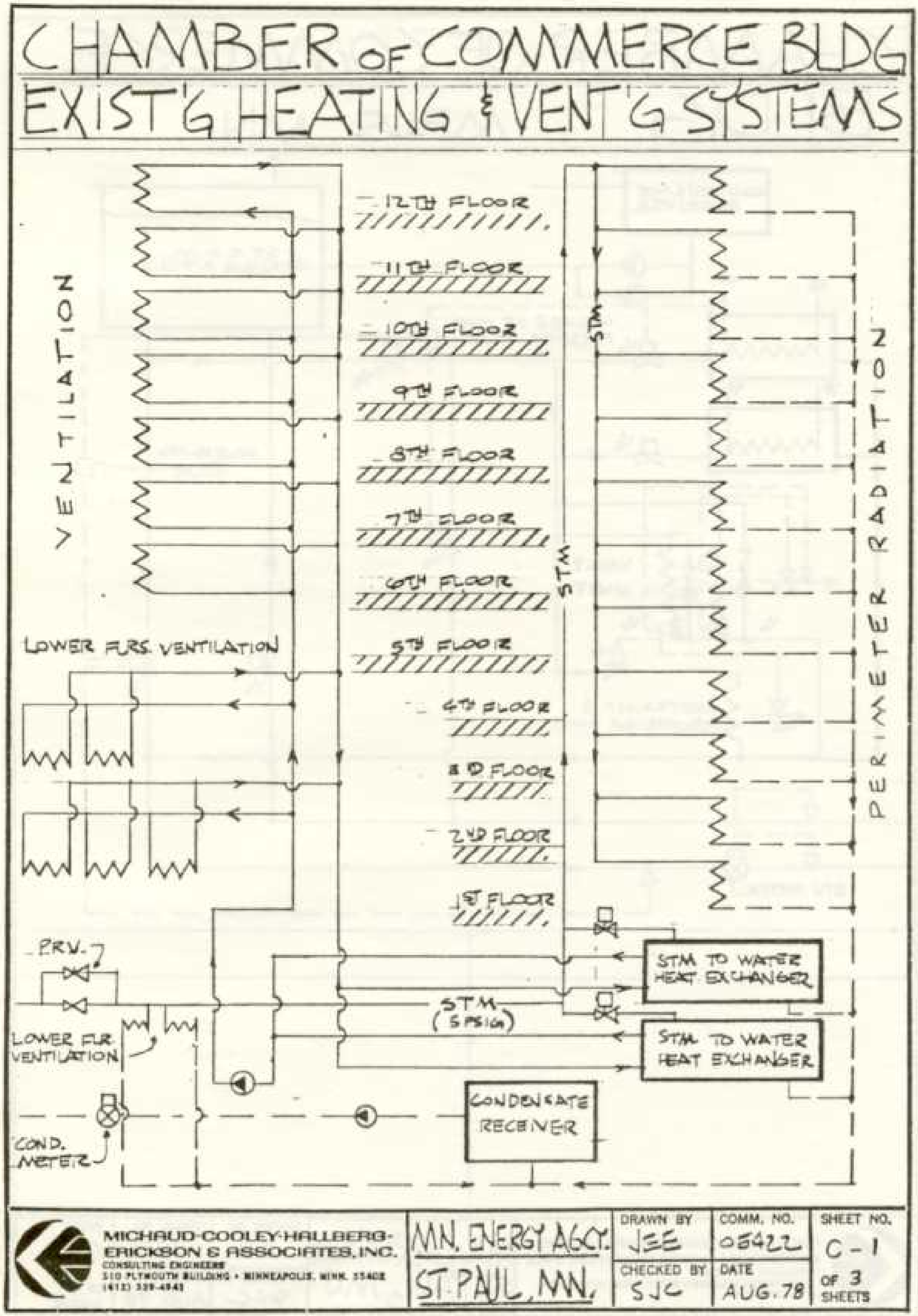
Instrument supply line to ventilation air equipment and heat exchangers maintains 5 psig steam at 227° F., modulates valve V_2.

Instrument in supply line in domestic water maintains 140° F. by modulating valves V_3 and V_4 in sequence; V_3 open first on call for heat, V_4 open only after V_3 is fully open.

Instrument sensor in main return to central heat plant will prevent temperature from rising above (212, 176, 140) by modulating V_1 directly, and through reversing relay modulating valve V_3.

V_1 closes, V_3 opens. Modulation of V_3 from instrument in domestic water line will override modulation of V_3 from instrument in main return line.

Valves V_a, V_b, etc. act independently through their respective sensor instrument in the leaving water side for domestic water and heat exchanger equipment.


CHAMBER OF COMMERCE BLDG
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PERIMETER RADIATION
12TH FLOOR
11TH FLOOR
10TH FLOOR
9TH FLOOR
8TH FLOOR
7TH FLOOR
6TH FLOOR
5TH FLOOR
4TH FLOOR
3RD FLOOR
2ND FLOOR
1ST FLOOR
STM
LOWER FLRS. VENTILATION
PRV.
STM (5PSIG)
LOWER FLR. VENTILATION
STM TO WATER HEAT EXCHANGER
STM TO WATER HEAT EXCHANGER
CONDENSATE RECEIVER
COND. METER
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MN. ENERGY AGCY.
ST. PAUL, MN.
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COMM. NO.
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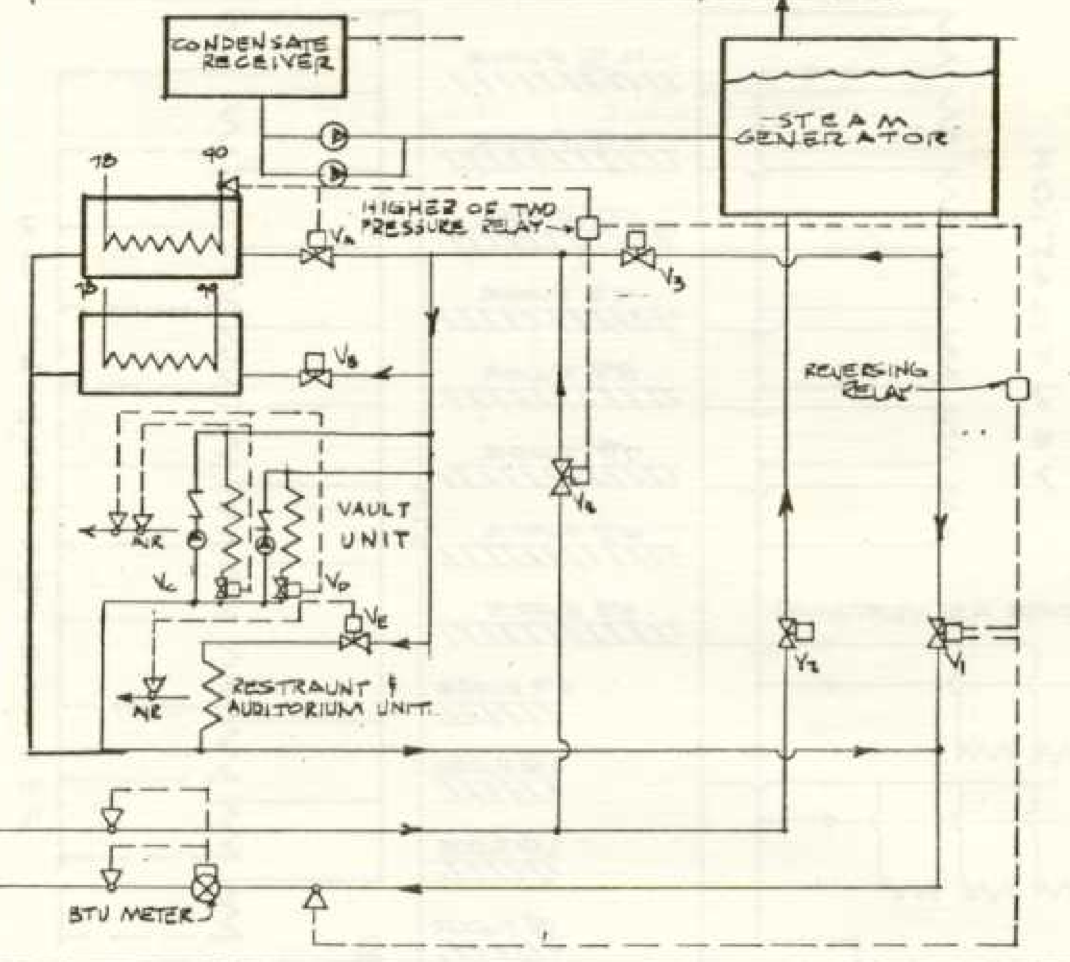
C-1
OF 3
SHEETS

CHAMBER OF COMMERCE BLDG. MPLS, MN.



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HEATING & VENTILATING

HOUSE LOAD					SUPPLY D.H.				
STEAM	L.W.T.	PRESS	MM BTU/HR	PIPE SIZE S. R	GPM	E.W.T.	L.W.T.	HEAT EXCH.	PIPE SIZE
	227	5	3.58	6" 1½	169	300	256		5"
GPM	E.W.T.	L.W.T.	MM BTU/HR	PIPE SIZE	GPM	E.W.T.	L.W.T.	HEAT EXCH.	PIPE SIZE
450	78	90	3.04	6"	114	256	200	WU12524	4"
	E.A.T.	L.A.T.							
	-20	6	.08		3	256	200	AIR COIL	1"
	6	50	.128		4.5	256	200	AIR COIL	1"
	-20	4	.167		5.96	256	200	AIR COIL	1¼
212° F. SYSTEM									
	227	5	3.58	6" 1½	120	300	237		4"
450	78	90	3.04	6"	82	237	160	WU14523	3"
	-20	6	.08		2.2	237	160	AIR COIL	1"
	6	50	.128		3.3	237	160	AIR COIL	1"
	-20	4	.167		4.3	237	160	AIR COIL	1¼"
176°F SYSTEM									

(OLD N.S.P.) CHAMBER OF COMMERCE BLDG.

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		CHECKED BY SJC	DATE AUG 78	OF 3 SHEETS

CHAMBER OF COMMERCE BUILDING

212° System

SUMMARY OF COST ESTIMATE

Labor	$12,300
Heat Exchangers	15,184
Piping, Condensate Pump, Receiver, Valves, Etc.	22,841
Demolition	12,650
Insulation	7,000
Temperature Control	12,600
Total	82,575
Mark-up	9,900
Total Price	$92,475

176° System

Labor	$10,800.00
Heat Exchanger	16,400.00
Pipe	18,100.00
Demolition	12,650.00
Insulation	5,500.00
Temperature Control	11,000.00
Total	74,450.00
Mark-up	8,934.00
Total Price	$83,384.00

DAYTON'S - ST. PAUL, MINNESOTA

This five story structure is a merchandizing department store having 388,000 sq. ft. area and 5,432,000 cu. ft. volume. The main mechanical equipment room sets in a penthouse housing two 400 HP hot water boilers having a capacity to heat 664 gpm of water each, from 160° to 200° F. In addition, the penthouse equipment room houses air handling units, domestic water and snow melting equipment.

Two separate snow melting equipment units have the following capacities:

MMBTU/ HR.	GPM	SHELL SIDE EWT	SHELL SIDE LWG	GPM	TUBE SIDE EWT	TUBE SIDE LWT
1.35	70	200	160	150	110	130
6.00	300	200	160	674	110	132

The tube side consists of a 50% solution of ethylene glycol.

The boilers may not be operated during the summer months because of the need for 200°F. hot water. Summer gas can be used for heating domestic water only. This unit is 750,00 BTU/Hr. which is 5.3% of the total winter load. Since the cooling is accomplished with electric centrifugal refrigeration units, it is not practical to use D.H. 300°F. water for summer conditions. The flow rates of D.H. water for 212, 176, and 140 F. return temperature is 18, 12 and 9 GPM respectively.

Consideration has been given to use heat exchangers in lieu of the existing boilers and operate a snow melting heat exchanger in series with the primary heating and ventilating exchanger.

FUEL CONSUMPTION

	1976	1977
#2 Fuel Oil (Gallons)	51,800	39,800
Gas Cu. Ft.	19,773,000	14,440,000

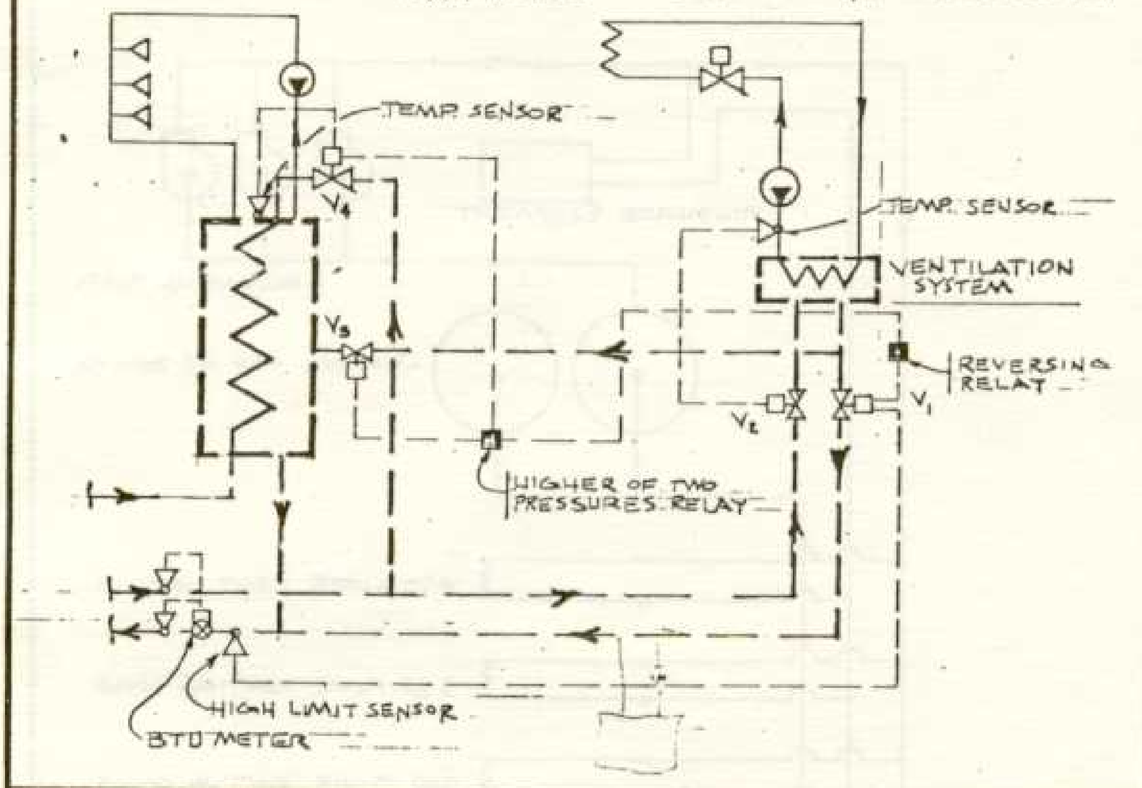
Firing Rate of Boilers

#2 Oil	124.4 Gallons/Hour
Gas	17.422 Cu. Ft./Hour

DAYTONS ST. PAUL, MINNESOTA

	MCF Firm Gas	MCF Int. Gas	Fuel Oil Gallons
Feb. 77	143	969	
Mar.	116	1,791	
April	124	1,221	
May	107	1,006	
June	112	922	
July	104	964	
Aug.	98.7	1,042	
Sept.	112.3	837	
Oct.	106.8	1,009	
Nov.	114.8	1,255	
Dec.	161.8	1,371	
Jan. 78	151.6	601	
	1,452	12,988	39,800 gal.

DAYTONS ST. PAUL, MINNESOTA



HEATING, VENTILATING & SNOW MELTING HEAT EXCHANGER

HOUSE LOAD					SUPPLY D. H.				
GPM	EWT	LWT	MMBTU/HR	PIPE SIZE	GPM	EWT	LWT	B & G HEAT EXCHANGER	PIPE SIZE
411	160	200	13.937	6"	335	300	249	WU188-10	5"
674	110	132	6.000	6"	170	249	175	WU16624	4"
MIXED WATER 212°F									
411	160	200	13.937	6"	237	300	228	WU161026	5"
674	110	132	6.000	6'	181	228	160	WU16725	4"
MIXED WATER 176°F									
411	160	200	13.937	6"	132	300	208	WU161045	4"
674	110	132	6.000	6"	169	208	135	WU181024	4"
MIXED WATER 140°F									

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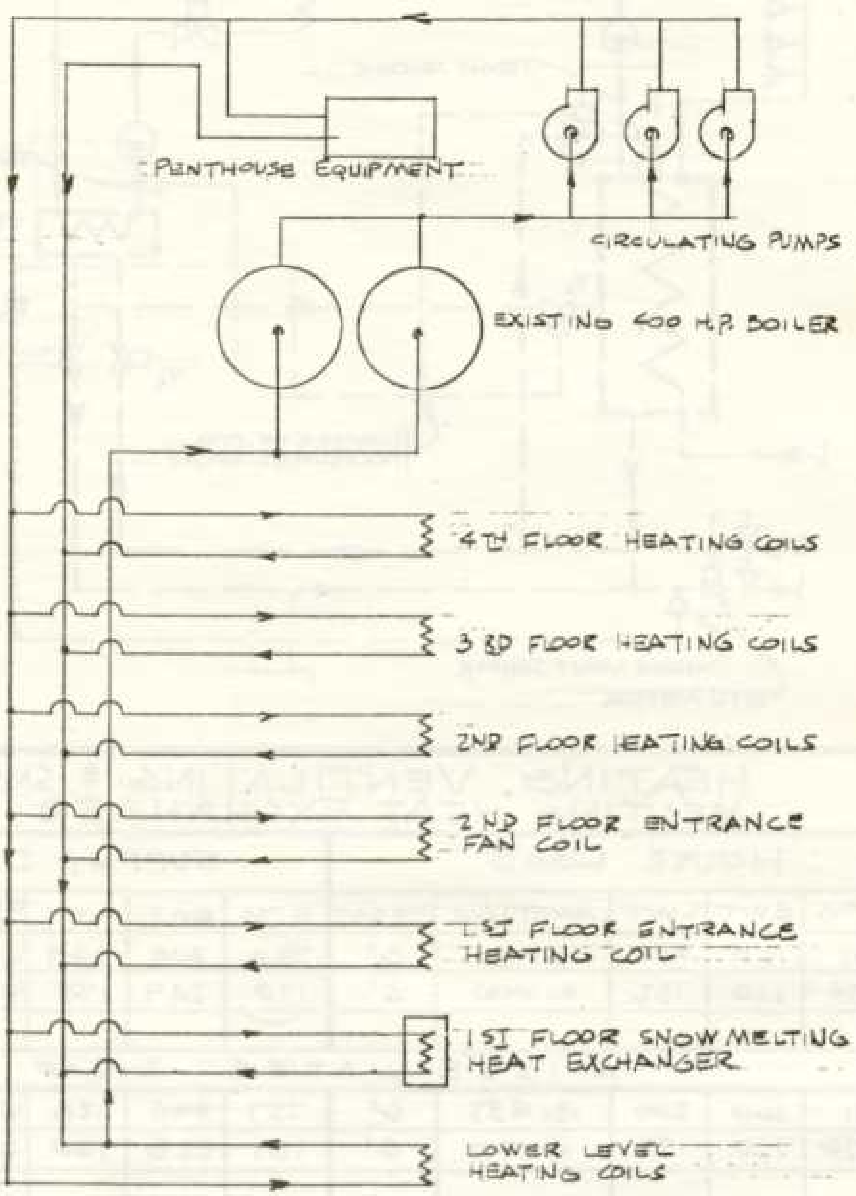
		CHECKED BY SJC	DATE AUG, 78	OF 2 SHEETS



EXISTING HOT WATER DISTRIBUTION

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DAYTONS ST. PAUL, MN	DRAWN BY JEE	COMM. NO. 04522	SHEET NO. D-1
	CHECKED BY SJC	DATE AUG '78	OF 2 SHEETS

DAYTON'S

ST. PAUL, MINNESOTA

COST ESTIMATE

212° System

Labor	$ 22,650.00
Heat Exchangers	15,800.00
Piping	18,200.00
Demo	12,000.00
Insul	12,000.00
Temp Control	16,560.00
Total	97,210.00
Mark up	14,600.00
Total Price	$111,810.00

176° System

Labor	$22,650.00
Heat Exchangers	16,000.00
Piping	18,200.00
Demo	12,000.00
Insul	12,000.00
Temp Control	16,560.00
Total	97,410.00
Mark up	14,600.00
Total Price	$112,010.00

Dayton's
St. Paul, Minnesota
Cost Estimate
Page -2-

140° System

Labor	$ 19,200.00
Heat Exchangers	16,000.00
Piping	16,600.00
Demo	12,000.00
Insul	11,800.00
Temp Control	13,400.00
Total	89,000.00
Mark up	13,350.00
Total Price	$102,350.00

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