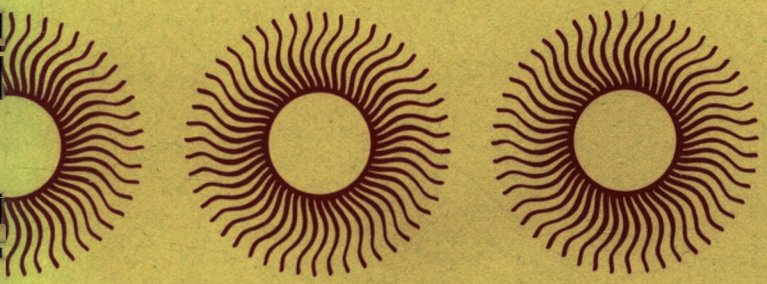

District Heating/Cooling Feasibility Study for Jamestown, New York

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ABSTRACT

This document presents the results of the District Heating/Cooling Feasibility Study for Jamestown, N.Y. The heat source for the system is a power plant located within the city limits. Several options for the extraction of heat from the power plant are developed and heat balances are presented. The options are based on the development of a hot water district heating system.

The geography and climate of the area are discussed and the primary potential district heat district is described. The heat load assessment was based on fuel consumption data collected from a sampling of various types of structures and operations. The data was reduced to per-square-foot figures and applied to areas of similar type buildings. The methodology is presented in detail followed by the block-by-block results which include the heated floor space, the annual total fuel consumed, the annual fuel consumed for comfort use, and the peak heat rate demands. The heating fuel demand and consumption for most of the major industries in the city is presented.

A transmission and distribution system is developed to deliver heat from the power plant to the district heating customers. The piping design is described and the proposed pipe routing for the primary district is presented.

Cost estimates are presented for the different district heating options developed. The cost of heat from the Jamestown district heating system has been determined using the required revenue approach to determine the minimum rate the utility must charge for district heat in order to break even. An analysis has also been performed to determine the maximum allowable charge for district heat that would allow consumers to recover their retrofit expenses in a five year period.

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Special appreciation is also extended to R.J. Gronquist of the Jamestown Board of Public Utilities and Plant Superintendent A. Olsen for providing necessary information on the Steele Street Power Plant.

The study was conducted by the Power Technology Division of Burns and Roe under the supervision of Dr. Ishai Oliker. The Heat Load Assessment was performed by American Energy Resources Corporation under the direction of Eugene C. Preston. Special appreciation is extended to Richard Harms who acted as principal investigator for the task of assessing the heat load.

SUMMARY

INTRODUCTION

The purpose of this study is to develop in a conceptual form a district heating system for Jamestown, New York. The study considers the Board of Public Utilities City of Jamestown, Steele Street Station as the heat source, and the downtown city area as the heat load.

The study assesses the available heat load for the City of Jamestown, determines the available heat from the Steele Street Power Station, develops a distribution network to integrate the heat source with the heat load, develops a system implementation plan and determines the relative cost of heat provided by the district heating system.

HEAT LOAD ASSESSMENT

The tasks associated with the heat load assessment for Jamestown were subcontracted to American Energy Resources Corporation by the City of Jamestown. The scope of work for the heat load assessment includes the following:

- Identify an appropriate primary district heat district.
- Develop and describe a methodology for determining heating loads on the potential district heat system.
- Specify heat loads for each block in the primary district.
- Indicate potential large commercial users and industrial users along the Chadakoin River industrial corridor.
- Provide an overview of the heat load for the entire City of Jamestown.
- Prepare a summary of hook-up and conversion cost estimates.

Primary District Heat District Identification

The City of Jamestown is located in the southwestern-most county in New York State. The city is an attractive site for a district heat system for several reasons:

- The climate is relatively cold, experiencing an average of nearly 8000 heating degree days per year during the last four years.
- The city has a municipal-owned, coal-fired, electricity generating station for a heat source.

- The central business district, two hospitals, the senior high school, senior citizen high rises, the municipal building (City Hall), the federal building (Post Office), and some industries are all within 0.8 mile from the power plant and in close proximity to the river which divides the city.
- Most of the city's 125 industries are located "down-river" from the power plant and could not only draw heat from a district heat system but, in some cases, contribute heat to the system.

The tentative borders of the potential primary district encircle 59 street-blocks containing the central business sector, the hospitals, high school, high rises, governmental buildings, and some industries. In addition to determining the heat loads for this district, data were compiled for most of the major industries in the industrial corridor.

Methodology for Determining Heating Demand

The district heat requirements were based on the fuel consumption records collected from a sampling of approximately 45 commercial businesses, industries, and the two hospitals, the high school and residential housing units. The heat usage and peak heat demand rates determined for these representative facilities were then applied to similar operations to complete the heat load assessment for the primary district and to provide an estimated heat load for the entire city.

This report contains a listing of the firms which provided the data base and the heat usage and heat demand rates determined for each.

Heat Load Assessment Summary

Table S-1 presents a heat load assessment summary. The first column of results indicates totals for the 59 block primary district heat district. The totals include all the buildings and operations (residential, commercial, and industrial) within the district, but the heat rate includes only that which could be supplied by a district heat system.

The second column of results states totals obtained from 14 of the major industries in the industrial corridor east of the primary district. The project scope did not allow contacting and processing information from all the industries. In the city there are approximately 125 industries of various types and sizes.

The third and fourth columns show the results of the estimated city-wide heat load. Results are given for housing and commercial operations, however, there was insufficient information available to assess the overall industrial heat load.

Table S-1

HEAT LOAD ASSESSMENT SUMMARY

	59 Block Primary District	14 of Major Industries[b]	City-Wide[c] Housing	Commercial	
Heated floor space	4,032,629	2,230,850	22,916,320	7,745,000	sq.ft.
Total annual heat use	375,872	453,968	2,136,792	565,385	MM Btu[a]
Annual comfort heat use	236,092	204,017	1,192,268	441,465	MM Btu
Building envelope peak heat loss rate	60.036	50.635	263.228	108.430	MM Btu/hr
Heat demand rate for uses other than envelope heat loss	19.847	19.452	123.872	15.490	MM Btu/hr

a/1 MM Btu = 1 million Btu

b/does not include industries located in primary district

c/city-wide assessment of industrial usage not available

POWER PLANT RETROFIT ANALYSIS

The study considers two major means of adapting the Steele Street Station units for district heating: modifying the existing turbines, and addition of a new district heating turbine capable of providing large quantities of steam to heat district water.

For both of the above cases, budgetary cost estimates are prepared based on a conceptual design of additional components and modifications to existing piping. Additional components include district heating condensers with associated valves, and drain pumps; district heating circulating pumps; and make-up water system for district heating water supply.

Description of the Existing Plant

The Steele Street Power Station consists of four operational units. The station burns coal. The station uses cooling towers for cooling its circulating water.

All four turbines were manufactured by General Electric Company. Units 3 and 4 are the oldest turbines, they have been installed about fifty years. Unit 5 was erected in 1951 and Unit 6 was erected in 1968.

Unit 3 is a 15,000 kw machine, Unit 4 is a 12,500 kw machine, Unit 5 is a 25,000 kw machine and Unit 6 is a 25,000 kw machine. Unit 5 has recently been redesigned by General Electric and is planned to be uprated to 28,750 kw in the next couple of years. District heating modifications are considered for the uprated machine.

Modification Alternatives

Modifications Considered

The following five alternatives have originally been considered for the conversion of the Steele Street plant to a cogeneration district heating plant: 1) Bypassing of the low pressure feedwater heaters; 2) Modifications of LP end of turbine to maximize extractions; 3) Use of the existing condenser for district heating; 4) Replacement of the proposed 55 MWe condensing turbine with a district heating turbine; 5) Retrofitting units 3 and 4 for district heating. The above alternatives were compared to a set of alternate selection criteria which include lowest cost, reliability, operating flexibility, thermodynamic constraints, mechanical constraints, space availability, and structural design limits. It should be noted that thermodynamic and mechanical constraints are turbine specific and

must eventually be assessed by the turbine manufacturer.

Based on the above criteria, use of the existing condenser for district heating is not being considered. For this alternate, the district water supply temperature is limited by the maximum allowable backpressure in the condenser to a maximum of approximately 130°F.

Preliminary investigation determined that units 3 & 4 are normally off line because of insufficient steam capacity. As a result, the use of these units for district heating was not pursued.

The remaining alternatives underwent investigation by Burns and Roe and calculations have been performed to estimate the effect of potential retrofit options.

Alternate Analysis

Alternative 1A involves the by-passing of the 12th and 16th stage feedwater heaters on unit 5. The 12th and 16th stage feedwater heaters are the lowest pressure heaters and are chosen so that the steam used for district heating can perform the most work before being extracted for district heating.

The district heat available from this option for unit 5 is 12.14 MWt. Based on a 140°F inlet temperature, this option will allow the heating of 522,247 lb/hr of district water to a temperature of 228°F. The decrease in electrical output for this option is estimated to be 4.45 MWe. A sketch of alternate 1A is shown in Figure 1.

Alternative 1B involves the by-passing of the 12th and 16th stage feedwater heaters in unit 6. This alternative is the same as option 1A for unit 5. The district heat available from this option is 7.28 MWt. Based on a 140°F inlet temperature for the district heating water, the full load extraction will allow the heating of 280,752 lbs/hr of water to a final temperature of 228°F. The decrease in electrical output for this option is estimated to be 1.2 MWe. A sketch alternate 1B is shown in Figure 2.

Alternative 2, the second turbine cycle modification alternative, is to increase extraction steam flow at the 12th and 16th stages of the uprated unit 5, by replacing the respective diaphragms, and deliver this increased extraction to new district heat exchangers. The new district heat exchangers are outside the feed-

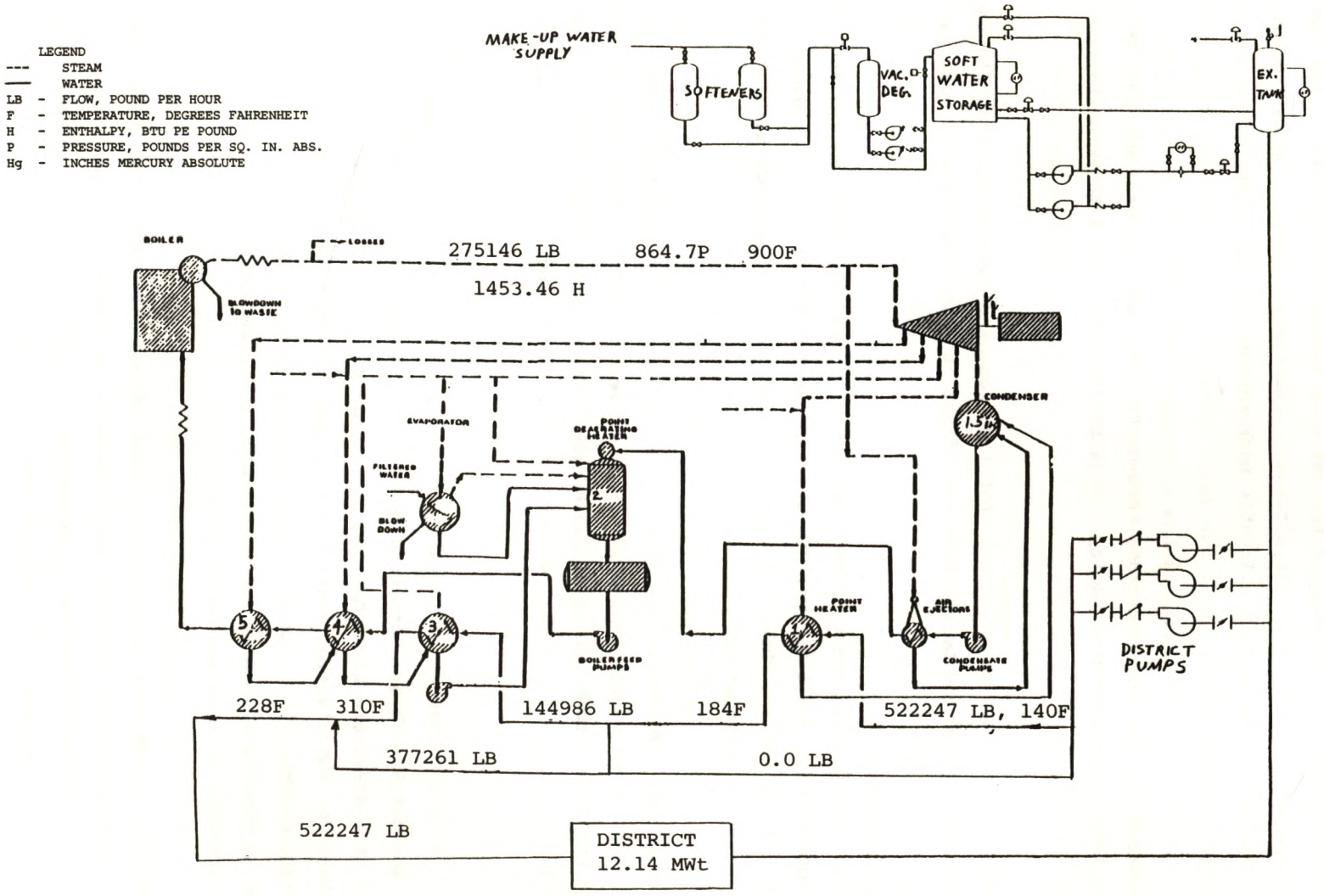


FIGURE 1 DISTRICT HEATING MODIFICATION ALTERNATIVE 1A, UNIT 5

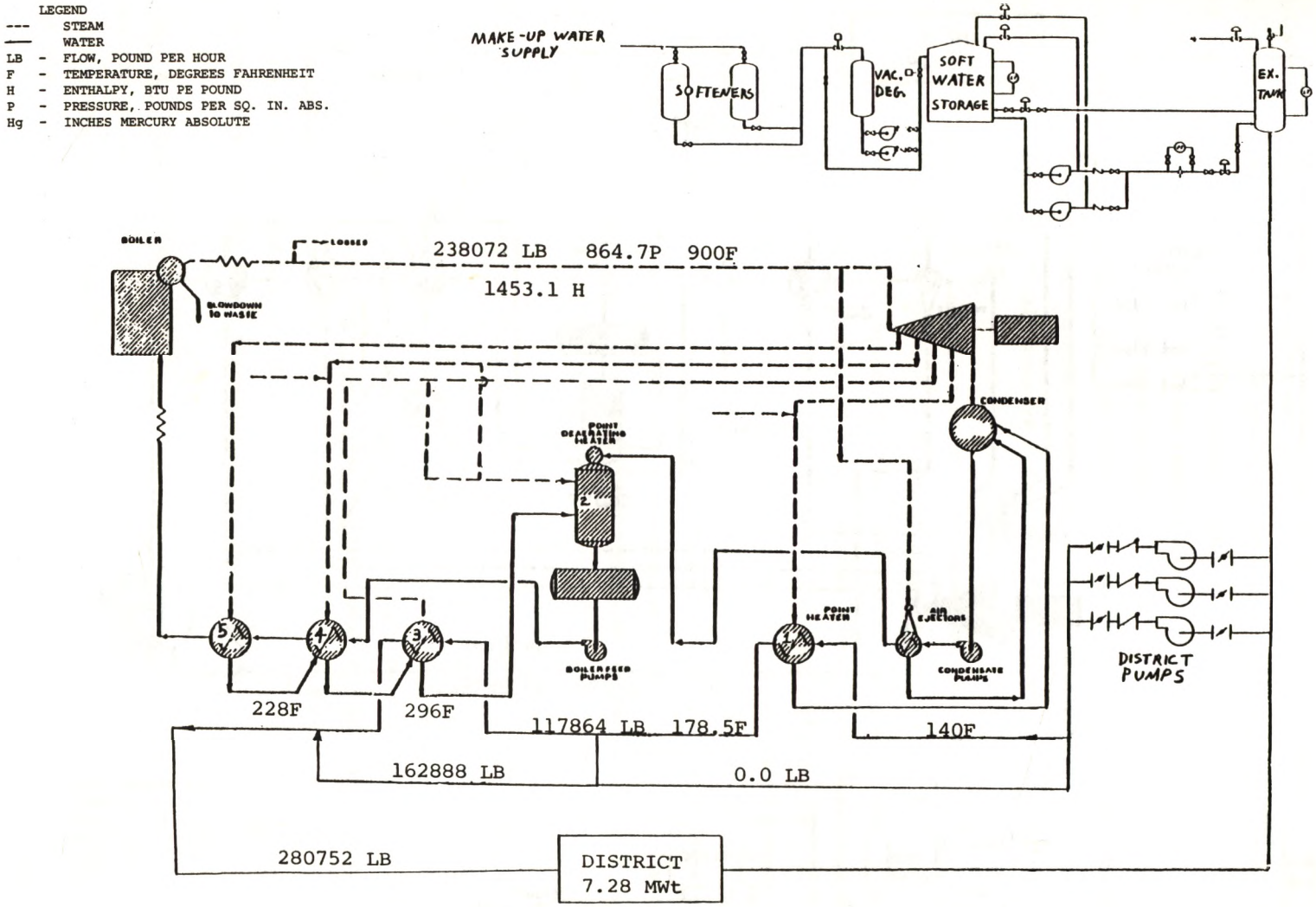


FIGURE 2 DISTRICT HEATING MODIFICATION ALTERNATIVE 1B, UNIT 6

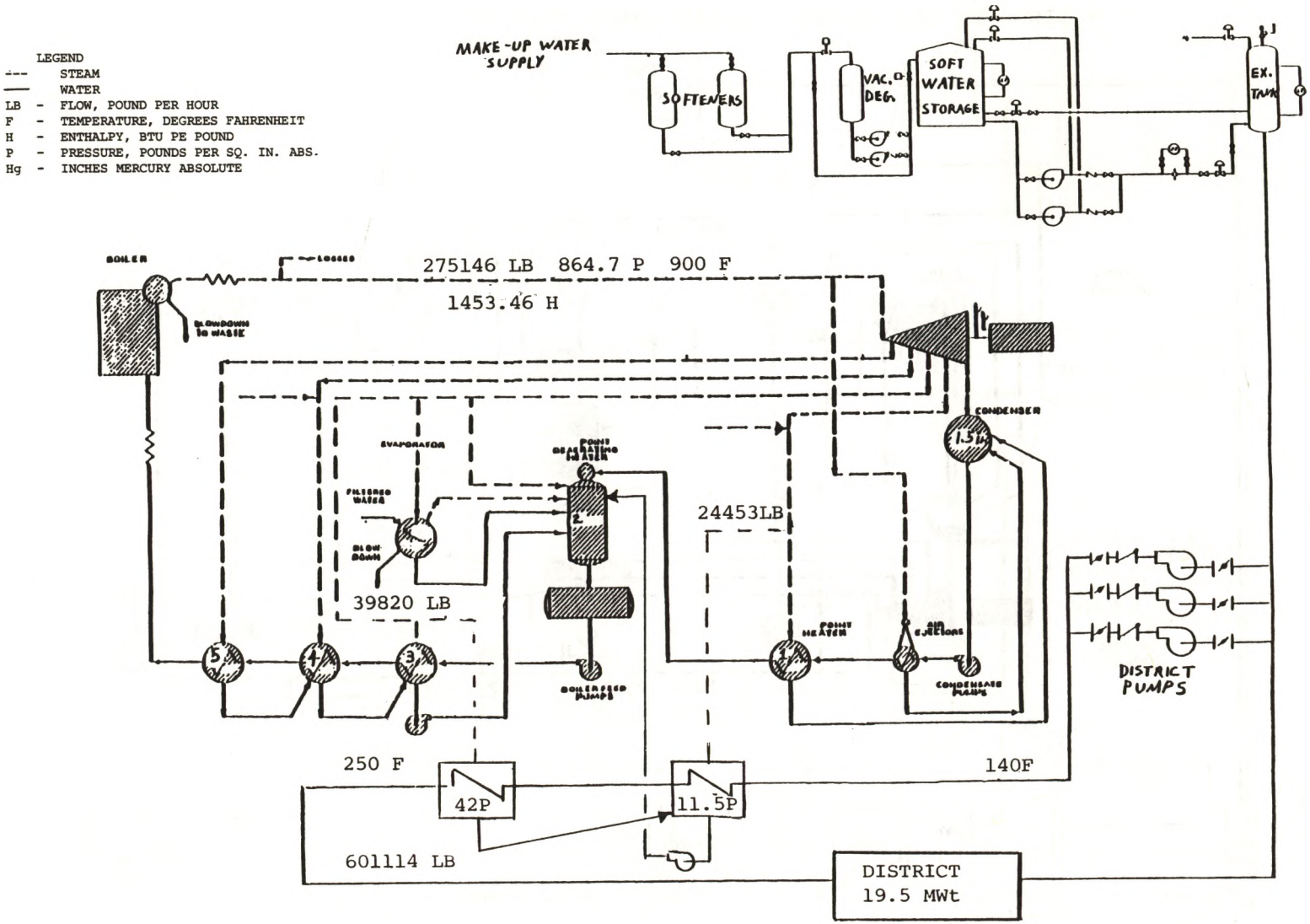


FIGURE 3 DISTRICT HEATING MODIFICATION ALTERNATIVE 2, UNIT 5

water cycle. The condensed extraction steam is returned to the cycle into the open heater. The criteria used to determine the increased extraction was to set a maximum extraction nozzle velocity of 300 feet per second. For this modification, all of the existing feedwater heaters were maintained in service. At the points where the maximum extraction was taken, the extraction flow to the feedwater heater was maintained the same as in the original balance and the additional flow was delivered to the new district heater. For this alternative the inlet and outlet district heating water temperatures were set at $140^{o}F$ and $250^{o}F$ respectively. The total district heating load available from the two stages of district heating is 19.5 MWt. The corresponding district heating flow rate is 601,114 lb/hr. The decrease in electrical output for this option is estimated to be 5.7 MWe. A sketch of alternative 2 for unit 5 is shown in Figure 3.

Alternative 4 involves the installation of a new district heating turbine. A feasibility study performed by General Electric Company for the Board of Public Utilities, City of Jamestown, determined that the largest single purpose turbine-generator that could be installed in the Steele Street Station without major structural changes was a 55 MWe capacity machine. The new district heating turbine alternatives is based on installing a 55 MWe dual purpose district heating machine in place of the single purpose machine. The dual purpose machine would have a full load electric only capacity of 55 MW and a full load heating only capacity of 80 MWt. The 80 MWt load would be supplied to two district heating condensers. The load is split equally between these two condensers and serves to heat district water from $140^{o}F$ to $250^{o}F$.

The district heating turbine would be installed in the same location proposed for the 55 MWe single purpose machine, in place of the existing 12.5 MW machine. The district heating turbine would require all the turbine-generator accessories and related steam cycle equipment required by the single purpose machine plus the necessary district heating additions. The district heating additions include the extraction steam system for the district heating condensers, the drain system for the district heating condensers, the district circulating water system and the district heating water make-up and treatment system.

Equipment and Piping Selection

Alternative 1A requires no changes to the extraction steam system. The condensate system requires modification to allow district heating water to be passed through the 12th and 16th stage feedwater heaters.

Alternative 1A will require the addition of three 50 percent capacity 60 horsepower district water pumps, a 77 cubic foot capacity expansion head tank and an 11.0 gpm make-up water system. The make-up water system would include two 100-percent capacity soft water pumps, a soft water storage tank, a vacuum degasifier, two 100% vacuum pumps and two 100% capacity zeolite softeners.

Alternative 1B, by-passing the 12th and 16th stage feedwater heaters on unit 6, is very similar to alternative 1A. Alternative 1B will require the addition of three 50 percent capacity 35 horsepower district water pumps, a 77 cubic foot capacity expansion head tank, and an 11.0 gpm make-up system identical to that for alternative 1A.

Alternative 2, maximum extraction from the uprated unit 5, requires the installation of two, two-pass district heating condensers. The district heating load is split approximately 60/40 between the high and low pressure condensers. The two heat loads are 11.8 MWt and 7.8 MWt respectively. The high pressure condenser has a surface area of 1200 sq. ft. and the low pressure condenser has a surface area of 1400 sq. ft. Two 100 percent capacity vertical can-type drain pumps are used to return the condensate to the feedwater cycle.

The district water system uses three 50 percent capacity 100 horsepower circulating pumps. The expansion head tank has a capacity of 77 cu. ft. The make-up water system is sized to produce treated water at 14 gpm. The make-up water system for alternative 2 also includes two 100 percent capacity soft water pumps, a soft water storage tank, a vacuum degasifier, two 100 percent capacity vacuum degasifier pumps, and two 100 percent capacity zeolite softeners.

Alternative 4, the new district heating turbine alternative requires the selection and installation of a new cogeneration district heating turbine rated for 55 MW electric output and 80 MW thermal output. The turbine will be designed to operate with throttle conditions of 1000 PSIG, 900^{o}F and a full load flow of 534,450 lbs/hr. The turbine will incorporate two district heating extractions. One district heating extraction will supply the high pressure district heating condenser which will operate at 42 psi. The second district heating extraction will supply the low pressure district heating condenser which will operate at 15 psi.

The two district heating condensers are shell and tube type heaters, each having two passes. The heat load is split equally between the two condensers, thus each district heating condenser has a design load of 40 MWt. The district heating condensers each contain approximately 4,580 square feet of heat transfer area.

Other equipment required for this alternative includes two 50 percent capacity vertical drain pumps, three 50 percent capacity 300 horsepower circulating pumps, an expansion head tank, and a make-up water system.

The make-up system components are sized to produce treated water at 26 gpm to compensate for system losses corresponding to about one half percent of the district heating water flow rate. There are two 100 percent capacity soft water pumps, one 38,000 gallon soft water storage tank, one 26 gpm vacuum degasifier, two 100 percent capacity vacuum degasifier pumps, and two 100 percent capacity zeolite softeners.

Costs for District Heating Retrofit Alternatives

Table S-2 presents the estimated costs for district heating modification alternatives 1A, 1B, 2, and 4. All figures represent installed costs. Piping costs are based on estimated piping lengths determined from approximate equipment locations.

TRANSMISSION AND DISTRIBUTION ANALYSIS

The distribution system for the Jamestown district heating system is a two pipe closed system. The system is characterized by a peak load supply temperature of 250^{o}F and a peak load return temperature of 140^{o}F. The system utilizes a conduit design with the supply and return lines in the same trench.

The conduit system will consist of a carbon steel carrier pipe, polyurethane insulation, a polyethylene casing, and a leak detection system.

Installation of the distribution system will be beneath sidewalks and along the railroad right of way in order to minimize interferences and costs.

Implementation Plan

The transmission and distribution system will be installed in four phases coincident with the power plant retrofits. The objective is to begin with the least expensive turbine retrofit option and develop a matching load that will require

Table S-2

COST BREAKDOWN FOR DISTRICT HEATING RETROFIT ALTERNATIVES

	Alternative 1A	Alternative 1B	Alternative 2	Alternative 4
1. Turbine-Generator Modifications	Not Applicable	Not Applicable	500,000	1,200,000
2. District Heating Condensers	Not Applicable	Not Applicable	130,000	380,000
3. District Heating Circulating Pumps	33,500	32,500	35,500	50,000
4. Extraction, Drain, District Heating Circulating Water Branch Piping and Valves	82,000	73,600	131,700	199,000
5. District Heating Water Make-up System	203,000	203,400	207,500	302,000
6. Electrical and Control Items	40,000	40,000	60,000	150,000
Direct Cost	$358,900	$349,500	$1,064,700	$2,281,700
Engineering, Construction Management and Contingency, 25%	$ 89,725	$ 87,375	$ 266,175	$ 570,425
TOTAL COST	$448,625	$436,875	$1,330,875	$2,852,125

a minimum amount of piping. This will minimize the cash outlay required and the time from initial cash outlay to revenue production. The first phase uses retrofit option 1B, bypassing feedwater heaters on unit 6, producing approximately 7 MWt of available heat. The transmission and distribution costs for this phase are $1,036,811. Phase two uses option 2, maximizing extraction from the uprated unit 5 turbine, to produce an additional 19 MWt at the plant. With this retrofit, an additional load of approximately 15 MW will be developed with an associated transmission and distribution system cost of approximately $888,781. The third phase will develop the industrial corridor. This phase will involve the addition of a new 55 MW electric turbine-generator to the Steele Street Plant. This unit will have a thermal capacity as high as 80 MW and will produce district heat with a higher efficiency than the first two retrofits. Therefore, in addition to supplying the industrial corridor which has a connected peak load of 19 MWt, the load from the first two phases will be switched to the new turbine and the old units will be used for back-up units. The transmission and distribution piping costs for phase three are $1,629,727. Phase four involves expansion of the district heating system into the residential and commercial area north of the phase one and phase two load. The expansion will have an additional load of 24 MWt and will be supplied from the new turbine. The transmission and distribution costs associated with this phase are $3,273,603.

The schedule developed for the implementation of the system calls for phase I to be completed in 1985, phase two in 1987, phase three in 1990, and phase four in 1993. A summary of the implementation plan is shown in Figure 4.

SYSTEM OPERATION

In order to determine the annual generation of heat from the power plant and the associated reduction in electrical output, a heat load duration curve was developed for the Jamestown district heating system. The curve is based on an outdoor design temperature of $3^{o}F$, an indoor design temperature of $65^{o}F$, and the annual temperature profile. The general heat load duration curve is shown in Figure 5. Using the heat load duration curve, the annual performance of the district heating system was assessed. Table 4 presents the results of this assessment.

ECONOMIC ANALYSIS

The cost of heat from the Jamestown district heating system has been determined for two cases. The first case involves implementing phases one and two only and the second case involves implementing all four phases. Our analysis uses a

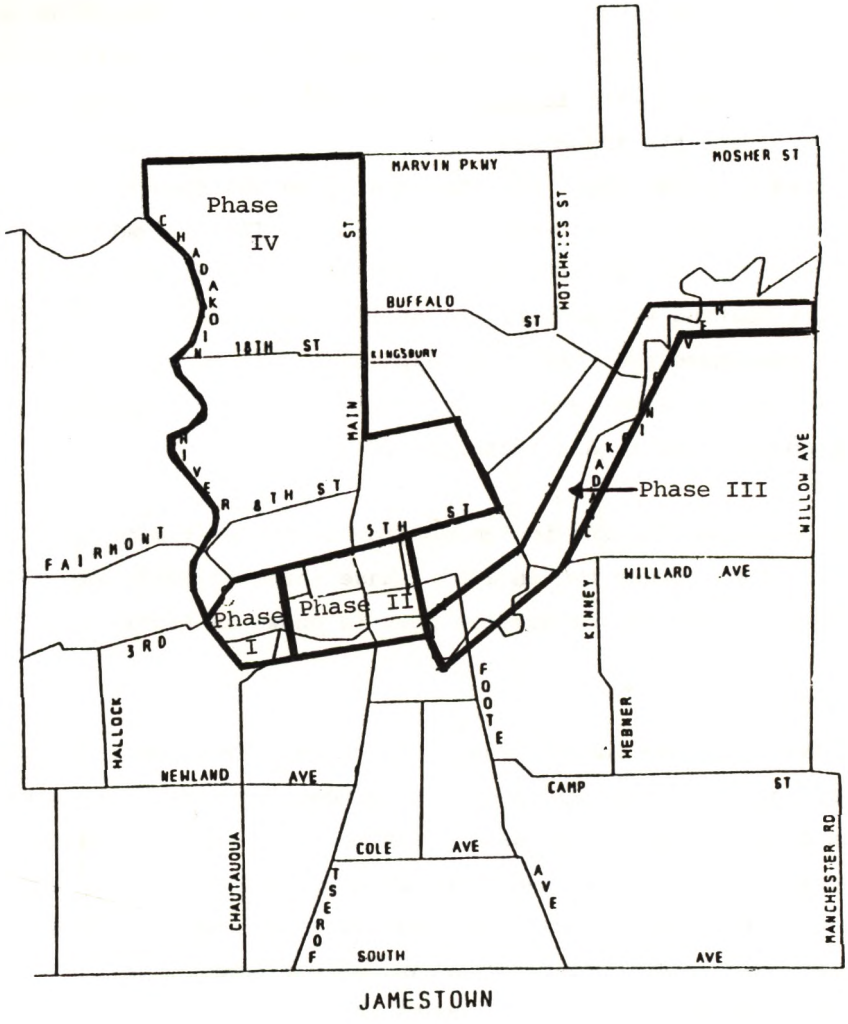


FIGURE 4 IMPLEMENTATION PLAN

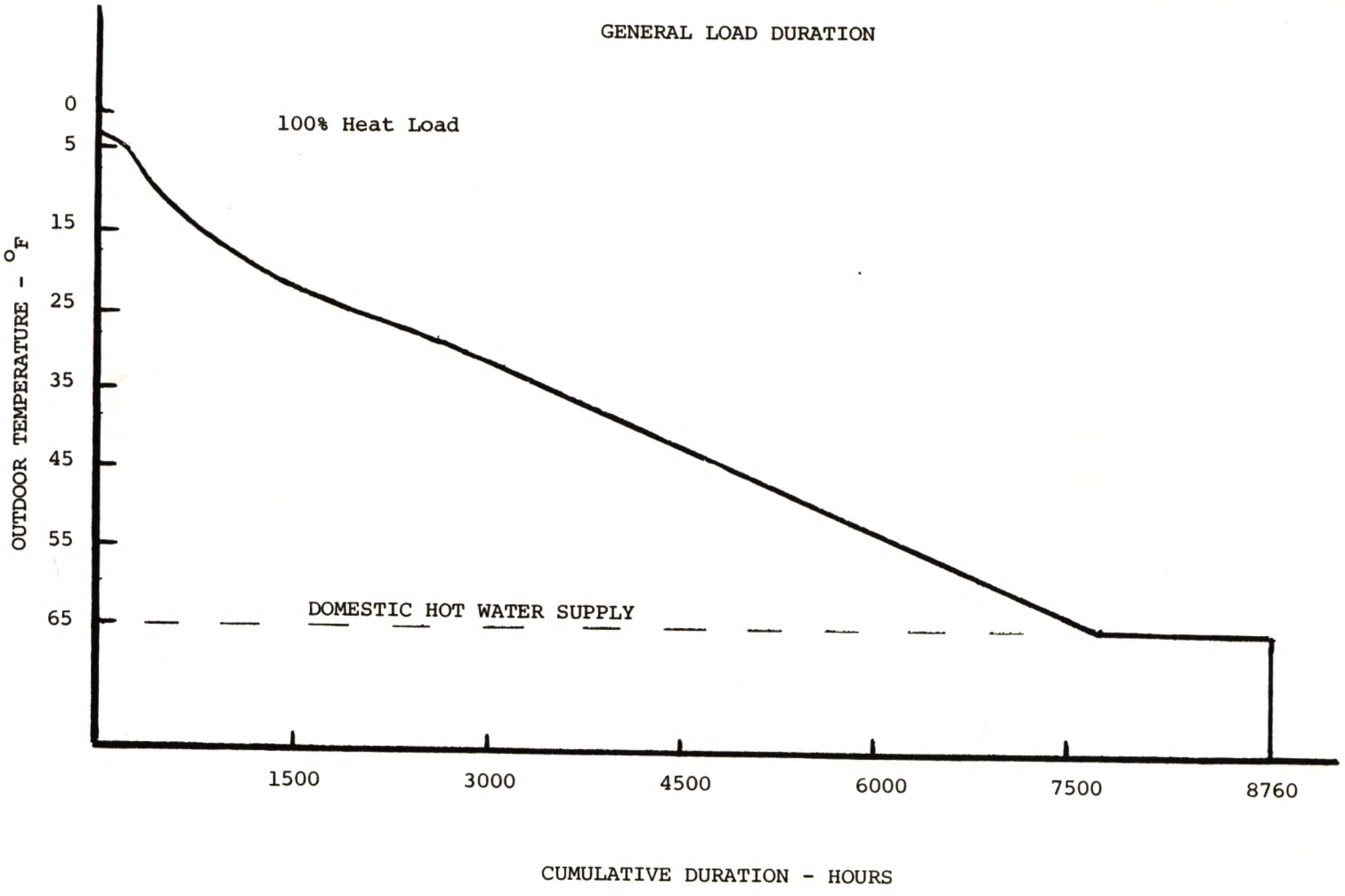

GENERAL LOAD DURATION
100% Heat Load
DOMESTIC HOT WATER SUPPLY
OUTDOOR TEMPERATURE - °F
0
5
15
25
35
45
55
65
1500
3000
4500
6000
7500
8760
CUMULATIVE DURATION - HOURS

Figure 5

Table 4

SYSTEM OPERATION

	Phase I	Phase II	Phase III	Phase IV
Date on Line	1985	1987	1990	1993
Cumulative Connected Peak load, MW_t	6.92	22.24	41.24	64.94
Annual Heat Production, MW-HR	33,229	106,853	198,142	322,423
Annual Heat Sold, MW-HR	30,903	99,373	184,272	299,853
Annual Lost Electrical Generation, KW-HR	5.477×10^6	2.698×10^7	2.546×10^7	4.143×10^7

required revenue approach to determine the minimum rate the utility must charge for district heat to break even based on a twenty year life cycle. The total system costs are derived and used to determine the minimum cost of heat for a range of fixed charge rates on an annual basis and levelized. These costs are compared to the costs of heat from fuel oil and natural gas. The levelized fuel costs are presented in table 5.

A consumer payback analysis was performed and is presented in table 6.

Table 5

LEVELIZED DISTRICT HEATING COSTS

Fixed Charge Rate	Case One $/10^6 BTU	Case Two $/10^6 BTU
15%	13.36	10.29
20%	14.14	11.31
25%	14.92	12.33

LEVELIZED FUEL COSTS

Energy Escalation Rate	Gas $/10^6 BTU	Oil $/10^6 BTU
9%	23.83	23.94
11.76%	32.13	32.21
15%	46.33	46.38

Table 6

USER PAYBACK ANALYSIS FOR 1 MW CUSTOMER

ASSUMPTIONS: 5 YEAR PAYBACK PERIOD
RETROFIT COSTS $130/KW
FINANCE COST 12.5%
ENERGY ESCALATION 11.76%
GENERAL ESCALATION 8.5%

YEAR	ESCALATED RETROFIT COST	HEAT SALES (MMBTU)	ANNUAL LOAN PAYMENT	REQUIRED SAVINGS ($/MMBTU)	PROJECTED FUEL ($/MMBTU)	MAXIMUM CHARGE ($/MMBTU)
1985	166048	15242	46641	3.06	13.96	10.90
1986	180162	15242	50603	3.32	15.60	12.28
1987	195475	15242	54871	3.60	17.44	13.84
1988	212091	15242	59596	3.91	19.49	15.58
1989	230118	15242	64626	4.24	21.78	17.54
1990	249679	15242	70113	4.60	24.34	19.74
1991	270901	15242	76058	4.99	27.20	22.21
1992	293928	15242	82612	5.42	30.40	24.98
1993	318912	15242	89623	5.88	33.98	28.10
1994	346019	15242	97244	6.38	37.97	31.59
1995	375431	15242	105475	6.92	42.44	35.52
1996	407342	15242	114467	7.51	47.43	39.92
1997	441967	15242	124070	8.14	53.01	44.87
1998	479534	15242	134739	8.84	59.24	50.40
1999	520294	15242	146171	9.59	66.21	56.62
2000	564519	15242	158517	10.40	73.99	63.59
2001	612503	15242	172082	11.29	82.69	71.40
2002	664566	15242	186715	12.25	92.42	80.17
2003	721054	15242	202566	13.29	103.29	90.00
2004	782344	15242	219790	14.42	115.43	101.01

Table 7

SYSTEM IMPLEMENTATION

	Phase I	Phase II	Phase III	Phase IV
Date on Line	1985	1987	1990	1993
Rating MWt	7.3	19.5	20	25.5
Connected Peak Load MWt	6.9	15.3	19	23.7
Power Plant Retrofit Costs, 10^3	436.9	1330.9	2852.1	-
Distribution System Costs, 10^3	1036.8	888.8	1629.7	3273.6
User Conversion Costs, 10^3	897.0	1989.0	2470.0	3081.0
Total System Implementation Costs*, 10^3	2370.7	4208.7	6951.8	6354.6

* Costs are presented in 1982 dollars

Section 1

INTRODUCTION

PURPOSE AND SCOPE OF WORK

The purpose of this study is to develop in a conceptual form a district heating system for Jamestown, New York. The study considers the Board of Public Utilities City of Jamestown, Steele Street Station as the heat source, and the downtown city area as the heat load. District heat is provided by hot water as a transport medium.

The study assesses the available heat load for the city of Jamestown, determines the available heat from the Steele Street Power Station, develops a distribution network to integrate the heat source with the heat load, develops a system implementation plan and determines the relative cost of heat provided by the district heating system.

The assessment of the heat load was performed by American Energy Resources Corporation. This assessment is presented as section 2 of this report. The remaining work included in this report was performed by Burns and Roe, Incorporated.

The determination of available heat from the Steele Street Plant is based on different retrofit options developed for the existing plant. These options include modifications to the existing turbine generator cycle and the installation of a new district heating turbine-generator set. The analysis was performed using existing plant heat balances, existing plant drawings and manufacturers technical and pricing information.

To develop the distribution network and the implementation plan extensive use was made of the heat load assessment performed by American Energy Resources Corporation and the Greenhorne and O'Mara, Inc. maps of Jamestown.

The relative cost of heat provided by the district heating system is determined in an economic analysis that is based on budgetary cost estimates from equipment and material manufacturers, manhour estimates and current operating and maintenance costs for the Steele Street Power Station.

Section 2

HEAT LOAD ASSESSMENT

INTRODUCTION

This section will provide the heat load assessment necessary to complete the feasibility study of district heating for the City of Jamestown. This section describes the Jamestown area, its geography and climate, and specifically the primary district heat district; presents the methodology for and the results of the heat load calculations concerning the primary district; gives a heat load overview of the entire city; and summarizes the hook-up and conversion cost estimates and the significant findings of the heat load assessment effort.

To complete this task, extensive use was made of the Sanborn maps of Jamestown (scale 1" = 100') to obtain building details. Along with the heating loads reported herein, the Greenhorne and O'Mara maps (scale 1" = 100') with contours at two foot intervals will be useful in the preliminary layout of the district heat distribution system. These map series are available from the City of Jamestown Department of Development.

DEFINITION OF THE DISTRICT

Geography and Climate of Jamestown

The City of Jamestown, Figure 2-1, is situated at the southeastern end of Chautauqua Lake in Chautauqua County, the southwesternmost county in New York State. The city is approximately three miles long and three miles wide, with a population of nearly 38,000. It is immediately bounded by the Village of Falconer to the east and the Village of Lakewood to the west. The Jamestown terrain is best described as rolling hills. The average elevation is 1390 feet above sea level, the highest being 1620 feet and the lowest being approximately the lake level which is 1308 feet. The Chadakoin River, the outlet for Chautauqua Lake, divides the city. Along the river are the municipal-owned electricity generating station, most of the city's 125 manufacturing establishments and the downtown business area. Buffering this industrial/commercial corridor are residential neighborhoods extending to the city limits.

Jamestown is located in a cold climate (approximately 8000 Fahrenheit degree days) as evidenced by the five years of degree day data given in Table 2-1. Tables 2-2 and 2-3 present minimum temperature profiles for 1980 and 1981 respectively. To illustrate, Table 2-3 shows that in 1981, a minimum temperature of $-25^{\circ}F$ occurred on one day and minimum temperatures between -17.5 and $-15^{\circ}F$ occurred on two days. The table also indicates that the minimum temperature was $2.5^{\circ}F$ or less on 21 days out of the year.

Tentative Borders of Primary District Heat District

The tentative borders of the primary district were defined so as to include the coal fired electricity generating station at the west end, the senior high school and WCA Hospital at the east end, Fifth Street on the north, and Jamestown General Hospital on the south. (See Figure 2-2) This is an area approximately 0.5 mile wide and 0.8 mile long.

The most probable extension of the primary district would be in an easterly direction along the industrial corridor.

Key Topographical Features Within Primary District

The most prominent topographical features inside Jamestown and the primary district are the Chadakoin River and the hills sloping to the river. For example, the General Hospital is within 1000 feet of the electricity generating station and at an elevation 100 feet above that of the station.

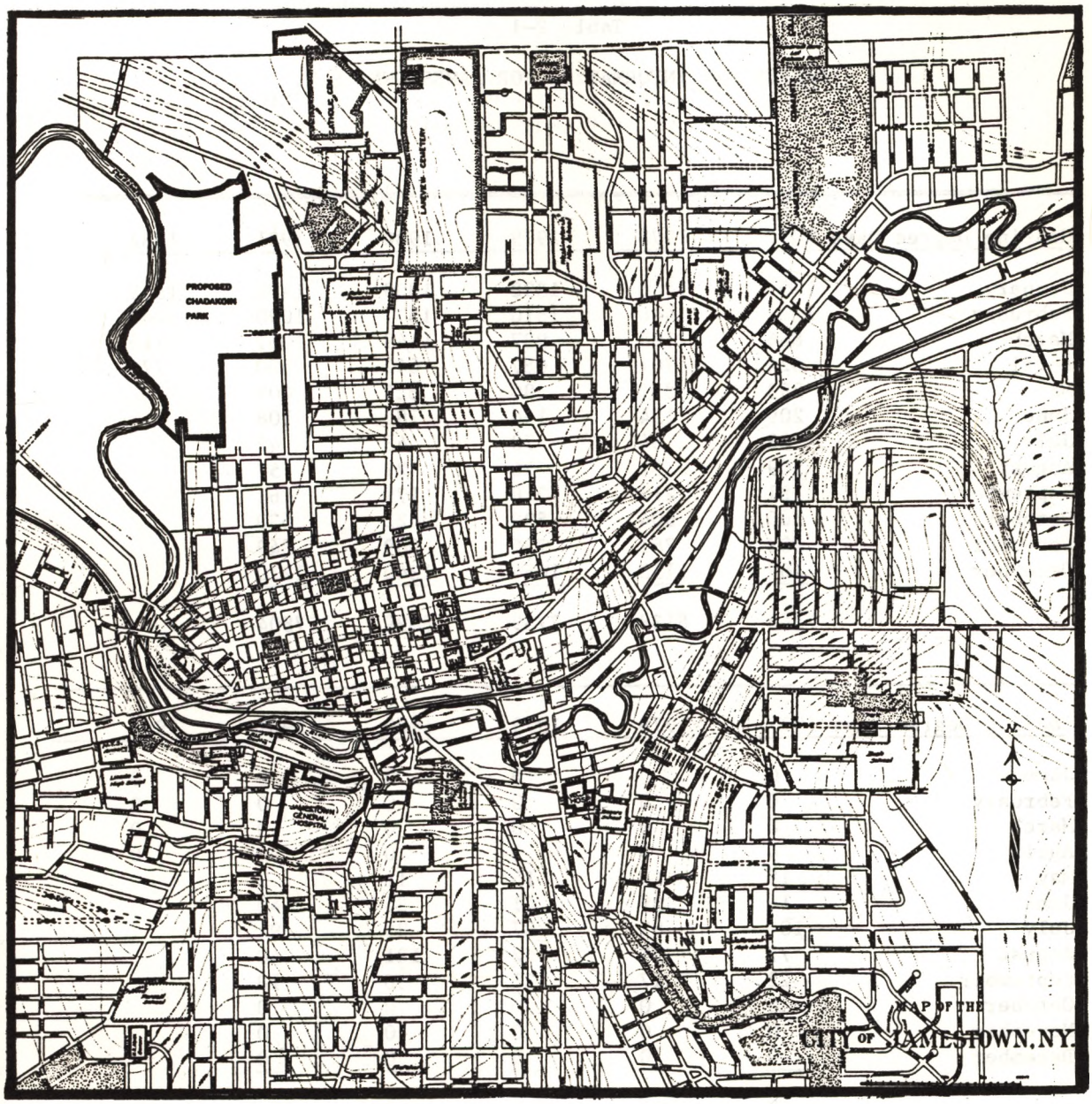


Figure 2-1. City of Jamestown, New York

Table 2-1

DEGREE DAY INFORMATION FOR JAMESTOWN, N.Y.

Heating Degree Days	1977	1978	1979	1980	1981	1982
January	1701	1446	1398	1309	1495	1558
February	1182	1446	1510	1373	1090	1240
March	866	1195	937	1149	1067	1116
April	624	701	687	642	590	776
May	293	351	390	325	405	
June	209	154	156	187	108	
July	52	64	70	43	42	
August	109	31	76	21	57	
September	181	212	218	179	261	
October	566	604	508	622	630	
November	702	781	735	909	849	
December	1167	1153	1054	1340	1210	
	7568	8138	7739	8099	7804	

Cooling Degree Days	1977	1978	1979	1980	1981	1982
January	0	0	0	0	0	0
February	0	0	0	0	0	0
March	0	0	0	0	0	0
April	4	0	3	0	0	0
May	18	14	15	11	2	
June	14	39	41	36	40	
July	107	82	87	85	94	
August	77	51	62	131	40	
September	22	17	21	36	18	
October	0	0	0	0	0	
November	0	0	0	0	0	
December	0	0	0	0	0	
	242	203	224	299	194	

Table 2-2

MINIMUM TEMPERATURE PROFILE - 1980

INTERVAL'S MAXIMUM MINIMUM IS: 67
INTERVAL'S MINIMUM MINIMUM IS: -23

OUTDOOR TEMP (DEG. F)	DAYS	TOTAL DAYS
-25	0	0
-22.5	1	1
-20	1	2
-17.5	1	3
-15	1	4
-12.5	3	7
-10	2	9
-7.5	1	10
-5	3	13
-2.5	6	19
0	7	26
2.5	5	31
5	11	42
7.5	3	45
10	10	55
12.5	5	60
15	12	72
17.5	7	79
20	10	89
22.5	7	96
25	25	121
27.5	8	129
30	25	154
32.5	21	175
35	30	205
37.5	11	216
40	17	233
42.5	13	246
45	17	263
47.5	15	278
50	19	297
52.5	14	311
55	15	326
57.5	6	332
60	15	347
62.5	5	352
65	12	364
67.5	2	366

Table 2-3

MINIMUM TEMPERATURE PROFILE - 1981

INTERVAL'S MAXIMUM MINIMUM IS: 65
INTERVAL'S MINIMUM MINIMUM IS: -25

OUTDOOR TEMP (DEG. F)	DAYS	TOTAL DAYS
-25	1	1
-22.5	0	1
-20	0	1
-17.5	0	1
-15	2	3
-12.5	3	6
-10	2	8
-7.5	3	11
-5	3	14
-2.5	0	14
0	3	17
2.5	4	21
5	2	23
7.5	5	28
10	14	42
12.5	4	46
15	9	55
17.5	14	69
20	12	81
22.5	6	87
25	32	119
27.5	20	139
30	35	174
32.5	12	186
35	24	210
37.5	5	215
40	26	241
42.5	7	248
45	19	267
47.5	12	279
50	20	299
52.5	7	306
55	21	327
57.5	10	337
60	20	357
62.5	2	359
65	6	365
67.5	0	365

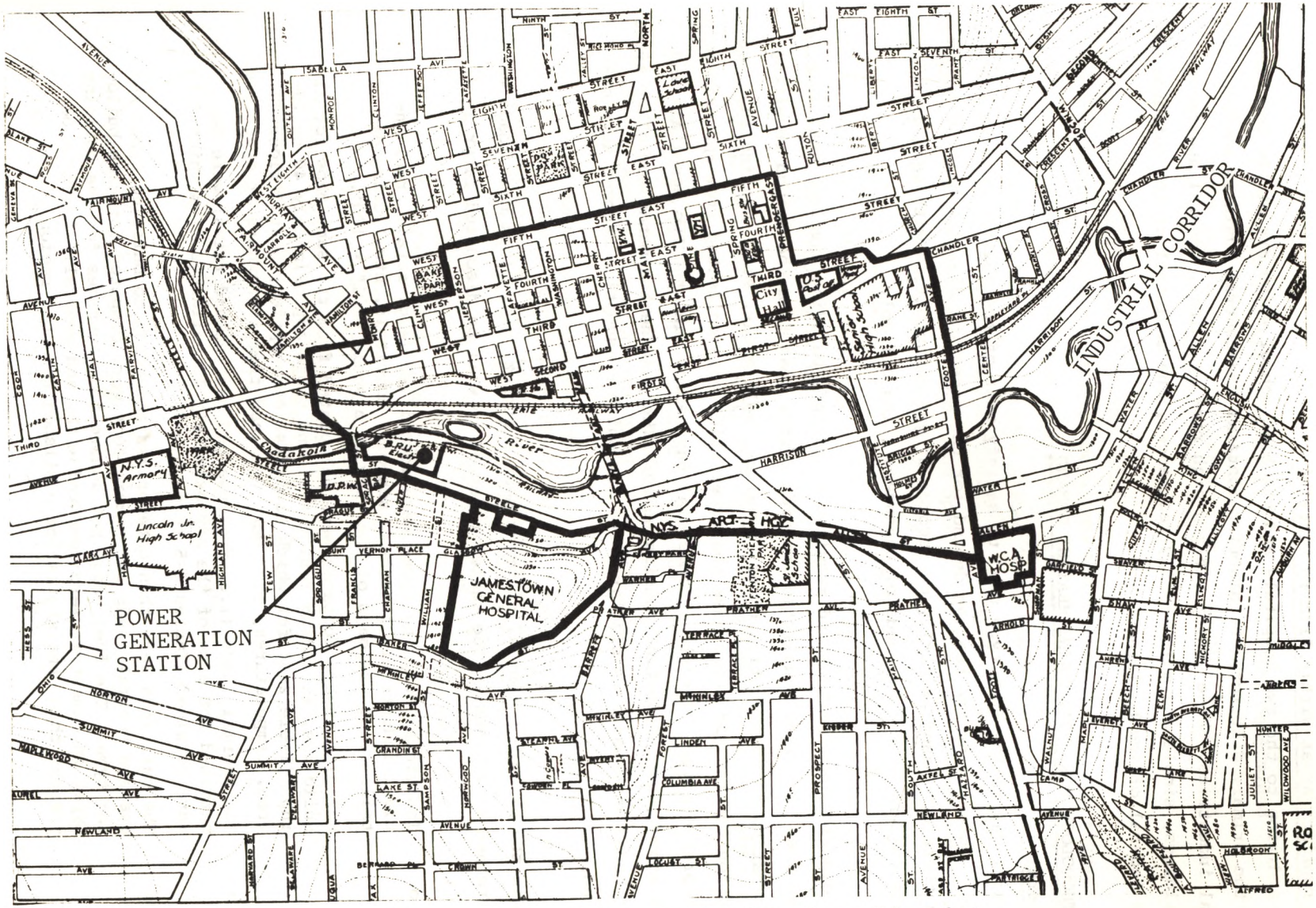


Figure 2-2. Primary District Heat District

Appropriate Areas Within Primary District

In addition to the two hospitals and the high school which are at the boundaries of the primary district, the district contains the central business section, several industries, three senior citizen high rise buildings, several apartment buildings, single and multi-family residences, the municipal office building and the federal office building.

METHODOLOGY FOR DETERMINING HEATING DEMAND

General

Natural gas is the fuel type used to satisfy most of the heating load in Jamestown. Quantifying the heating demand for the potential district heating system was therefore based primarily on records of gas consumptions with some adjustments for the heating demands of consumers using oil only.

The district heat peak demand required to satisfy building envelope heat loss was determined from fuel consumption records rather than from the method requiring information on construction types, U-values, wall areas, etc. Heating fuel consumption records and energy use characteristics were collected from approximately 45 representative industries, commercial businesses, and the two hospitals and high school and residential housing units. The peak heat demands for other sites were based on demands at similar sites for which consumption records were obtained.

Within the primary potential district heat district, city block heat loads were determined as follows. (The tables referred to will be discussed later in detail.)

- Individual building types were identified (e.g. retail, residential, industrial, churches, schools, hospitals, etc.) using detailed land use maps of the city at a scale of 1" = 100'.
- Building square footages were calculated from the same maps for all buildings, excluding residential and those approximately 40 buildings (Table 2-4) for which heat fuel consumption, heated floor area, temperatures, etc. were obtained from the owners or operators.
- The thermal loads (i.e. fuel use and heat demand rates) were determined for each of the approximately 40 buildings from which data were obtained (Tables 2-5 through 2-7).
- The buildings were then categorized according to building types and average thermal loads per square foot were computed for each building type. The fuel usage per square foot averages for the building types in Jamestown were compared with, and generally found to be greater than, the statistics published for this region.

- The fuel usage and heat loss rates per square foot, determined from data collected, were applied to the floor areas of other Jamestown structures in the primary potential district and summed for each street block (Table 2-6).

Buildings and Operations Providing Data Base

Table 2-4 presents a listing of those operations which responded to the request for information concerning heating fuel usage. Column 1 includes the identification number assigned to those operations listed in Column 2. (The analytical results given in Table 2-7 are listed according to ID number.) Column 3 indicates the number of the Sanborn map on which the operation appears. The maps are property of the City. Column 4 indicates the block number (from the Sanborn map) in which the building or operation is located. Column 5 indicates the sheet number of the Greenhorne & O'Mara, Inc. map on which the building or operation appears. These maps are also property of the City.

The methodology employed in analyzing data from the representative sites is as follows:

- From the heating fuel billings of the past 12 months, assess the fuel quantity consumed for comfort heating (QCH) and the portion consumed for internal use (QIU), i.e. process, services, domestic, etc.
- Calculate the envelope heat transfer coefficient (UA) knowing the local heating degree days (HDD) for the 7 month heating season and adjusting the HDD to account for the site-specific indoor environment (indoor temperature and internal heat generation).
- With the UA determined above, and selected design temperature conditions (effective DT), compute the envelope design heat demand rates (Q) for comfort heating.

The estimated district heat usage rate for the purposes other than comfort heating was assumed constant throughout the year and occurring only during normal (operating) hours. The rate was determined from the heating fuel quantity consumed for internal use (QIU) averaged over the normal hours and adjusted by a percentage of the overall heat need which, by estimate, could be satisfied by a district heat supply.

A complete discussion of the assumptions and equations follows.

Determining Fuel Consumed for Comfort Heat and Internal Use

Average Daily Fuel Consumption. Natural gas consumption data were obtained from

individual consumer billings. These data (service period, quantity used, and net cost) from the most recent 12 months were input to a computer program which calculated the average daily consumption (MM Btu/day) within each service period. See Table 2-5 and Figure 2-3.

Average Daily Fuel Consumption for Internal Use. The gas consumption from May 1 through September 30 (5 months) was calculated and then divided by the number of days in the five month period (i.e. 153). This was judged to be the average daily fuel usage rate for the entire year for internal use (ADIU), i.e. for purposes other than comfort heating. See Figure 2-3.

Annual Fuel Consumption for Internal Use. The yearly fuel consumption for internal uses (QUI) was computed as:

$$QUI = 365 \times ADIU \qquad (2\text{-}1)$$

Annual Fuel Consumption for Comfort Heating. The yearly fuel consumption for comfort heating (QCH) was computed as:

$$QCH = \text{Total Fuel Use} = QUI \qquad (2\text{-}2)$$

Determining Site-Specific Envelope Heat Transfer Coefficient

Site-specific envelope heat transfer coefficients (UA) were computed using the equation:

$$UA = \frac{QCH \times EFF}{HDD \times AF \times 24} \qquad (2\text{-}3)$$

where:

UA = effective heat transfer coefficient times the effective area of heat transfer - Btu/hr Deg.F

QCH = yearly consumption for comfort heating - MM Btu

EFF = combustion efficiency

HDD = heating degree days in 7 month heating season using $65^{\circ}F$ base - Deg.F days

AF = HDD adjustment factor to relate site-specific temperatures and times to the $65^{\circ}F$ base - dimensionless

The HDD adjustment factor, AF, is calculated as follows:

$$AF = \left(\frac{TI1-TR1-TOA}{65-TOA}\right)\left(\frac{HR1}{168}\right) + \left(\frac{TI2-TR2-TOA}{65-TOA}\right)\left(\frac{HR2}{168}\right) \qquad (2\text{-}4)$$

Table 2-4

BUILDINGS AND OPERATIONS PROVIDING DATA BASE

ID #	Name	Sanborn Map #	Block #	G & O'M Map #
Industrial:				
1001	Weber-Knapp Company	203	682	045
1002	Jamestown Plywood Corp.	006	265	024
1003	Monitor Furniture - Office	005	265	024
1004	Monitor Furniture - Plant	005	265	024
1005	Dawson Metal Co., Inc.	058	395	046
1006	Crescent Tool Company	011	300	034
1007	Van Stee Corp.	059	395	045
1008	Jamestown Electroplating Works, Inc.	078	536	044
1009	TRW Bearing Division	061	308	045
1010	Jamestown Royal, Inc.	057	395	045
1011	Mason Carvings, Inc.	078	536	044
1012	Watson Industries	012	301	034
1013	Jamestown Metal Manufacturing Co.	239	761	056
1014	Jamestown Metal Products	241	761	057
1015	Dahlstrom Manufacturing	234	758	046
1016	Crawford Furniture Manufacturing	241	763	056
1017	Maddox Table Co.	010	299	034
Commercial:				
2001	Bankers Trust Bank Building	003	278	034
2002	YMCA	019	345	034
2003	YWCA	018	343	034
2004	Field & Wright Co.	003	286	034
2005	Scottish Rite Temple	009	347	035
2006	Bigelows Department Store	002	270	024
2007	Jamestown Boys Club	079	554	033
2008	Nazzaro Realty	017	328	024
2009	Lafayette Corners Furniture	002	269	024
2010	Furniture Mart Offices	002	282	024
Other:				
3001	Hotel Jamestown	002	270	024
4001	Wilcox Apartments	019	344	035
4002	Cameo Apartments	020	342	035
6001	James Prendergast Library	018	324	025
7001	WCA Hospital	080	542	033
7002	Jamestown General Hospital	064	515	023
7003	Senior High School	010	293	034
8001	City Hall	004	280	034
8002	U.S. Post Office Building	009	290	034
9001	First Lutheran Church	011	296	034

Table 2-5

NATURAL GAS CONSUMPTION AND COST DATA

YEAR: 1980/1981

FIRM NAME: EXAMPLE

UTILITY COMPANY: NATIONAL FUEL

PLANT/BUILDING: 51 GLASGOW AVE.

RATE SCHEDULE IDENTIFICATION OR SERVICE CLASSIFICATION: 3

METER LOCATION:

SERVICE DATES FROM - TO	QUANTITY USED (100'S CU.FT.)	TOTAL NET COST ($)	$/100 CU.FT.	HIGHER HEATING VALUE (BTU/CU.FT)	MMBTU *	TOTAL DAYS	AVERAGE DAILY USE PER BILLING PERIOD (MMBTU)	
11/20 - 12/23	29590	10844.83	.367	1000	2959.00	33	89.667	358
12/23 - 1/26	35990	14081.62	.391	1000	3599.00	34	105.853	26
1/26 - 2/25	28820	11259.18	.391	1000	2882.00	30	96.067	56
2/25 - 3/26	27310	10711.79	.392	1000	2731.00	29	94.172	85
3/26 - 4/27	22890	8783.83	.384	1000	2289.00	32	71.531	117
4/27 - 5/27	18950	7359.01	.388	1000	1895.00	30	63.167	147
5/27 - 6/25	11600	4420.58	.381	1000	1160.00	29	40.000	176
6/25 - 7/28	9920	3793.12	.382	1000	992.00	33	30.061	209
7/28 - 8/21	8860	3503.75	.395	1000	886.00	24	36.917	233
8/21 - 9/22	11840	5066.30	.428	1000	1184.00	32	37.000	265
9/22 - 10/21	19950	8476.62	.425	1000	1995.00	29	68.793	294
10/21 - 11/20	20910	8713.55	.417	1000	2091.00	30	69.700	324
TOTALS	246630	97014.18			24663.00			

* 1 MMBTU = 1,000,000 BTUS

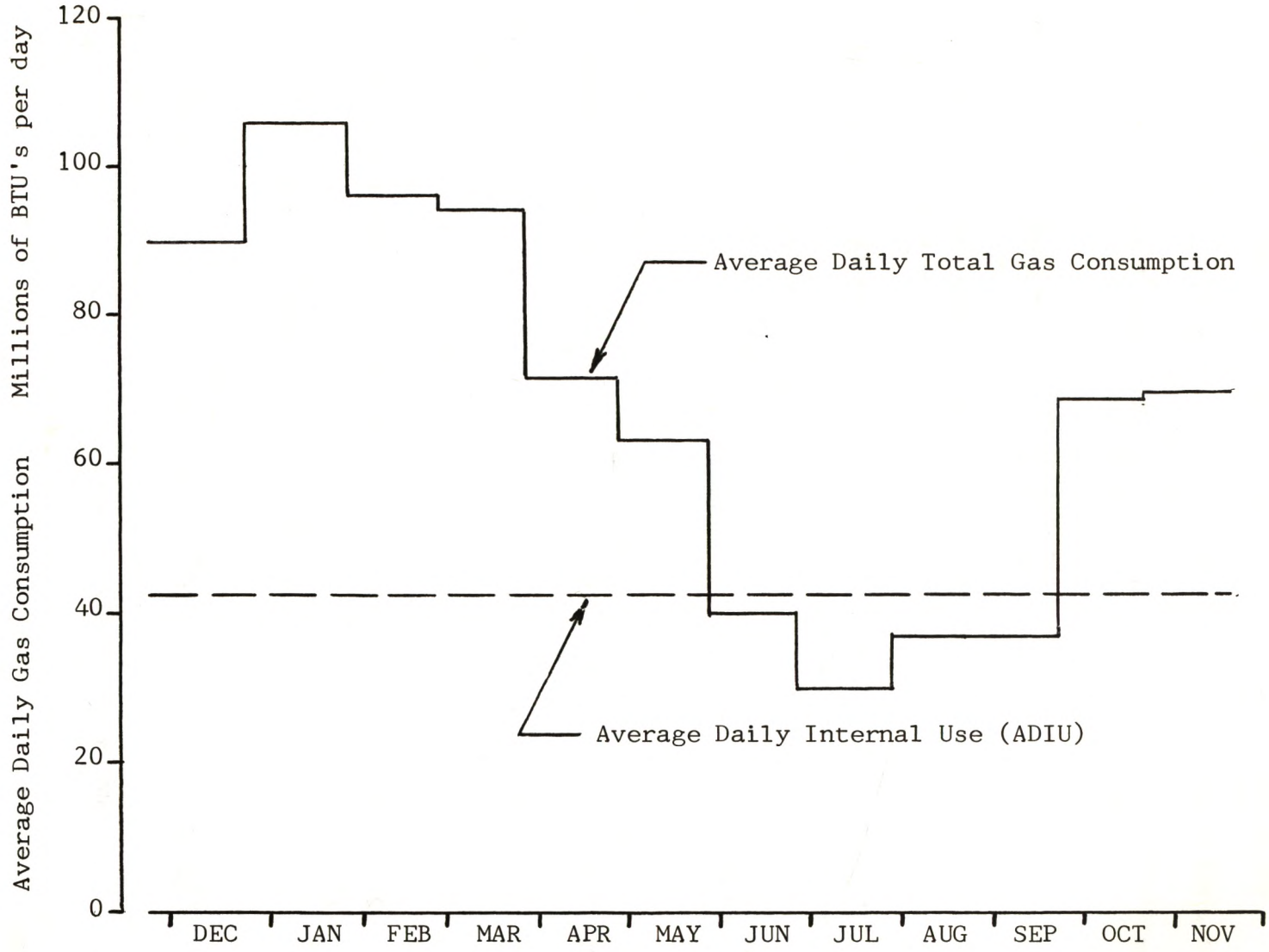


Figure 2-3. Natural Gas Consumption - Example

where:

TI1 & TI2 = comfort temperature setting during normal hours and set-back hours respectively - Deg.F

TR1 & TR2 = indoor temperature gain due to activity during normal hours and set-back hours respectively - Deg.F

TOA = average outdoor temperature during October 1 through April 30 heating season, computed as follows:

$$TOA = 65 - \frac{\text{HDD per heat season}}{\text{no. of days in heat season}} - \text{Deg.F} \qquad (2\text{-}5)$$

HR1 & HR2 = average number of normal hours and set-back hours per week respectively - hr

Values for TR1 and TR2 were generalized based on best engineering judgement. The estimates were usually as follows:

	TR1	TR2
Residential, Institutional	5 Deg.F	5 Deg.F
Commercial	5 Deg.F	0 Deg.F
Industrial	10-15 Deg.F	0 Deg.F

Determining Site-Specific Peak Heat Loss Rates

Envelope Heat Loss. The peak envelope heat loss rates were calculated from the equations:

$$Q1 = UA\ (TI1 - TR1 - TOD) \qquad (2\text{-}6)$$

$$Q2 = UA\ (TI2 - TR2 - TOD) \qquad (2\text{-}7)$$

where:

Q1 & Q2 = peak envelope heat loss rates during normal and set-back hours respectively - MM Btu/hr

TOD = outdoor design temperature - Deg.F
Based on climatological data for Jamestown, a value of $+3^{o}F$ was used for TOD.

Internal Heat Use. The internal heat use rates were calculated from the following:

$$Q3 = \frac{ADIU \times EFF \times ADH\ 7\ days/week}{HR1} \qquad (2\text{-}8)$$

where:

Q3 = internal heat use rate (computed for normal hours only) - MM Btu/hr

ADIU = average daily fuel usage for internal uses - MM Btu/day

ADH = estimate of internal heat use adaptable to district heat supply percent as a decimal

The algorithms in the previous sections have been programmed for a computer. An example of the output is given in Table 2-6.

Data Base Heat Load Summary

Table 2-7 presents the summary of the heat loads calculated for the buildings and operations listed in Table 2-4. In Table 2-7:

Column 1: The assigned identification number

Column 2: The heat floor space in the building.

Column 3: The total heating fuel consumed annually (1 MM Btu = 1 million Btu).

Column 4: The quantity of heating fuel consumed annually for comfort heat.

Column 5: The comfort heat usage per square foot of floor space.

Columns 6 through 9 were explained in the previous discussion.

BLOCK HEAT LOAD SUMMARY

Based on the information contained in Table 2-7 and with engineering judgement, fuel usage and heat loss rates per square foot were derived for the various building categories and then applied to the areas computed for similar buildings. The results computed for the buildings in each block were then summed. Figure 2-4 indicates the block numbers in the primary district heat district and Table 2-8 presents the corresponding summations. In Table 2-8:

Column 1: The block number as designated on the Sanborn Maps and Figure 2-4.

Column 2: The total heated floor space of all buildings within the block.

Column 3: The total heating fuel consumed annually (1 MM Btu = 1 million Btu).

Column 4: The quantity of heating fuel consumed annually ror comfort heat.

Column 5: The heating rate demand necessary to satisfy the comfort heat requirements, i.e. the building envelope heat loss.

Column 6: The heating rate demand necessary to satisfy other heat requirements, i.e. domestic hot water, building operations, process, etc.

It should be noted that building uses of heat which cannot be satisfied by a district heat system were not included in Column 6, e.g. high temperature heat treating of metal products.

Column 7: The sum of Columns 5 and 6.

On assessing the potential for a district heat system in the primary district, it is of interest to note the characteristics of certain blocks.

Table 2-6

HEATING FUEL USE ANALYSIS - EXAMPLE OUTPUT

FIRM NAME:
PLANT/BUILDING:
ID#:

CONDITIONS:

HEATING SEASON HDD:	7057.5 HDD
DAYS IN SEASON:	212 DAYS
AVERAGE OUTSIDE TEMPERATURE:	31.71 DEG. F
OUTSIDE DESIGN TEMPERATURE:	3 DEG. F
NORMAL HOURS PER WEEK:	168 HRS
COMFORT SETTING:	72 DEG. F
INTERNAL TEMP GAIN:	5 DEG. F
SET-BACK HOURS PER WEEK:	0 HRS
COMFORT SETTING:	0 DEG. F
INTERNAL TEMP GAIN:	0 DEG. F
HDD ADJUSTMENT FACTOR:	1.06
HEATED FLOOR SPACE:	107200 SQ.FT.
COMBUSTION EFFICIENCY:	70 PERCENT
INTERNAL HEAT USE TO BE OBTAINED FROM D.H. :	90 PERCENT

RESULTS:

FUEL USE SUMMARY:

INTERNAL USE PER DAY =	42.376 MMBTU/DAY
ANNUAL INTERNAL USE =	15467.105 MMBTU/YEAR
ANNUAL HEATING USE =	9195.895 MMBTU/YEAR
TOTAL ANNUAL USE =	24663 MMBTU/YEAR
HEAT USE/FLOOR SPACE =	.085782 MMBTU/SQ.FT.

FACILITY HEAT LOSS COEFF. (UA) = .03585 MMBTU/HR DEG. F

ENVELOPE DESIGN HEAT LOSS RATE:

NORMAL HOURS (64 DEL. T) =	2.294 MMBTU/HR
SET-BACK HOURS (—— DEL. T) =	—— MMBTU/HR

INTERNAL HEAT USE RATE TO BE OBTAINED FROM D.H. = 1.112 MMBTU/HR

Table 2-7

HEAT LOAD SUMMARY - DATA BASE

ID #	HEATED FLOOR SPACE	ANNUAL TOTAL FUEL (MMBTU)	ANNUAL COMFORT USE (MMBTU)	HEAT/ SPACE (MMBTU/ SQ.FT.)	UA (MMBTU/ HR DEG.F)	HEAT LOSS RATE (MMBTU/HR) Q1	Q2	Q3
1	2	3	4	5	6	7	8	9
			RECORD LISTING					
1	1200	136	79	.0656	3E-04.00	.018	.015	.014
2	1296	144	96	.0738	3E-04.00	.017	.017	3E-03.000
66	1536	116	57	.0370	2E-04.00	.012	.012	6E-03.000
324	1144	125	67	.0590	3E-04.00	.016	.015	.011
330	1568	139	83	.0531	3E-04.00	.018	.018	6E-03.000
408	1928	158	70	.0361	3E-04.00	.017	.016	.010
422	1680	152	85	.0508	3E-04.00	.020	.018	6E-03.000
1001	140650	45911	16906	.1202	.0745	4.471	4.247	6.026
1002	78440	15882	10975	.1399	.0713	3.710	3.353	1.223
1003	2080	471	298	.1434	1.3E-03.	.079	.075	.048
1004	68000	8905	5903	.0868	.0263	1.580	1.501	.832
1005	51000	6379	4714	.0924	.0168	1.090	1.090	.124
1006	100000	75954	17904	.1790	0.000	0.000	0.000	0.000
1007	32000	4160	2293	.0717	.0144	.792	.677	.414
1008	19900	19348	4889	.2457	.0191	1.184	1.184	1.073
1009	295000	73955	24333	.0825	.1086	6.189	6.732	1.289
1010	44500	2568	2238	.0503	9.3E-03.	.522	.569	.082
1011	11700	1053	1013	.0866	3.7E-03.	.220	.239	.011
1012	289100	21538	17262	.0597	.0930	5.115	4.650	.444
1013	257000	49687	32958	.1282	.1835	9.543	9.543	.782
1014	160000	10263	5431	.0339	.0243	1.435	1.386	.402
1015	550000	102449	48804	.0887	.2461	12.795	13.533	4.012
1016	130000	2603	2344	.0180	.0105	.600	.600	.065
1017	150000	38101	22929	.1529	.1214	6.679	6.315	4.728

(Note: ID#'s 1-422 are Residential)

Table 2-7 (Continued)

HEAT LOAD SUMMARY - DATA BASE

ID #	HEATED FLOOR SPACE	ANNUAL TOTAL FUEL (MMBTU)	ANNUAL COMFORT USE (MMBTU)	HEAT/ SPACE (MMBTU/ SQ.FT.)	UA (MMBTU/ HR DEG.F)	HEAT LOSS RATE (MMBTU/HR) Q1	Q2	Q3
1	2	3	4	5	6	7	8	9
			RECORD LISTING					
2001	30840	2243	1759	.0570	6.9E-03.	.428	.428	.159
2002	44368	7029	3224	.0727	.0132	.792	.792	.282
2003	28800	2154	1326	.0460	5.5E-03.	.328	.328	.061
2004	46000	1416	1174	.0255	4.6E-03.	.318	.263	.054
2005	16640	1971	1607	.0966	6.6E-03.	.394	.394	.027
2006	62720	2496	1833	.0292	8.6E-03.	.489	.489	.049
2007	15200	3998	2482	.1633	9.1E-03.	.585	.585	.112
2008	12600	1209	1050	.0833	3E-03.00	.202	.187	.034
2009	28000	1270	977	.0349	5E-03.00	.261	.261	.022
2010	165240	4309	3873	.0234	.0146	.904	.904	.101
3001	191816	16713	9529	.0497	.0308	1.973	2.127	.800
4001	16440	2455.	1797	.1093	6.5E-03.	.413	.413	.049
4002	17600	1992	1281	.0728	4.6E-03.	.294	.294	.053
6001	41200	3924	3250	.0789	.0124	.741	.803	.120
7001	300000	44803	18742	.0625	.0740	4.737	4.737	1.874
7002	107200	24663	9196	.0858	.0358	2.294	2.294	1.112
7003	277652	31547	23319	.0840	.1204	6.862	6.260	2.931
8001	107000	7065	4974	.0465	.0201	1.209	1.209	.155
8002	78540	4032	3703	.0471	.0141	.874	.874	.024
9001	33900	3383	2461	.0726	8.5E-03.	.525	.525	.063

Table 2-8

BLOCK HEAT LOAD SUMMARY - PRIMARY DISTRICT

	Block No.	HEATED FLOOR SPACE	ANNUAL TOTAL FUEL (MMBTU)	ANNUAL COMFORT USE (MMBTU)	HEAT LOSS RATE (MMBTU/HR) Q1	Q3	Q1+Q3
	1	2	3	4	5	6	7
	258	27254	4597	2438	.529	.097	.627
	259	20780	1766	1501	.334	.040	.374
	261	21388	1667	1143	.277	.062	.339
(1)	263	0	0	0	0.000	0.000	0.000
	265	164520	26404	18096	5.593	2.136	7.729
	269	62850	4904	2868	.702	.167	.869
	270	289044	21859	13052	2.844	.944	3.788
	271	94252	3864	2977	.786	.196	.982
	272	39270	3881	2468	.560	.115	.675
	273	132632	5232	4073	1.057	.337	1.395
	274	98370	5847	3981	1.010	.236	1.246
	275	92306	3773	2995	.710	.099	.809
	276	77224	6017	3749	.843	.218	1.062
	277	40800	2807	1923	.428	.089	.517
	278	128400	7660	5335	1.409	.438	1.848
	279	97236	4696	2974	.756	.202	.957
	280	107000	7062	4976	1.210	.155	1.364
(2)	281	0	0	0	0.000	0.000	0.000
	282	190858	9048	6512	1.357	.140	1.497
	283	79646	6399	4175	.968	.215	1.184
	286	119362	5372	3892	.985	.228	1.213
	287	69852	2242	1872	.430	.045	.475
(3)	288	221302	13992	11086	3.157	.315	3.473
(4)	289	0	0	0	0.000	0.000	0.000
	290	78540	4029	3699	.873	.024	.897
	291	77600	3220	2420	.581	.098	.679
	293	277652	31541	23323	6.862	2.930	9.792
	294	12360	1217	836	.179	.033	.212
	299	160960	39007	23742	6.861	4.743	11.605
	324	41200	3922	3251	.741	.120	.861
	325	28213	3115	1620	.348	.082	.430
	327	7040	726	451	.102	.028	.130
	328	32756	1954	1321	.303	.082	.384
	329	3460	284	176	.040	.010	.050

Notes: (1) Erie RR Station, vacant
(2) No heat using facilities
(3) Also includes block 292
(4) Hills Dept. Store, all electric

Table 2-8 (Continued)

BLOCK HEAT LOAD SUMMARY - PRIMARY DISTRICT

	Block No.	HEATED FLOOR SPACE	ANNUAL TOTAL FUEL (MMBTU)	ANNUAL COMFORT USE (MMBTU)	HEAT LOSS RATE (MMBTU/HR)		
					Q1	Q3	Q1+Q3
	1	2	3	4	5	6	7
	330	19504	1798	1160	.260	.070	.330
	331	39278	3883	2503	.566	.159	.725
	332	41298	2951	2059	.485	.091	.576
	343	38008	2583	1638	.402	.073	.475
	344	44332	4961	3461	.769	.117	.886
	345	62762	8494	4138	.998	.334	1.332
	346	50736	3896	2516	.574	.138	.712
	347	68826	7493	5579	1.103	.191	1.295
	352	71640	6556	4313	.942	.236	1.178
	514	20720	1939	1075	.237	.112	.349
	515	107200	24656	9198	2.292	1.112	3.404
(5)	518	24504	2395	1485	.366	.083	.449
(6)	522	52116	2531	1580	.323	.075	.398
	527	66242	5775	4251	.973	.140	1.113
(7)	529	77256	5856	5136	1.172	.121	1.293
(8)	535	31480	2521	1463	.333	.144	.477
	542	300000	44790	18750	4.736	1.875	6.611
	554	22600	4690	2862	.670	.152	.822
	TOTALS	4032629	375872	236092	60.036	19.847	79.888

Notes: (5) Also includes blocks 519 and 520
(6) Also includes block 523
(7) Also includes blocks 530 and 531
(8) Also includes block 534

Block #

263 Erie RR Station - Only structure using heat in this block. Currently vacant.

270 Hotel Jamestown Office and High Rise - Structure contains 2/3 of total floor space in the block. HVAC system recently modified to include heat pump.

273 Wellman Building · (15% of block floor area) upper 4 floors of the building no longer satisfy codes to permit occupancy.

274 Covenant Manor High Rise - Recently renovated for senior citizen use. HVAC system includes heat pump and resistance type units. Domestic water heated by gas. This structure was not included in the heat load assessment.

275 Commons Mall - 5 floor building recently renovated for retail stores. Most of the HVAC system converted to heat pumps. Only 7200 sq. ft. of space was included in the heat load assessment.

279 Palace Theater - Closed. Renovation feasibility being studied. A judgement for heat load was included.

280 Municipal Building - (City Hall, Police, Fire Departments) covers entire block.

289 Hills Department Store - Electric heat. Omitted from the heat load assessment.

290 Federal Building - (Post Office, Federal Offices) covers entire block.

293 Senior High School - Only structure on this block and is currently considering a major overhauling of the gas fired boiler system.

324 Chautauqua - Cattaraugus County Library - covers entire block.

327 Senior Citizen High Rise - (Approximately 10 years old) HVAC system is all electric. Contains 60,000 sq. ft. of floor space but was not included in the heat load assessment.

329 Holiday Inn - New building (approximately 3 years) equipped with heat pumps. Was not included in the heat load assessment.

515 Jamestown General Hospital - Until December 1969, this facility was heated by steam piped from the power plant. Gas fired boilers were then installed. This is the only structure considered in this block.

542 WCA Hospital - Covers entire block.

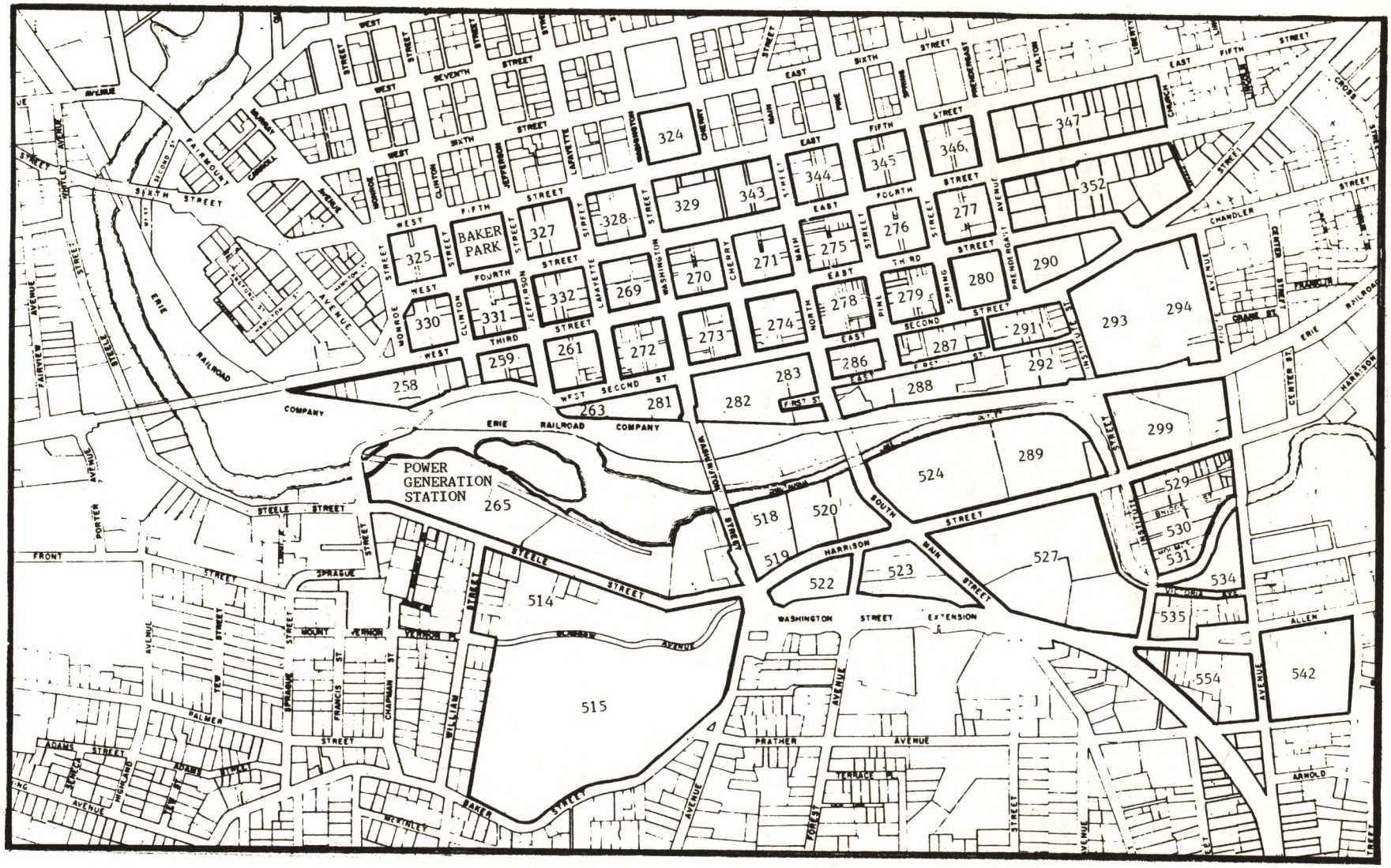


FIGURE 2-4

BLOCK NUMBERS IN THE PRIMARY DISTRICT

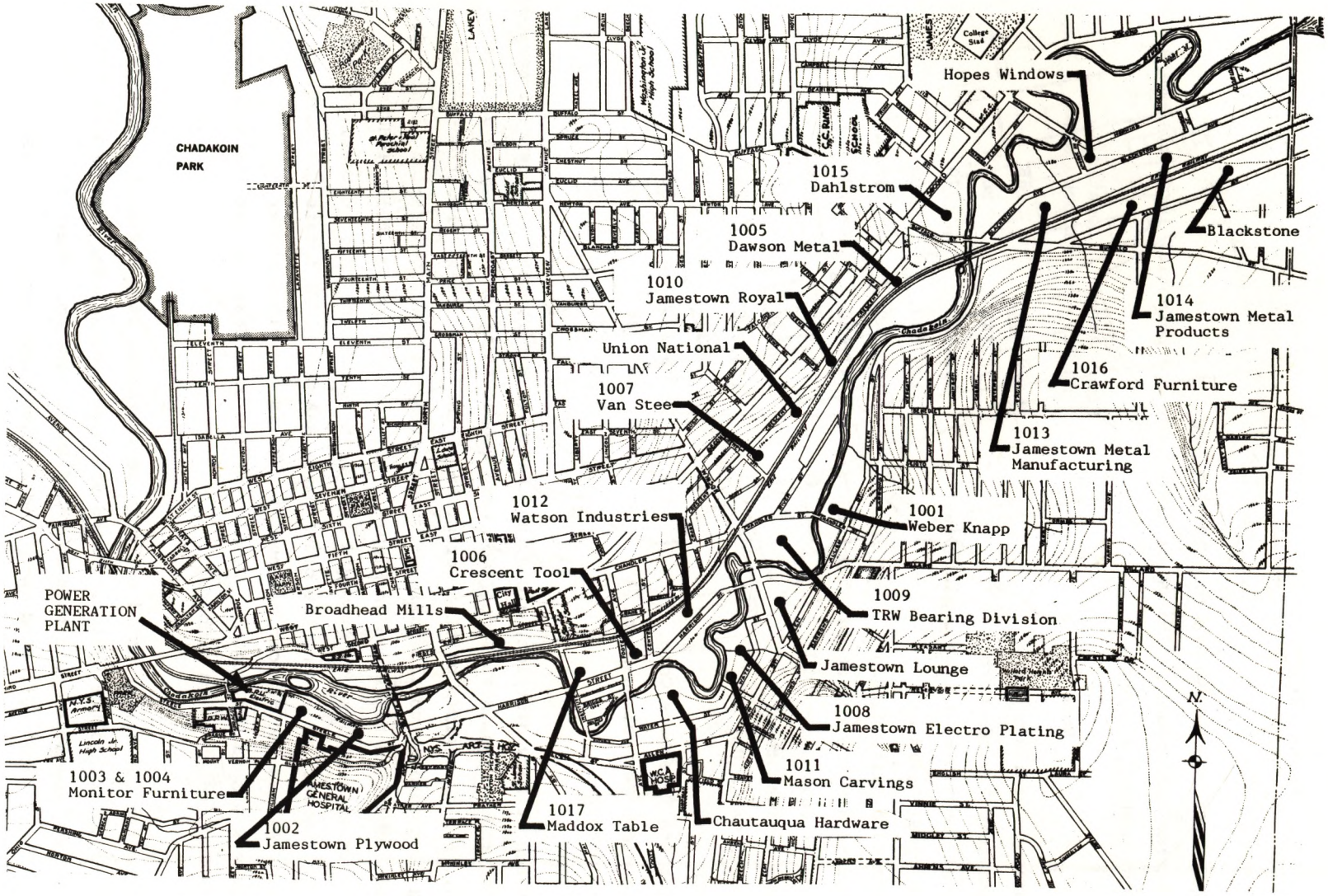
POTENTIAL LARGE COMMERCIAL AND INDUSTRIAL USERS

The following individual buildings or operations are potential large customers within the primary district.

Name	Floor Area Sq.Ft.	Located in Block No.
Monitor Furniture Co.	70,080	265
Jamestown Plywood Corp.	78,440	265
Hotel Jamestown Offices & High Rise	191,800	270
Municipal Building	107,000	280
Furniture Mart Building	165,240	282
Broadhead Mills Industrial Complex	147,650	288
Federal Building	78,540	290
Senior High School	277,650	293
Maddox Table Co.	150,000	299
YMCA	44,370	345
Midstate Telephone Corp.	39,160	346
Jamestown General Hospital	107,200	515
WCA Hospital	300,000	542

East of the primary district, along the Chadakoin River, is the industrial corridor. The major industries in this corridor were contacted by phone and several were visited. Following is a brief description of the industries. Position in the listing is according to increasing distance from the power generation plant. Approximate locations are shown on Figure 2-5. In the listing, those industries marked with an asterisk (*) provided AERC with records of their natural gas consumption. The numbers following the plant name, AAA(BBB)-CCC, locate the plant on the maps, i.e. AAA is the Sanborn map number, BBB is the block number and CCC is the Greenhorne & O'Mara map number. Results of the data analysis are included in Table 2-7 according to ID number.

Several of the industries could not only be customers of a district heat system, but also contributors to the system. There are opportunities for heat recovery from processes and the heat could then be added to the system. There are also some industries which burn their wood waste and at times have excess heat available. The scope of this project phase did not allow for an assessment of these opportunities.



MAJOR INDUSTRIES IN THE INDUSTRIAL CORRIDOR

FIGURE 2-5

ID#

1003&4 * Monitor Furniture Co. 005(265)-024- Use waste wood to fuel one boiler. Second boiler, gas fired, is used as needed. Current steam pressure at 50 psig.

1002 * Jamestown Plywood Corp. 006(265)-024 - Uses wood waste generated in-house to fuel steam boilers. Supplement with natural gas. Require process steam at approximately 65 psig.

Broadhead Mills Complex 008(288)-034 - Houses several small industries. Uses gas primarily for comfort heat, very little for process.

1017 * Maddox Table Co. 010(299)-034 - Use wood waste generated in-house to fuel low pressure steam boiler. Backup boiler uses natural gas.

1006 * Crescent Tool Co. 011(300)-034 - Natural gas usage is almost entirely for process (heat treating, etc.).

Chautauqua Hardware Corp. 077(537)-034

1012 * Watson Industries 012(301)-034 - Sheet metal fabrication. Natural gas used for bonderizer, paint bake oven, and comfort heat.

1011 * Mason Carvings 078(536)-044 - Waste wood is supplemented by gas to provide low pressure steam for comfort heat.

1008 * Jamestown Electro Plating 078(536)-044 - Use steam at 40 psig to heat plating tanks and for comfort heat.

Jamestown Lounge 061(310)-044

1009 * TRW Bearing Division 061(308)-045 - Gas usage primarily for heat treat and process steam at 100 psig. Opportunities for heat recovery.

1001 * Weber-Knapp Co. 203(682)-045 - Process usage of gas is primarily for metal plating. Presently use steam at 30 psig.

1007 * VanStee Corp. 059(395)-045 - Use gas fired boiler at 60 psig for wood drying kilns, ovens and comfort heat. Company does not use its wood waste for fuel.

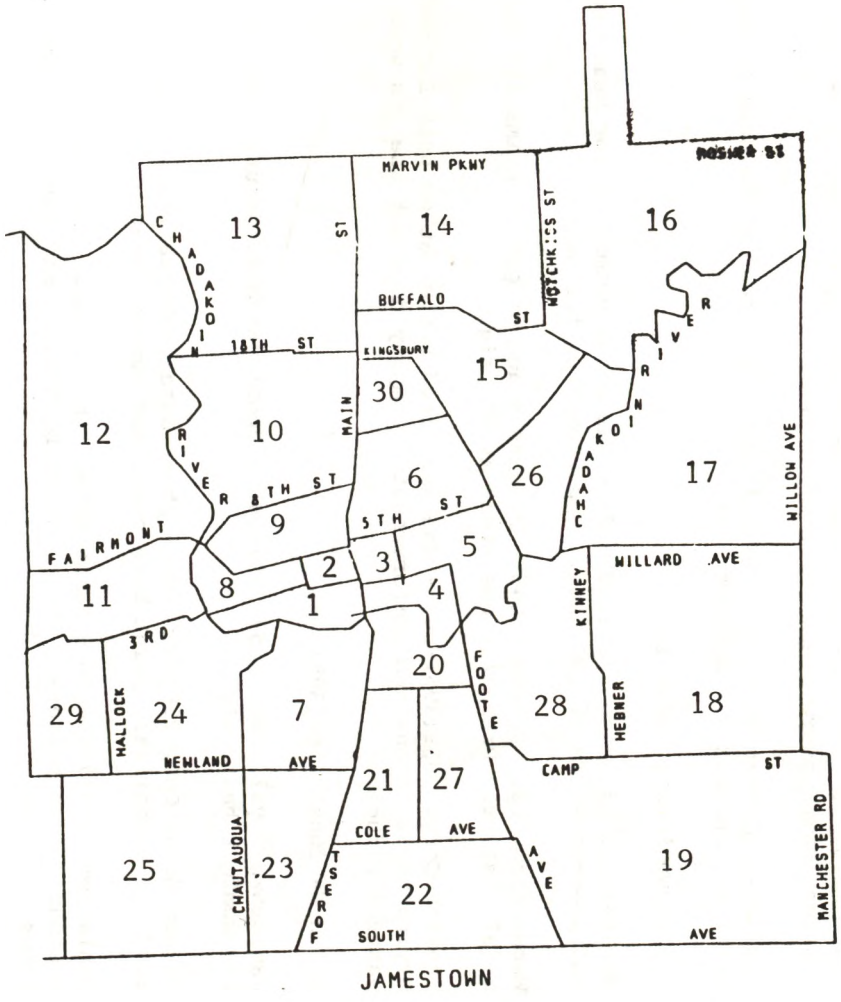
Union National 060(395)-045

1010 * Jamestown Royal, Inc. 057(395)-045 - Upholstered furniture. Gas usage for comfort heat only.

1005 * Dawson Metal Co. 058(395)-046 - Sheet metal fabrication. Natural gas used for bonderizer, paint bake oven, and comfort heat.

1015 * Dahlstrom 234(758)-046 - Sheet metal fabrication. Use gas in high pressure steam boilers. Steam use in bonderizer and paint bake operations.

1013 * Jamestown Metal Manufacturing 239(761)-056 - Gas used to generate 60 psig steam for bonderizing and paint drying at 350°F to 450°F.



Zone No.	No. of Housing Units	No. of Commercial Units
1	25	143
2	145	176
3	88	115
4	112	109
5	511	77
6	843	70
7	840	50
8	247	29
9	652	86
10	611	59
11	722	38
12	442	22
13	161	90
14	556	5
15	905	9
16	617	79
17	637	64
18	544	11
19	670	6
20	135	58
21	947	19
22	484	51
23	620	5
24	669	35
25	383	13
26	691	73
27	547	11
28	866	31
29	338	11
30	476	6
Totals	15,484	1,549

Figure 2-6 Graphic Representation of Zones in City of Jamestown

Hopes Windows, Inc. 236(765)-057

1016 * Crawford Furniture Mfg. 241(763)-056 - Most fuel need (95%) is satisfied by burning wood waste. Generate 50 psig steam for drying kilns and dry ovens.

1014 * Jamestown Metal Products 241(761)-057 - Sheet metal fabrication. Use gas for low pressure steam in bonderizer and paint bake oven.

Blackstone Corp. 242(763)-056 & 057

POTENTIAL FUTURE HEATING/COOLING LOADS

The City of Jamestown does not forsee any major new construction in the primary district in the next five years. Rehabilitation of some structures is certain, however, the increase in district heat demand would be minimal. There are vacant parcels available for development but the construction will be small in scale. Most likely, any increase in district heat demand from rehabilitation and new developments will be offset by the energy conservation efforts in existing operations.

CLASSIFICATION AND ZONING MAPPING OF THE ENTIRE CITY

General

In the previous report section, the discussion centered on the primary potential district heat district and the industrial corridor. This section gives a brief overview of the entire City of Jamestown, i.e. the district heat usage potential of residential and commercial neighborhoods.

Determination of Heat Loads for Zones

The industrial/commercial corridor is surrounded by typical variations in housing units and commercial units. A count of the units was derived from Polk Co. (Urban Statistical Div.) and 1980 census information obtained from the City Department of Development. Figure 2-6 is a graphic representation of the 30 Polk enumeration zones for the city. Listed on the figure are the current best estimates for the number of housing units and commercial units for each zone.

The data collected from the sampling of residential units yielded the following averages.

	Average per housing unit
Heated floor space	1480 sq. ft.
Total fuel usage	138 MM Btu
Total annual fuel usage for comfort heat	77 MM Btu
Peak envelope heat loss rate (Q1)	.017 MM Btu/hr
Heat rate for other uses (domestic hot water, etc.)	.008 MM Btu/hr

These consumption figures and heat demand rates were applied to the number of housing units listed on Figure 2-6 and the results are presented in Table 2-9.

The project scope did not permit a categorization of the types and sizes of commercial units and a determination of appropriate heat loads in zones outside of the primary potential district heat district. However, to obtain an approximation, an average floor area of 5000 sq. ft. per unit was assumed with heat loads characteristic of a single floor retail operation, i.e.

	Average per commercial unit
Heated floor space	5000 sq. ft.
Total annual fuel usage	365 MM Btu
Total annual fuel usage for comfort heat	285 MM Btu
Peak envelope heat loss rate (Q1)	.07 MM Btu/hr
Heat rate for other uses	.01 MM Btu/hr

These consumption figures and heat demand rates were applied to the number of commercial units listed on Figure 2-6 and the results presented in Table 2-10.

SUMMARY OF HOOK-UP AND CONVERSION COST ESTIMATES

Heating Systems Description

Building in zones chosen are currently heated by hot water or low pressure steam or electricity. Process uses for manufacturing or for sterilization (in the hospitals) can be handled by small steam generators, (not included in this report).

The Hotel Jamestown has just been converted from steam heat to partial (approximately 60%) hot water supplied by a heat pump system and the Olean Junior High School has been converted from all electric to steam and hot water heat. Equipment and installation costs for these projects are used as a local frame of refer-

Table 2-9

CITY ZONES HEAT LOAD SUMMARY - HOUSING

Zone #	No.of Units	Heated Floor Area	Annual Total Fuel MM BTU	Annual Comfort Use MM BTU	Heat Loss Rate (MMBTU/HR) Q1	Q3	Q1+Q3
1	25	37000	3450	1925	.425	.200	.625
2	145	214600	20010	11165	2.465	1.160	3.625
3	88	130240	12144	6776	1.496	.704	2.200
4	112	165760	15456	8624	1.904	.896	2.800
5	511	756280	70518	39347	8.687	4.088	12.775
6	843	1247640	116334	64911	14.331	6.744	21.075
7	840	1243200	115920	64680	14.280	6.720	21.000
8	247	365560	34086	19019	4.199	1.976	6.175
9	652	964960	89976	50204	11.084	5.216	16.300
10	611	904280	84318	47047	10.387	4.888	15.275
11	722	1068560	99636	55594	12.274	5.776	18.050
12	442	654160	60996	34034	7.514	3.536	11.050
13	161	238280	22218	12397	2.737	1.288	4.025
14	556	822880	76728	42812	9.452	4.448	13.900
15	905	1339400	124890	69685	15.385	7.240	22.625
16	617	913160	85146	47509	10.489	4.936	15.425
17	637	942760	87906	49049	10.829	5.096	15.925
18	544	805120	75072	41888	9.248	4.352	13.600
19	670	991600	92460	51590	11.390	5.360	16.750
20	135	199800	18630	10395	2.295	1.080	3.375
21	947	1401560	130686	72919	16.099	7.576	23.675
22	484	716320	66792	37268	8.228	3.872	12.100
23	620	917600	85560	47740	10.540	4.960	15.500
24	669	990120	92322	51513	11.373	5.352	16.725
25	383	566840	52854	29491	6.511	3.064	9.575
26	691	1022680	95358	53207	11.747	5.528	17.275
27	547	809560	75486	42119	9.299	4.376	13.675
28	866	1281680	119508	66682	14.722	6.928	21.650
29	338	500240	46644	26026	5.746	2.704	8.450
30	476	704480	65688	36652	8.092	3.808	11.900
		22916320	2136792	1192268	263.228	123.872	387.100

Table 2-10

CITY ZONES HEAT LOAD SUMMARY - COMMERCIAL

Zone #	No.of Units	Heated Floor Area	Annual Total Fuel MM BTU	Annual Comfort Use MM BTU	Heat Loss Rate (MMBTU/HR) Q1	Q3	Q1+Q3
1	143	715000	52195	8835	10.01	1.43	11.44
2	176	880000	64240	50160	12.32	1.76	14.08
3	115	575000	7475	32775	8.05	1.15	9.20
4	109	545000	39785	31065	7.63	1.09	8.72
5	77	385000	28105	21945	5.39	0.77	6.16
6	70	350000	25550	19950	4.90	0.70	5.60
7	50	250000	18250	14250	3.50	0.50	4.00
8	29	145000	10585	8265	2.03	0.29	2.32
9	86	430000	31390	24510	6.02	0.86	6.88
10	59	295000	21535	16815	4.13	0.59	4.72
11	38	190000	13870	10830	2.66	0.38	3.04
12	22	110000	8030	6270	1.54	0.22	1.76
13	90	450000	32850	25650	6.30	0.90	7.20
14	5	25000	1825	1425	0.35	0.05	0.40
15	9	45000	3285	2565	0.63	0.09	0.72
16	79	395000	28835	22515	5.53	0.79	6.32
17	64	320000	23360	18240	4.48	0.64	5.12
18	11	55000	4015	3135	0.77	0.11	0.88
19	6	30000	2190	1710	0.42	0.06	0.48
20	58	290000	21170	16530	4.06	0.58	4.64
21	19	95000	6935	5415	1.33	0.19	1.52
22	51	255000	18615	14535	3.57	0.51	4.08
23	5	25000	1825	1425	0.35	0.05	0.40
24	35	175000	12775	9975	2.45	0.35	2.80
25	13	65000	4745	3705	0.91	0.13	1.04
26	73	365000	26645	20805	5.11	0.73	5.84
27	11	55000	4015	3135	0.77	0.11	0.88
28	31	155000	11315	8835	2.17	0.31	2.48
29	11	55000	4015	3135	0.77	0.11	0.88
30	6	30000	2190	1710	0.42	0.06	0.48
	1549	7745000	565385	441465	108.43	15.49	123.92

ence for private and publicly bid heating system conversion costs. In addition, costs developed by the Minnesota Energy Agency and Gibbs Hill for other, similar district heating projects were used for backup.

Four typical heating systems found in this area:

- o hot water/air
- o steam
- o electric

Hot water systems can be converted by bypassing the existing boiler as shown in Figure 2-7. This leaves the installed unit for backup during startup and in case there is not enough heat in the DHC system to satisfy a particular need. After a few years of successful operation the old system will probably be removed.

Steam systems can be converted by furnishing a re-boiler in place of the fired boiler as shown in Figure 2-8, where DHC water is hot enough. Where design temperature is too low to make low pressure steam, central air handling units and forced convection wall units can be converted to hot water and other radiation can be left for a time when energy costs justify replacement. The latter conversion would be the same as shown in Figure 2-7.

- o Steam System conversions to hot water are made in two ways, depending on final district heat supply temperature.
- o Low temperature hot water conversions will be as shown in Figure 2-7. Powered heaters (heaters with forced air blowing across heating coils) will be provided with new coils designed for hot water instead of steam. Existing steam lines will usually be usable, but returns will have to be enlarged, as condensate lines are too small for required hot water flow. Buildings with more than 2 floors may require steam line replacement as well, due to age and static heat pressure requirement with water.

  Convection heaters and radiators will not always be cost effective to convert due to extensive piping and convector requirements. The existing boiler may be left in service to provide makeup heat in these cases. Usually the building envelope can be pressurized with new hot water heated warm air supply units to supplement heat provided by steam radiators, reducing steam loads to a minimum level and eliminating the need for some radiators.
- o High temperature heating water conversions are made as shown in Figure 2-8. Pressurized water from the district heating system is supplied to the building hot enough to make low pressure steam in a re-boiler. The re-boiler then replaces the fired boiler as a steam source. This conversion is simpler and more cost effective to building owners, but requires hot water from the district heat-

ing system. This may not be a cost effective choice in the power plant or for supply lines, as it may necessitate 3 pipes instead of 2 as presently envisioned, one for high temperature water, one for medium temperature water, and one for low temperature water return.

Electric system conversions are practical where a large portion of the heating units are powered, i.e.: classroom unit ventilators or central air handling units. A typical system is shown in Figure 2-9 and exemplifies the system utilized in the Olean Junior High School conversion.

- Conversion of a resistance electric heated feasibility to hot water heat requires the installation of a hot water heating system and piping to all points of use. Where powered heaters are utilized extensively, such as in a school or factory, existing air handling units are relatively easy to convert, by just replacing electric heater coils with water coils. Wall heaters found in offices and residential heaters are more expensive to convert due to extensive piping and added convector costs.

Hot air systems can be converted inexpensively by adding a hot water coil to the existing furnace bonnet or return air line, as shown in Figure 2-10.

Each system includes a meter to measure the amount of water used and temperature differential, for billing purposes.

Unit Cost Estimate

Private Residences

o	Hydronic water heat exchanger (200 MBH)	$ 670
o	Control valve (1/2")	220
o	Domestic water heat exchanger (390 MBH, 10 gpm)	620
o	Control valve (1/2")	220
o	Btu meter	350
o	Piping and fittings	450
o	Installation	750
		$3280
o	Contingency (15%)	490
		$3770

($3770/200 MBH average =$1.89/MBH = $59/equivalent KW heat)

Private residence conversion requirements vary somewhat, but for purposes of an initial evaluation, are considered constant. As noted from the above items, al-

most all are fixed costs for relatively large variations in heat requirements. Exchangers do vary in cost with size, but the variation is small compared to total system cost. This provides the added advantage of being able to quote a specific number to the majority of individuals who may be interested in tieing into the system. There will be cases when a housing complex will cost more to connect than a small house, and there may be need for two or three standard rates rather than one.

Costs for residential systems were taken from specific equipment costs for items needed to convert heating and domestic water systems. To be cost effective (and attractive) for an owner, some if not all of these costs could be capitalized with the DHC system and capital costs built into the heat rate structure.

Hot Water Conversion - Industrial and Commercial

	$/MBH
o Hydronic water heat exchanger	$ 3.55
o Domestic water heat exchanger	incl above
o Control valves	2.15
o Piping and fittings	5.50
o Installation	12.00
	$23.20
o Contingency (25%)	5.80
	$29.00

($29/MBH = $98.9/equivalent KW heat)

Hot water conversions for industrial and commercial users vary considerably, depending on type of existing systems, facility size, and process use. Also, these firms are usually considered on a case by case basis by the utilities as their usage tends to be significantly greater than for private residences. There is commonality in unitizing rates rather than trying to use a fixed rate structure.

Hot water conversions will be a small portion of the total requirement in Jamestown, as most facilities use steam. The conversion is made by placing a district water heated exchanger in the hot water boiler return line just before the boiler. It will heat water to the desired temperature before entering the boiler, and make firing unnecessary, except in case of failure. In this way the expense of circulators and controls will be minimized.

Low Temperature District Heating Water to Steam Conversion -
Industrial and Commercial

	$/MBH
o Hydronic water heat exchanger	$ 3.55
o Domestic water heat exchanger	incl above
o Control valves	2.15
o Building heat exchangers (60% conversion)	7.00
o Pipings and fittings	15.00
o Installation	20.00
	$47.70
o Contingency (25%)	11.90
	$59.60

($59.6/MBH = $203/equivalent KW heat)

District heating water to building steam conversion costs are unitized as they also apply to industrial and commercial users. Costs are significantly higher per BTU because of extra piping, conversion exchangers, and associated installation costs.

Conversion of Resistance Electric to District Heat - Industrial and Commercial

	$/MBH
o Hydronic water heat exchanger	$ 3.55
o Domestic water heat exchanger	incl above
o Control valves	2.15
o Building heat exchangers (60% conversion)	7.00
o Pipings and fittings	15.00
o Installation	20.00
	$47.70
o Contingency (25%)	11.90
	$59.60

($59.6/MBH = $203/equivalent KW heat)

Costs include supply of a hot water heating system, piping to heat users, and replacement of powered unit heater coils. This is estimated to handle about 60% of the total load. The rest will not be cost effective to convert due to excessive piping and convector costs.

Costs for each individual type of installation will vary widely, depending on project requirements. A building like the Hotel Jamestown would cost about $30

per MBH, while the High School could cost as much as $150/MBH.

An inexpensive project would be where most heating is provided by central air handling units. In this case a circulating water system would be required, but it would only have to furnish heat to a few users. Total heat exchange surface would be approximately constant, but would be concentrated in a few large units, minimizing equipment and installation costs.

In the case of a facility with many points of use, smaller exchangers, added piping, longer runs, and added installation costs are involved.

Most installations are expected to evaluate cost effective conversions and eliminate high cost portions of the project, thereby allowing the cost to approach the lower limit indicated.

Overall Cost Estimate

Using an average cost of $40 per MBH, total cost for the primary district could be over $3 million. Any further generalization can be misleading. A more detailed study, including preliminary utilization estimates and designs for major users listed in the following paragraphs will be required to provide more accurate data.

Minimal conversion will provide least cost user installations. If district heating system temperature is maintained at about 300^{o}F, average installation costs can be reduced to $20-25/MBH instead of $40/MBH with low temperature water.

Comparison With Other Similar Projects

Other projects of a similar nature such as the St. Paul, Minnesota heating system have found similar costs to those quoted above. For example, the St. Paul District Heating Development Company, Inc. reports an expected building conversion cost of $22 million for a 165 MW system. This averages $133 per KW, compared with the $59 to $203 per KW quoted for Jamestown in 1982, averaging about $130 per KW.

SUMMARY OF SIGNIFICANT FINDINGS

Primary District Heat Load Assessment

The following outlines the heat loads determined for the 59 city street blocks in the proposed primary district heat district, as shown in Figure 2-4. The totals

TYPICAL HOT WATER CONVERSION

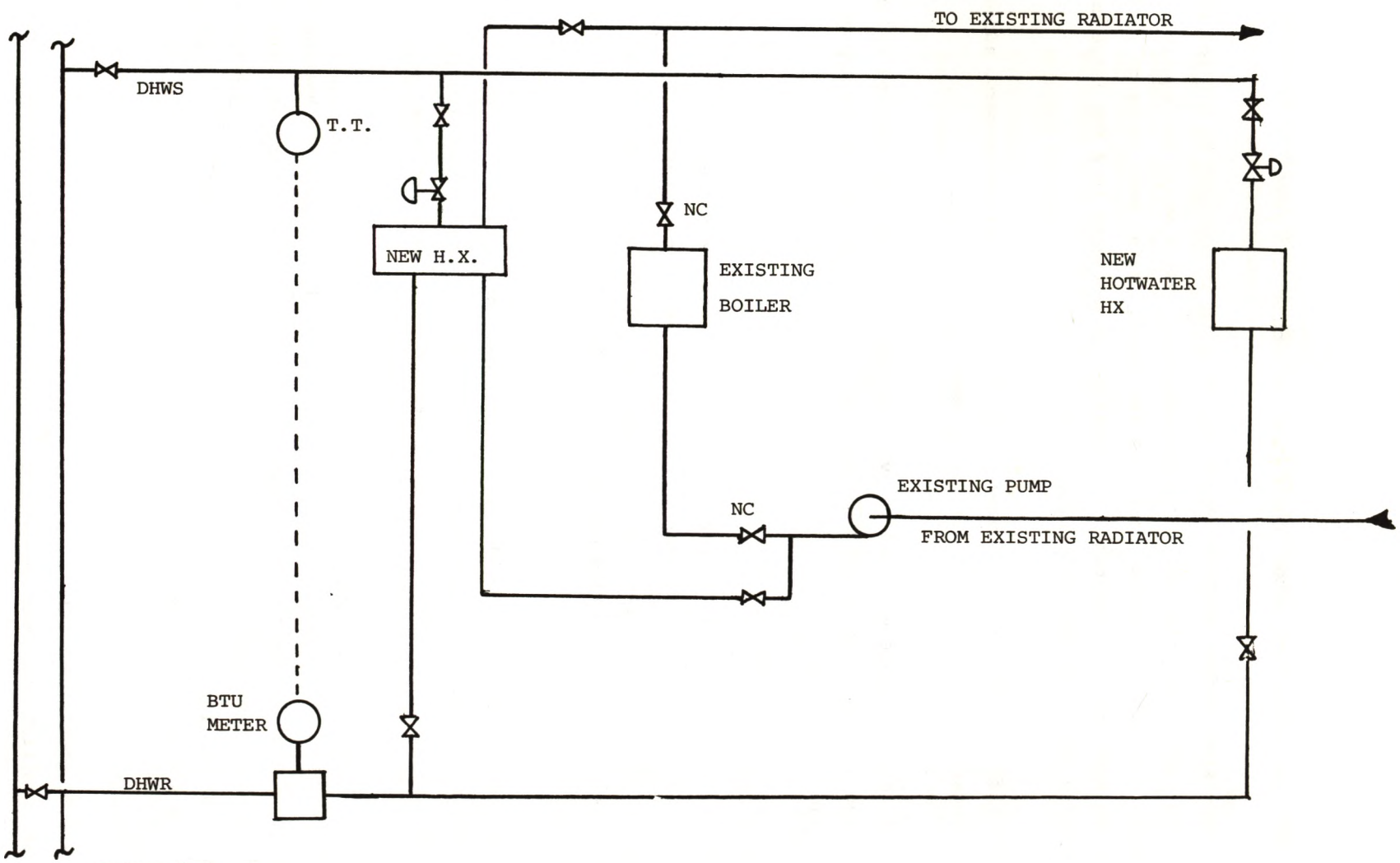


FIGURE 2-7

TYPICAL STEAM CONVERSION

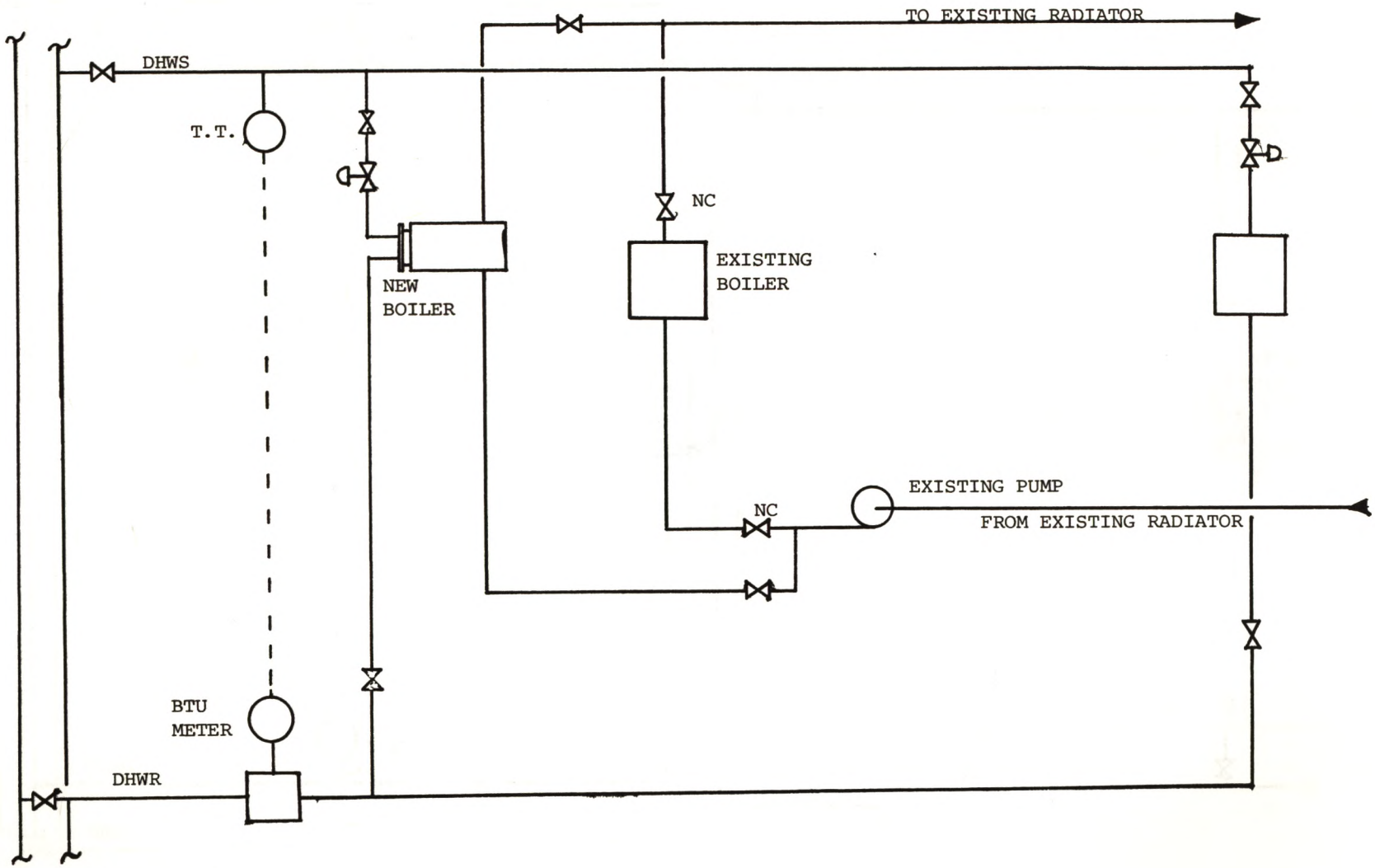


FIGURE 2-8

TYPICAL ELECTRIC CONVERSION

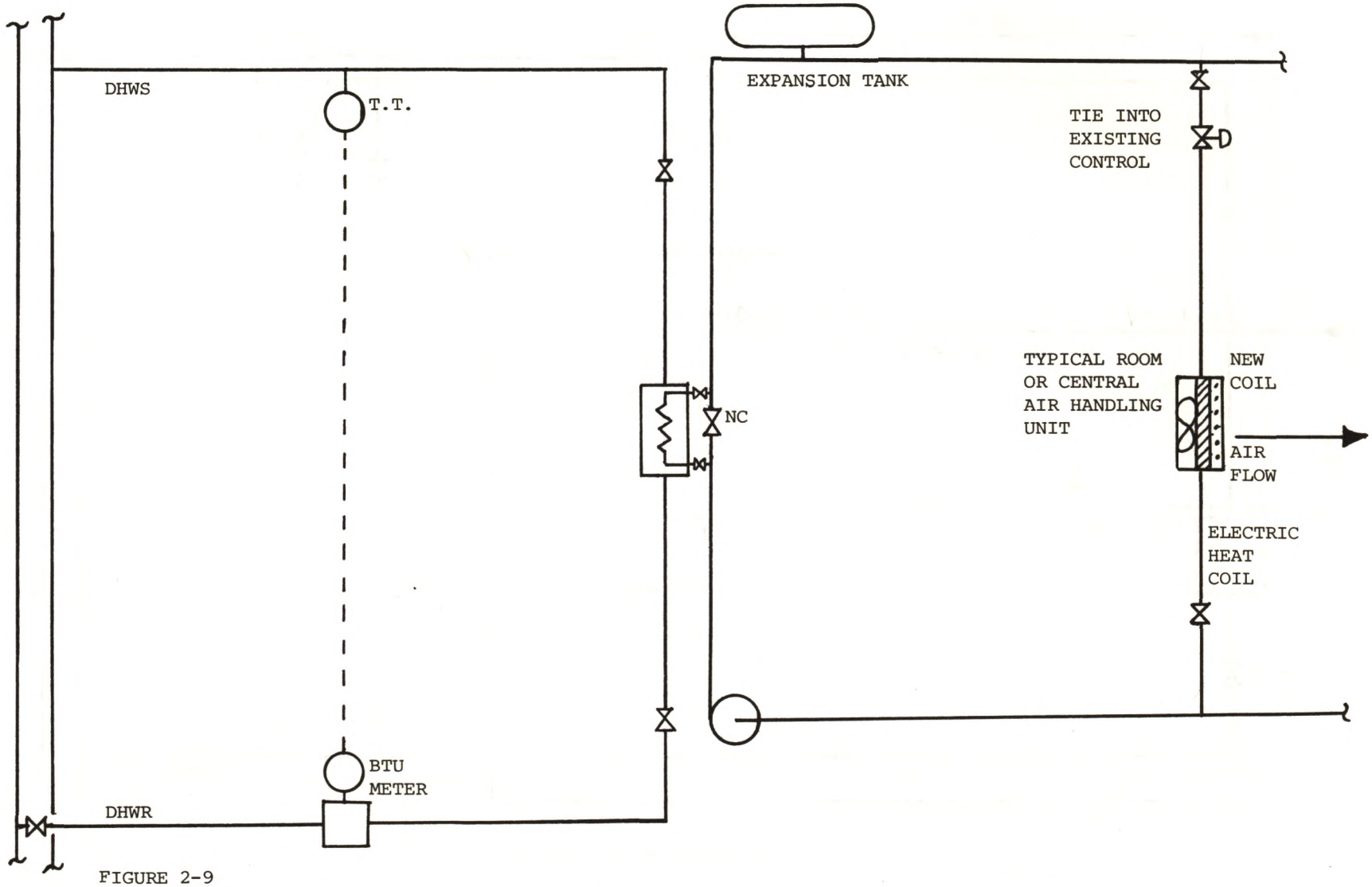


FIGURE 2-9

TYPICAL HOT AIR HEAT CONVERSION

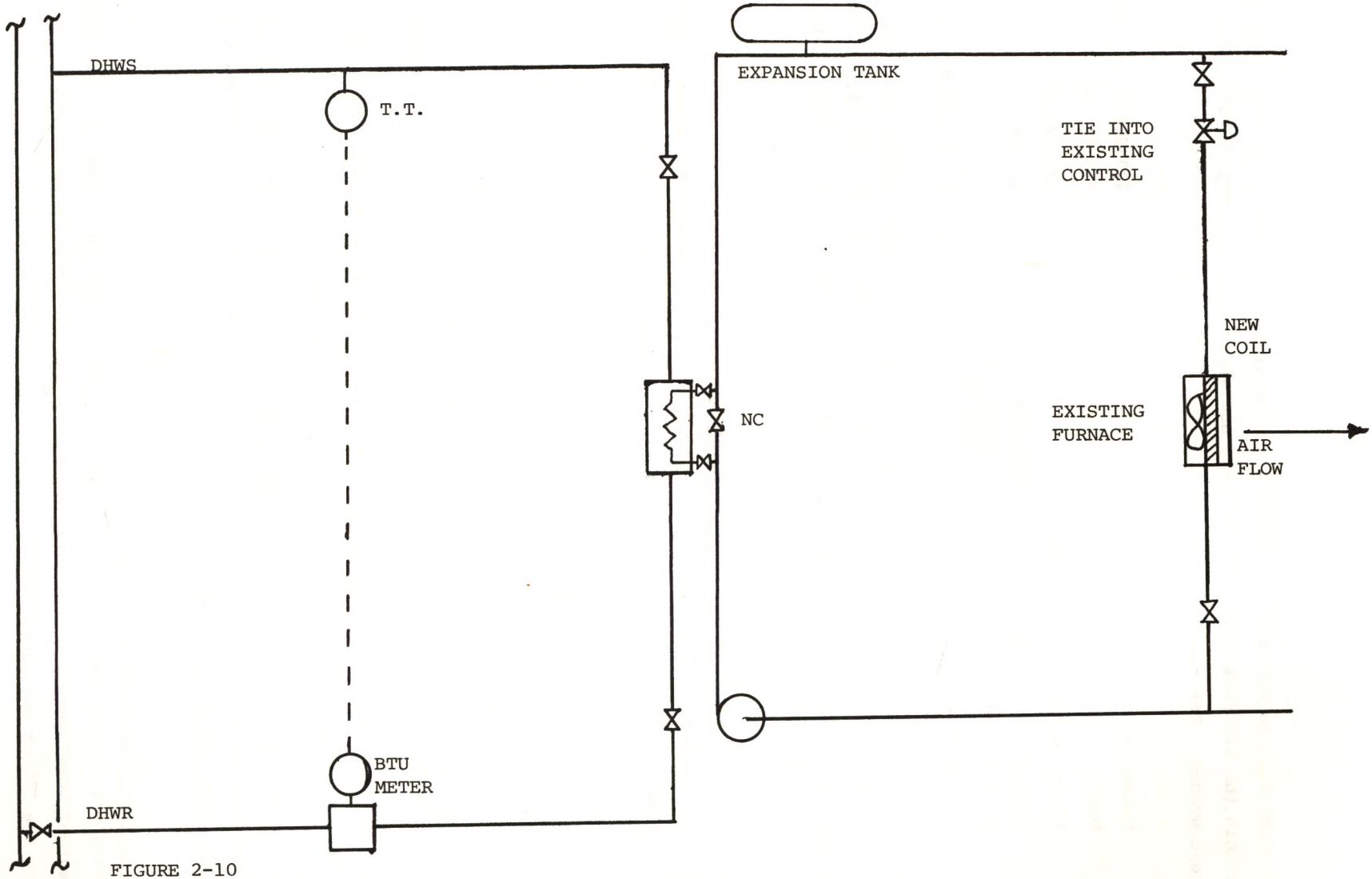


FIGURE 2-10

include all the buildings and operations (residential, commercial and industrial) within the district, but only the heat use which could be supplied by a district heat system. For the 59 blocks:

Heated floor space	4,032,629 sq. ft.
Total annual heat use	375,872 MM Btu
Annual comfort heat use	236,092 MM Btu
Building envelope peak heat loss rate	60.036 MM Btu/hr
Heat demand rate for uses other than envelope heat loss	19.847 MM Btu/hr

It is of interest to note that, of the 375,872 MM Btu total annual heat use, 175,468 MM Btu or 47% is attributable to the two hospitals and the high school, Municipal Building, Federal Building, and three industries which are in line between the hospitals.

Industrial Corridor Heat Load Assessment

Data obtained from 14 of the major industries in the industrial corridor east of the primary district (see Figure 2-5) yielded the following results:

Heated floor space	2,230,850 sq. ft.
Total annual heat use	453,968 MM Btu
Annual comfort heat use	204,017 MM Btu
Building envelope peak heat loss rate	50.635 MM Btu/hr
Heat demand rate for uses other than envelope heat loss	19.452 MM Btu/hr

At this time it is impossible to estimate a heat load that would include all industries in the corridor.

Again, the heat demand rate for "uses other than envelope heat loss" does not include that amount which could not be supplied by a district heat system, e.g. high temperature heat treat processes.

City Wide Heat Load Assessment

Using the housing and commercial count information obtained from the City Department of Development, a heat load assessment was made for the entire city, omitting the 100 or more industries.

	Housing	Commercial	
Heated floor space	22,916,320	7,745,000	sq. ft.
Total annual heat use	2,136,792	565,385	MM Btu
Annual comfort heat use	1,192,268	441,465	MM Btu
Building envelope peak heat loss rate	263.228	108.43	MM Btu/hr
Heat demand rate for uses other than envelope heat loss	123.872	15.49	MM Btu/hr

A heat load assessment for all the industries in the city would require contacting each industry. This was not possible during this study phase.

Section 3

POWER PLANT RETROFIT ANALYSIS

INTRODUCTION

The purpose of this section is to develop in a conceptual form power plant retrofit alternatives necessary to adapt the Board of Public Utilities City of Jamestown, Steele Street Station for district heat supply. District heat is provided by hot water as the transport medium.

The study considers two major means of adapting the units for district heating: modifying the existing turbines, and addition of a new district heating turbine capable of providing large quantities of steam to heat district water.

For both of the above cases, budgetary cost estimates are prepared based on a conceptual design of additional components and modifications to existing piping. Additional components include district heating condensers with associated valves, and drain pumps; district heating circulating pumps; and make-up water system for district heating water supply. The cost of hot water piping outside the plant boundary is not included in this section of the report.

General Considerations

District heating is a rapidly expanding sector of the energy market and represents a basic means of saving fuel. Power plants supplying heat and electricity present the opportunity to increase thermal efficiency. This is especially important because conventional power plants have generally reached the limit of thermal efficiency. The main advantages of district heat supply are overall fuel conservation replacement of oil and gas by coal, improved environmental quality due to more efficient fuel use, replacement of multiple point emissions with a single point emission, and reduction of heat discharged to the environment.

Countries which have developed extensive district heating systems supplied from cogeneration power plants have already achieved a high degree of energy conservation. Price escalations and concern over oil and gas availability have given con-

siderable impetus to studies of the use of heat from power plants. In the last few years this concept has been under serious investigation in the U.S. The United States was the pioneer in the practical application of district heating and about forty district heating systems are in operation in this country supplying approximately one percent of the heating demand. District heating systems in the U.S. generally use steam as the heating medium, while hot water systems are more commonly used in Europe. Hot water as a heating medium offers a number of advantages in comparison to steam and, therefore, is more widely used in large district heating systems. A typical district heating plant utilizes a turbine designed for extraction of large amounts of steam to heat water which is supplied to the customers.

The main advantages of using hot water as a heating medium in comparison to steam are:

- Cogeneration of heat and power at the power plant is achieved with a higher thermal efficiency. In a hot water system, low-pressure steam from turbine bleeds is used for heating the water which is supplied to the customers. In the steam system, the steam has to be extracted from the higher pressure bleeds of the turbine to allow for required pressure drop in the piping network.
- Hot water provides the capability of heat transmission over long distances with relatively low heat losses and an inherent capability for expanding the service area.
- A more economical central system for the heat supply from the power plant can be used. For example, the relationship between supplied hot water temperature and ambient conditions can be maintained more easily.
- The connection of most of the customers to the district network is simplified.
- The condensate from the extraction steam can be saved at the power plants. In many steam district heating systems, the condensate is not returned to the power plant for a number of reasons. To replace the lost condensate in a steam system, a high quality make-up for the boilers is required, thus imposing a high cost penalty against steam systems.
- Lower surface temperatures on the water radiators in the residential buildings provide better sanitary and safety conditions for the inhabitants. In steam heating systems, organic dust is partially decomposed on high-temperature steam radiators, and as a result harmful substances are released in the living space. Therefore, in some countries steam heating systems are not permitted for use in residential buildings.
- The hot water network inherently constitutes a large storage capacity of the network is directly proportional to the additional temperature increase above the water temperature required by the customers. The temperature increase can be achieved during periods of

low-load demand at the power station. Usually, the temperature of the water in the return line is increased by bypassing water from the supply line. Such a possibility does not exist in steam networks.

Most of the existing power plants in the U.S. are of the single purpose, condensing type, and are not designed for the extraction of large amounts of steam required for district heating. In a typical condensing fossil-fueled power plant, the exhaust steam flow into the condenser constitutes about 60 to 65 percent of the throttle steam flow. For district heating purposes, a substantial part of this steam must be extracted from the turbine stages before it reaches the condenser. It must be emphasized that the retrofitting of existing turbines to extract the required steam flow for district heating with high efficiency is difficult. Such modifications involve redesign of the turbine and its control system, and consequently, some outage time may be necessary. The efficiency of district heat extraction can be presented as the ratio of district heat produced to lost electrical generation, MWt/MWe. The typical ratio for a single purpose turbine that is retrofitted to supply district heat is in the range of 3.0 to 4.5 while the ratio for a cogeneration district heating turbine is in the range of 6.0 to 7.5. Therefore, the efficiency penalty for converting an existing single purpose machine instead of replacing it with a new district heating turbine is in the range of 1.5 to 3.0. It should be noted, however, that in either case the overall thermal efficiency of the power plant will be increased. The thermal efficiency for a single purpose plant is in the neighborhood of 35 percent while the thermal efficiency of a cogeneration district heating plant on an annual basis may be as high as 55 percent.

In evaluating the feasibility of district heat supply, the magnitude and phasing of system load increases are major economic factors. Premature introduction of a base load district heating plant or delay in the development of the network system will lead to an excess of power plant rated heat capacity and may result in a considerable reduction in the efficiency of the district heating system. To prevent such situations, two approaches can be used in developing a district heating system.

The first of these is a step-by-step approach. The growth of a district heating network in this case can best be accommodated by starting with small heating-only plants or by retrofitting turbines of existing peaking or intermediate load power plants, located close to the heat load centers. As the system grows, new

base load district heating turbines can be introduced, with a high capacity factor already assured. The heating-only plants will thereafter serve as peaking and standby units.

Another way is to build a district heating power plant in advance, equipped with all provisions for the addition of a future heat supply capacity. A new power plant for electric generation could be equipped with district heating turbines with condensing exhaust ends and cold condensers capable of providing the same electric output as conventional units. The district heating turbines can be installed at sites where a district heat load will be developed in the future. In the meantime, district heating turbines can operate in a pure condensing mode. When the district heat load and the piping network have been developed, the required district heating condensers, pumps and related equipment can be installed at the power plant. This approach reduces the initial investment in the district heating power plant, while providing the capability for flexible operation.

It must be noted that the electric output of the plant is reduced when the turbine is supplying district heating load. The electricity lost depends directly on the extracted steam flow rate, pressure, and the number of extraction points.

Steam turbines in district heating power plants may carry a combination of space heating, domestic hot water, cooling and industrial loads. These loads usually vary hourly, weekly, or seasonally and require turbines of special design to meet the particular load duration curve, while generating electric power. District heating turbines, therefore, have a number of special features not incorporated in single-purpose turbines. The maximum combined electric and heat generation efficiency is achieved when the turbine is designed to match the heat consumption.

A typical district heating load duration curve is presented in Figure 3-1. When the outdoor temperature increases, the load decreases; it becomes almost constant in the summer for domestic hot water supply only.

Different methods exist for controlling the heat supply. The simplest is a central temperature control system in which the required heat is provided to the customer by varying the temperature in the supply line at the power plant as a function of outdoor temperature (Figure 3-2). The flow rate of the water circulated in the district heating system is almost constant during the heating period.

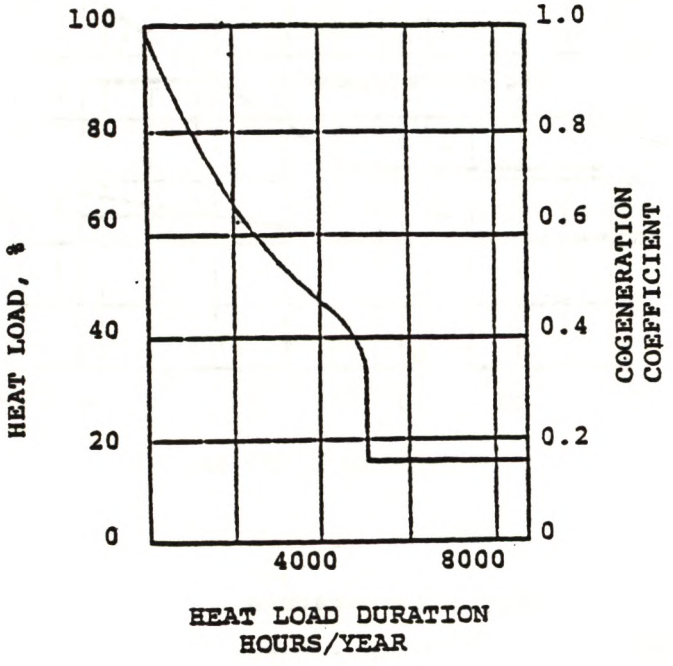
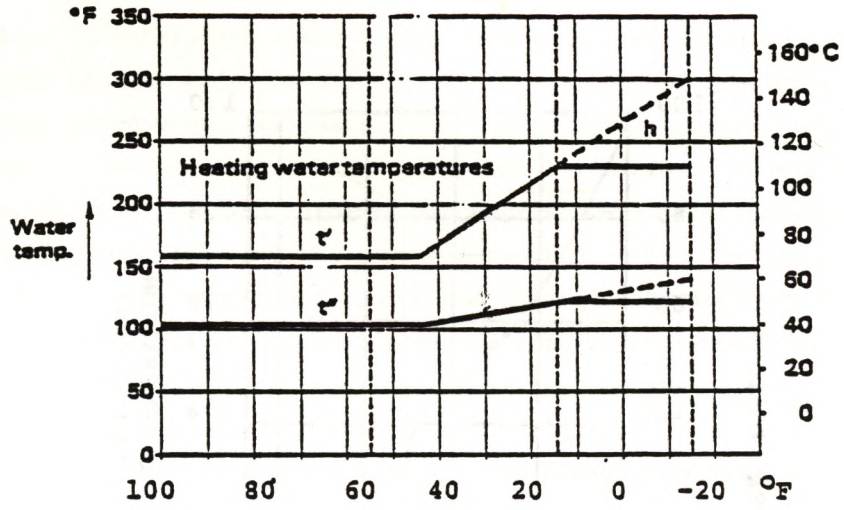


FIGURE 3-1 TYPICAL DISTRICT HEATING LOAD DURATION CURVE



t' - Supply temperature

t" - Return temperature

h - Additional peaking heat source

FIGURE 3-2 DEPENDENCE OF DISTRICT HEATING SUPPLY AND RETURN WATER TEMPERATURE ON OUTDOOR TEMPERATURE

The maximum supply temperature of the district heating water is determined by optimization analysis. By increasing the water temperature, the piping size and pumping power can be reduced, but the extraction pressure at the turbine must be increased and the electrical generation is reduced. District heating turbines are designed for base load operation and do not supply the peak load. Peaking boilers are usually used for this purpose. The optimal cogeneration coefficient* for a district heating system is determined by economic tradeoffs.

The pressure of the steam extracted from the turbine must change to correspond with the required district heating water temperatures. Therefore, the district heating turbine must be designed to follow the district heating loads although it must also operate in a pure condensing (power-only) mode. The turbine should provide economical operation throughout the year in both district heating and power-only modes.

The specific features of district heating turbines may be summarized as follows:

- Suitable openings in the turbine cylinders for extraction of large amounts of low pressure steam.
- Capability to control concurrently and independently electrical load and the steam extractions over a wide range of load demands.
- Capability to operate in the condensing mode.
- Heat of the district water in stages, in series extraction heat exchangers.
- Minimum throttling of extraction steam to ensure optimal operation of the bleed system over a wide range of parameters.

Series heating of district water is similar in principle to feedwater heating although the temperature difference between entering and leaving water is 70° to 110°F in a district heating condenser as compared with 270° to 450°F in a regenerative feedwater system. Whereas 20 to 30 percent of throttle steam is used in a regenerative feedwater system, 70 to 80 percent is used in a district heating system. This condition imposes difficulties on the turbine design and necessitates optimization of the series heating system for district heating.

The effectiveness of the series heating depends on many factors: number of stages, distribution of load between stages, load level, flow rate and temperature of district heating water (including changes during the year), type of heat

* Cogeneration coefficient is the ratio of heat load supplied by the district heating turbine to the maximum peak demand.

load control, climatic conditions, cogeneration coefficient, throttle steam conditions, type of turbine, and auxiliary equipment.

Use of two-stage series heating increases electrical output by 3 to 5% over single-stage heating.

If the cogeneration coefficient increases, the steam pressure in the extraction stages increases accordingly. When the extraction pressure changes, the heat load is redistributed between the district heat exchangers and affects the steam flow in the upstream turbine stages. The efficiencies of these upstream stages change accordingly. Substantial variation of extraction pressure and volumetric flow takes place in upstream stages when the seasonal heating period changes or when the turbine operates in the condensing mode. Therefore, the turbine bleed system must be designed for maximum annual efficiency.

In a single-purpose turbine there is a proportional relationship between the steam flow rate through the turbine and the amount of drain and pressure drop between the feedwater heaters. This generally provides reliable cascading of the drains from one feedwater heater to another. In a district heating turbine such a relationship does not exist. When operating with controlled extraction, the flow rate through the LP section is reduced. When the extraction stages are operated with small steam flow rates, the pressure differences between the interconnected heaters are not enough to provide cascading of the drains. Therefore, drain pumps are often used.

When the turbine runs with high heat load, the flow rate of steam entering the cold condenser is so low that there may not be enough condensate to cool the gland steam condenser and the ejector. Therefore, a recirculation line is provided from the feedwater system to the condenser.

In the district heating mode the turbine provides steam flow for cooling the LP section, and this flow enters the condenser. The minimum cooling flow requirements are determined by features such as types of LP stages, control diaphragm leakage, and operational factors such as pressure in the extraction stage and condenser.

Various types of turbine controls are used in district heat supply systems. The two major types are the butterfly valve type of turbine control and the variable

diaphragm type of turbine control.

District heating turbine output may be controlled by butterfly valves which make it possible to vary the ratio of heat to electric output. These turbines use butterfly valves in the crossover pipes and in the extraction pipes between the IP and LP elements in order to control heat and electrical generation.

A comparison of two-stage district heating turbine arrangements is shown in Figure 3-3. Figure 3-3a shows a typical West European district heating arrangement. In this design all steam passes through the IP section and is partially extracted for district heating when required.

Figure 3-3b shows the district heating arrangement using a GE turbine. This machine has a separate two-flow symmetrical LP element which provides large quantities of extraction steam to the district heating condensers from its exhausts at two different pressures. This element is located between the IP and the LP sections.

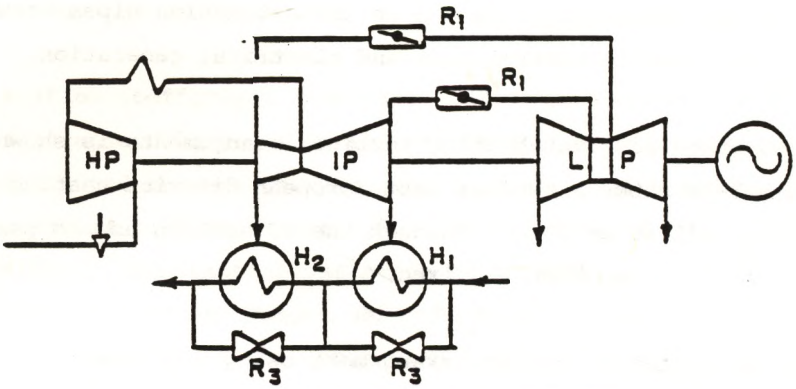
Crossover steam flow from the IP exhaust to the symmetrical (heating) LP and condensing LP sections is controlled by large butterfly valves located in the inlet pipes of these elements. Depending on the outdoor temperature, the district heating condensers require lower or higher pressure steam. Variation of steam extraction pressures is achieved by adjusting the flow split between the heating and condensing LP sections. During maximum heat load conditions the butterfly valve in the inlet to the heating LP element is fully open, while the valve in the inlet to the condensing element is fully closed. In the pure condensing operation (at zero heat load conditions), all steam is diverted to the condensing LP section while the butterfly valve in the inlet to the heating LP section is fully closed. It should be noted, however, that when the crossover butterfly valves are "fully closed," a small amount of steam must still pass through them for cooling purposes.

It can be seen that in the GE arrangement not all steam leaving the LP section enters the heating LP section to be partially extracted. The flow split is adjusted by the butterfly valves before entering the section from which district heating steam is provided.

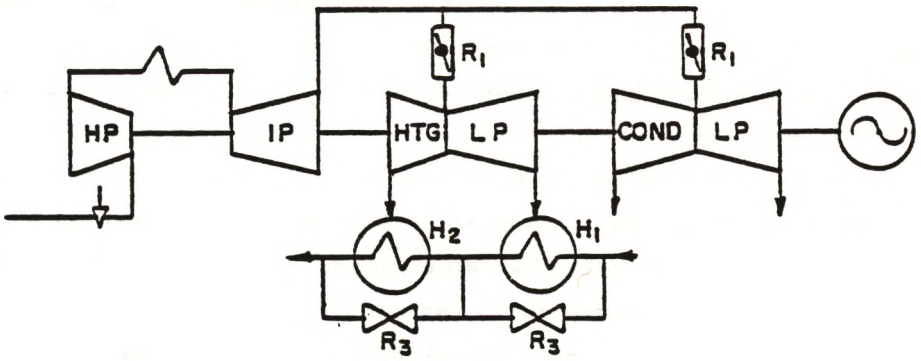
Figure 3-3c shows a typical arrangement of the variable diaphragm type of turbine

COMPARISON OF TWO-STAGE DISTRICT HEATING TURBINE ARRANGEMENTS

A.



B.



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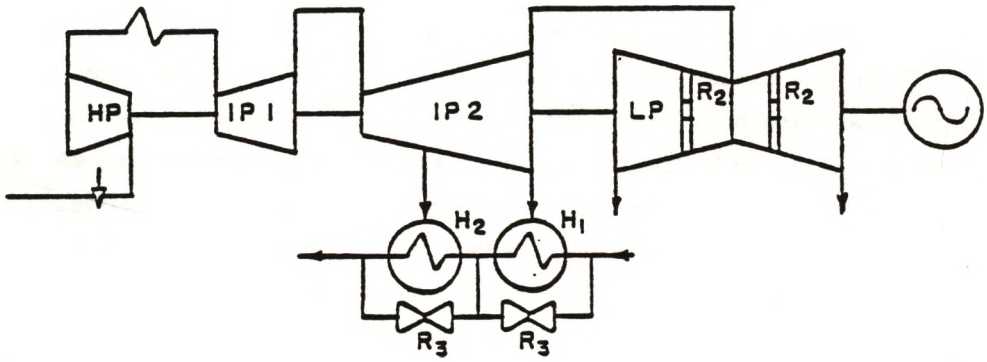


LEGEND:

H - DISTRICT HEATING CONDENSER.
R_1 - CROSSOVER BUTTERFLY VALVE.
R_2 - VARIABLE DIAPHRAGM.
R_3 - CONTROL BYPASS.

FIGURE 3-3

control most common in the USSR.

This type of turbine usually has two extractions for heating district water for series. It has one pressure regulator, a grid type variable control diaphragm located in the LP cylinder.

The pressure in the district heating condenser is controlled by adjusting the position of the diaphragm. The maximum heat load from both extractions occurs when the diaphragm in the LP element is closed. In this condition, the pressure in the controlled extraction increases, and the flow rate of the steam into the LP section also increases in proportion to the pressure in front of the diaphragm.

The steam flow to the lower extraction stage cannot be reduced below that required for LP section cooling purposes.

The extraction pressure can be controlled either in the upper stage only by operating two extractions or in the lower stage by disconnecting the upper stage. Operation of the turbine with the upper stage only is not permitted.

The above paragraphs were described here in order to put the modifications proposed for the Steele Street Plant into perspective, and to insure that all potential retrofit options are properly considered.

MODIFICATION OF THE STEELE STREET POWER PLANT FOR DISTRICT HEATING

Description of the Existing Plant

The Steele Street Power Station consists of four operational units. The station burns coal. The station uses cooling towers for cooling its circulating water. The cooling towers are connected to ponds which receive water from and discharge water to the river.

All four turbines were manufactured by General Electric Company. The four units are non-reheat units. Units 3 and 4 are the oldest turbines, they have been installed about fifty years. Unit 5 was erected in 1951 and Unit 6 was erected in 1968.

Unit 3 is a 15,000 kw, 3600 RPM condensing unit designed to operate at 275 psig steam pressure and 600°F temperature. It is a single-flow unit with a rated throttle flow of 154,950 lbs/hr at 1.0 inche Hg. condenser pressure. Extraction steam for regenerative feedwater heating is taken from a single extraction for use in one stage of feedwater heating. The cycle conditions for Unit 3 are shown in Table 3-1.

Unit 4 is a 12,500 kw, 3600 RPM, 12 stage condensing unit designed to operate at 275 psig steam pressure and 200°F temperature. It is a single-flow unit with a rated throttle flow of 136,000 lbs/hr at 1.5 inches Hg. condenser pressure. Extraction steam for regenerative feedwater heating is taken from the 6th and 9th stages. There is one stage of feedwater heating. The cycle conditions for Unit 4 are shown in Table 3-2.

Although units 3 and 4 are operational, they are normally off line due to insufficient steam capacity from the steam generator.

Unit 5 is a 25,000 kw, 3600 RPM, 19 stage condensing unit designed to operate at 850 psig steam pressure and 900°F temperature at 1.5 inches Hg. condenser pressure. It is a single flow unit. Unit 5 has recently been redesigned by General Electric and is planned to be uprated to 28,750 kw in the next couple of years. District heating modifications considered in this report are for the uprated machine. The throttle steam flow is 275,146 lb/hr at 1.5 inches Hg. condenser pressure. Extraction steam for regenerative feedwater heating is taken from the 4th, 8th, 12th and 16th stages. Makeup to the cycle is from an evaporator. The feedwater heating cycle consists of four closed and one open feedwater heater. The heat balance at 100% load condition for Unit 5 is shown in Figure 3-4.

Table 3-1

UNIT 3 CYCLE CONDITIONS

General Conditions

Nominal Rating 15,000 KW

Number of Extractions 1

275 Psig - 600°F - 1.0" Hg. Abs.

Extracting Conditions	50%	75%	100%	VWO
Load - kw	7,500	11,250	15,000	18,750
Throttle Flow - lbs/hr	78,110	116,405	154,950	198,350
Extraction Stage Pressure Psia	4.55	6.65	8.83	11.2
Heater Pressure - Psia	4.23	6.18	8.21	10.4
Extraction Enthalpy - Btu/lb	1,064	1,075	1,088	1,102
Extraction Steam - lbs/hr	5,390	10,500	14,500	19,500
FWH Inlet Temp. -°F	88	85	84	83
FWH Outlet Temp. -°F	156	168	177	182
Condensate Temp. -°F	79	79	79	79
Heat Rate - Btu/Gross kwh.	12,550	12,220	12,180	12,400
Steam Rate - Lbs/kwh.	10.49	10.39	10.39	10.64

Table 3-2

UNIT 4 CYCLE CONDITIONS

General Conditions

Nominal Rating 12,500 KW

Number of Extractions 2

275 Psig - 200°F - 1.5" Hg. Abs.

Extracting Conditions	25%	50%	75%	100%	VWO
Load - kw	3065	5980	9165	12250	14165
Throttle Flow - lbs/hr	41800	74500	107000	144000	169000
6th Stage Shell Pressure - Psia	20.0	35.5	-	-	-
6th Stage Enthalpy - Btu/lb	1139	1161	-	-	-
9th Stage Shell Pressure - Psia	-	-	7.07	9.55	11.2
9th Stage Enthalpy - Btu/lb	-	-	1068.5	1082.5	1094
Heater Pressure - Psia	7.52	7.52	6.35	7.52	7.52
FWH Inlet Temp. -°F	100	100	100	100	100
FWH Outlet Temp. -°F	180	180	172.5	180	180
Extraction Steam - lbs/hr	3120	5430	7770	11350	13180

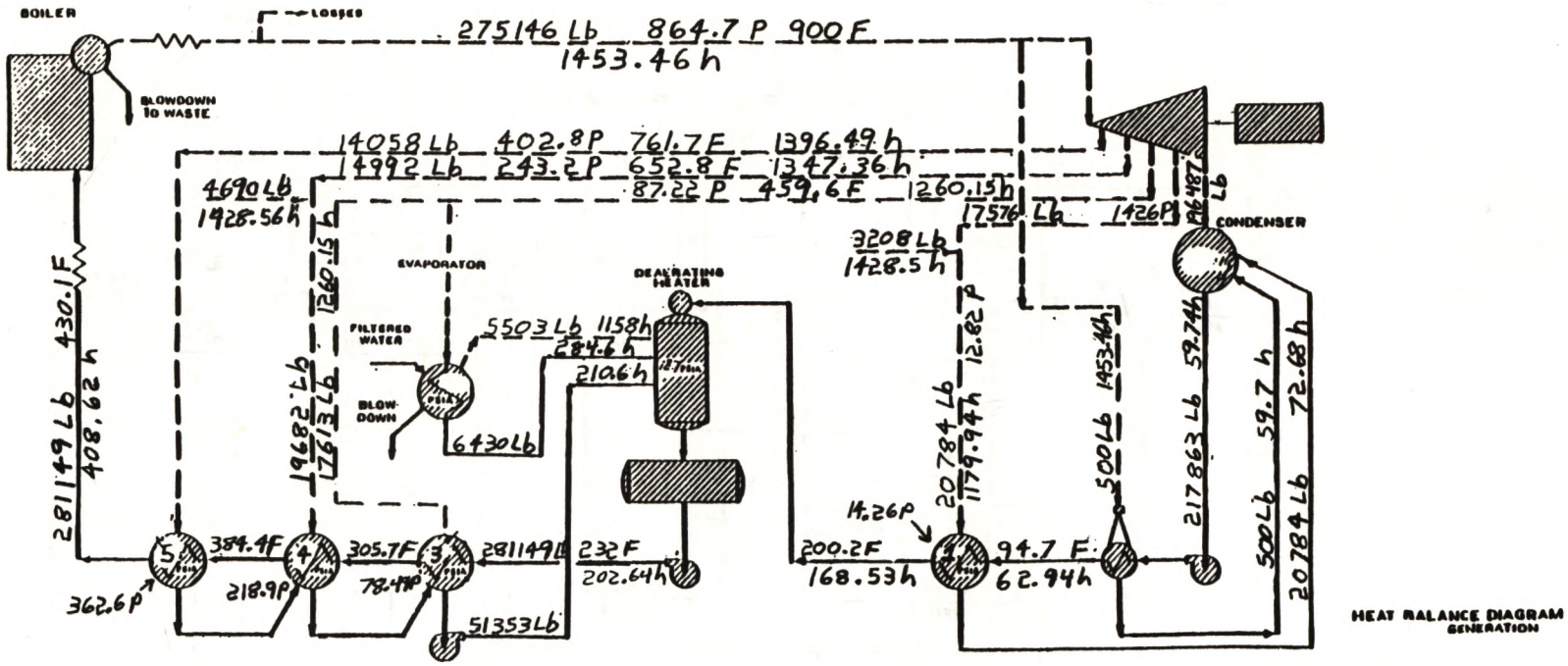
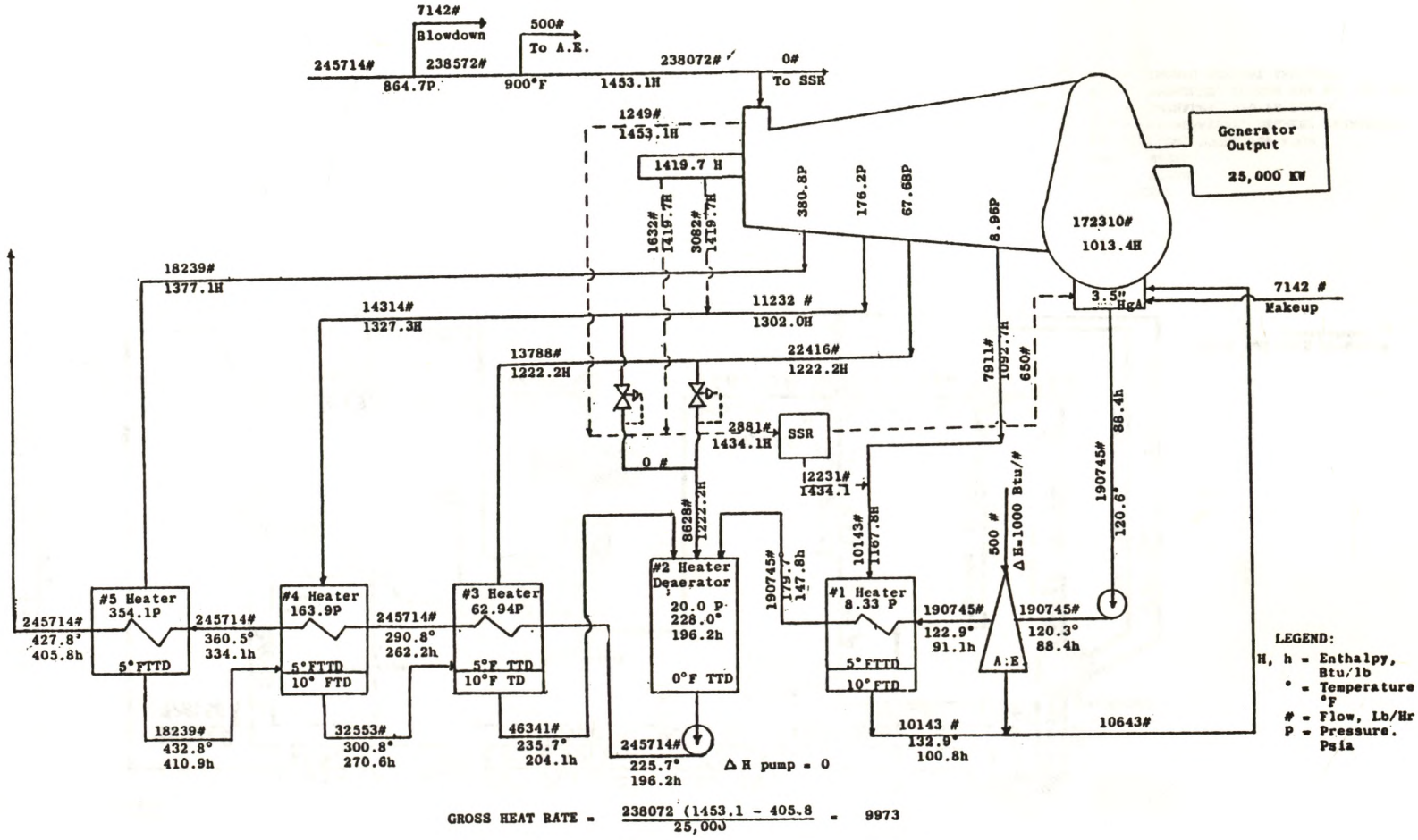


FIGURE 3-4 UNIT 5 HEAT BALANCE

LEGEND
--- STEAM
—— WATER
LB - FLOW, POUND PER HOUR
F - TEMPERATURE, DEGREES FAHRENHEIT
H - ENTHALPY, BTU PE POUND
P - PRESSURE, POUNDS PER SQ. IN. ABS.
Hg - INCHES MERCURY ABSOLUTE



$$\text{GROSS HEAT RATE} = \frac{238072\ (1453.1 - 405.8}{25{,}000} = 9973$$

FIGURE 3-5 UNIT 6 HEAT BALANCE

Unit 6 is a 25.000 kw, 3600 RPM, 19 stage condensing unit designed to operate at 850 psig steam pressure and 900°F temperature at 3.5 inches Hg. condenser pressure. It is a single flow unit with a rated throttle flow of 238,072 lbs/hr. Extraction steam for regenerative feedwater heating is taken from four extraction points. The feedwater heating cycle consists of four closed and one open feedwater heater. Makeup to the cycle is through the condenser hotwell. The heat balance at the 100% load condition is shown in Figure 3-5.

Modification Alternatives

Modifications Considered

The following alternatives have originally been considered for the conversion of the Steele Street Plant to a cogeneration district heating plant:

1. Bypassing of low pressure feedwater heaters. The main advantages of this alternative are that no major turbine modifications are required, rather most of the modifications must be done to the feedwater and condensate system. With this scheme, the original electric capacity of the turbine can be retained (in pure-condensing mode operation). The disadvantage of this alternative is that the thermal output is limited.
2. Modifications of LP End of Turbine. This alternative involves enlarging some of the low pressure extractions or tapping into the LP casing and installing additional extraction piping. The disadvantages of this option are that the LP turbine blade loading increases and unbalanced thrust load may be caused by the increased steam flow, and that new extraction piping may be impossible to install.
3. Use of Existing Condenser for District Heating. This requires operating the turbine in a backpressure mode and running district heating water through the condenser in place of normal plant circulating water. The advantage of this alternative is that no turbine modifications are required. The disadvantage is that the district heating water supply temperature is limited by the maximum allowable pressure in the condenser.
4. Replacement of the proposed 55 MWe condensing turbine with a District Heating Turbine. This option requires the removal of the existing 12.5 MWe turbine and installation of a new extraction condensing turbine, along with district heating condensers, pumps and other required equipment. This alternative has the advantage that the turbine, being specifically designed for district heating, has maximum efficiency. The turbine could be operated in district heating or in pure electric mode. There would also be increased reliability because the equipment is new. The disadvantage of this option is that a substantial capital expenditure is required.
5. Retrofitting units 3 and 4 for district heating. This alternative would be similar to alternative 3 in that it would involve using the Unit 3 and Unit 4 condensers as first stage heaters. The district heating water would be passed through the condenser in place of the normal plant circulating water. As in alternate 3 the condensers would have to be operated at a higher pressure. The advantage of

this alternate is that no turbine modifications are required. The disadvantages are that the amount of heat that can be extracted is limited by the maximum allowable pressure in the condenser and the small size of the units. If the units are used only for a first stage of district heating then the operation of the units would be directly related to another unit which would supply the second stage of district heating. This relationship would limit the flexibility of the plant operation. Another disadvantage is that presently these units are off line because of insufficient steam capacity at the plant.

The above alternatives were compared to a set of alternate selection criteria which include the following:

- o Lowest Cost. The selected alternative should provide the maximum thermal efficiency at the lowest capital and operating costs.
- o Reliability. The cogeneration system should reliably supply both electricity and heat.
- o Operating Flexibility. The ability to vary the unit heat load and electrical output independently should be considered. The ability to satisfy heat and electric demands by using various unit combinations increases overall reliability and lowers operating cost and must also be considered
- o Thermodynamic Constraints. These constraints include the maximum heat load that can be extracted, blade loading as a result of extraction, extraction line limitations, steam flow and pressure changes in turbine elements, backpressure increase in turbine exhaust, and windage losses in LP elements.
- o Mechanical Constraints. These include the number and type of casing designs, thrust considerations and physical arrangements.
- o Space Availability.
- o Structural Design Limits.
- o Other Considerations. Such as arrangements of existing other equipment, considerations for construction phase, etc.

It should be noted that thermodynamic and mechanical constraints are turbine specific and must eventually be assessed by the turbine manufacturer. Also, in order to properly assess the space availability, detailed plant drawing must be available.

Based on the above criteria, alternate 3 is not being considered. For this alternate the district water supply temperature is limited by the maximum allowable back pressure in the condenser to a maximum of approximately $130^{\circ}F$. Further, an additional set of pumps would be required. The $130^{\circ}F$ temperature limit limits the amount of useful heat that can be withdrawn from the condenser. During

the heating season the return temperature for the district heating system can be designed for a value of approximately 120°F as a minimum leaving a working temperature difference of only 10°F. A preliminary assessment of the available data shows that alternatives 1 and 2 would allow the extraction of higher heat loads from the plant. Further, the tube side condenser pressure would have to be limited to avoid physical damage to the condenser, this could have an adverse affect on the district heating transmission system. The limiting temperature would require additional heat sources which would require additional studies.

Alternative 5, the retrofit of units 3 and 4 is not being pursued at this time because of the limited heat capacity of this alternative and because insufficient steam capacity prevents the operation of these units on a regular basis.

If the district heating system load increases to the point where alternatives 1, 2 and 3 cannot supply the required heat, alternatives 3 and 5 should be reconsidered along with adding steam capacity and using additional heat sources external to the Jamestown Power Plant.

The remaining alternatives underwent investigation by Burns and Roe, and preliminary calculations have been performed to estimate the effect of potential retrofit options.

Alternative Analysis

Alternative 1A. This alternative involves the by-passing of the 12th and 16th stage feedwater heaters on unit 5. The 12th and 16th stage feedwater heaters were chosen because they are the lowest pressure closed feedwater heaters. The lowest pressure heaters are chosen so that the steam expanding inside the turbine can do the most work. In determining the amount of heat that can be extracted, the steam flow rate for the selected heaters was maintained the same as in the original cycle. The inlet temperature of the lower pressure heater was set at 140°F. Based on the above information, the new feedwater heater exit conditions were calculated for both the shell and tube sides. The outlet district heating water conditions for the first bypassed heater were used as the inlet conditions for the second heater. It was determined that for the second stage bypassed heater (12th stage) to operate with the extraction flow the same as in the original cycle, a portion of the tube side flow leaving the first stage would have to bypass the second stage heater. This bypassed flow was mixed with the exit flow

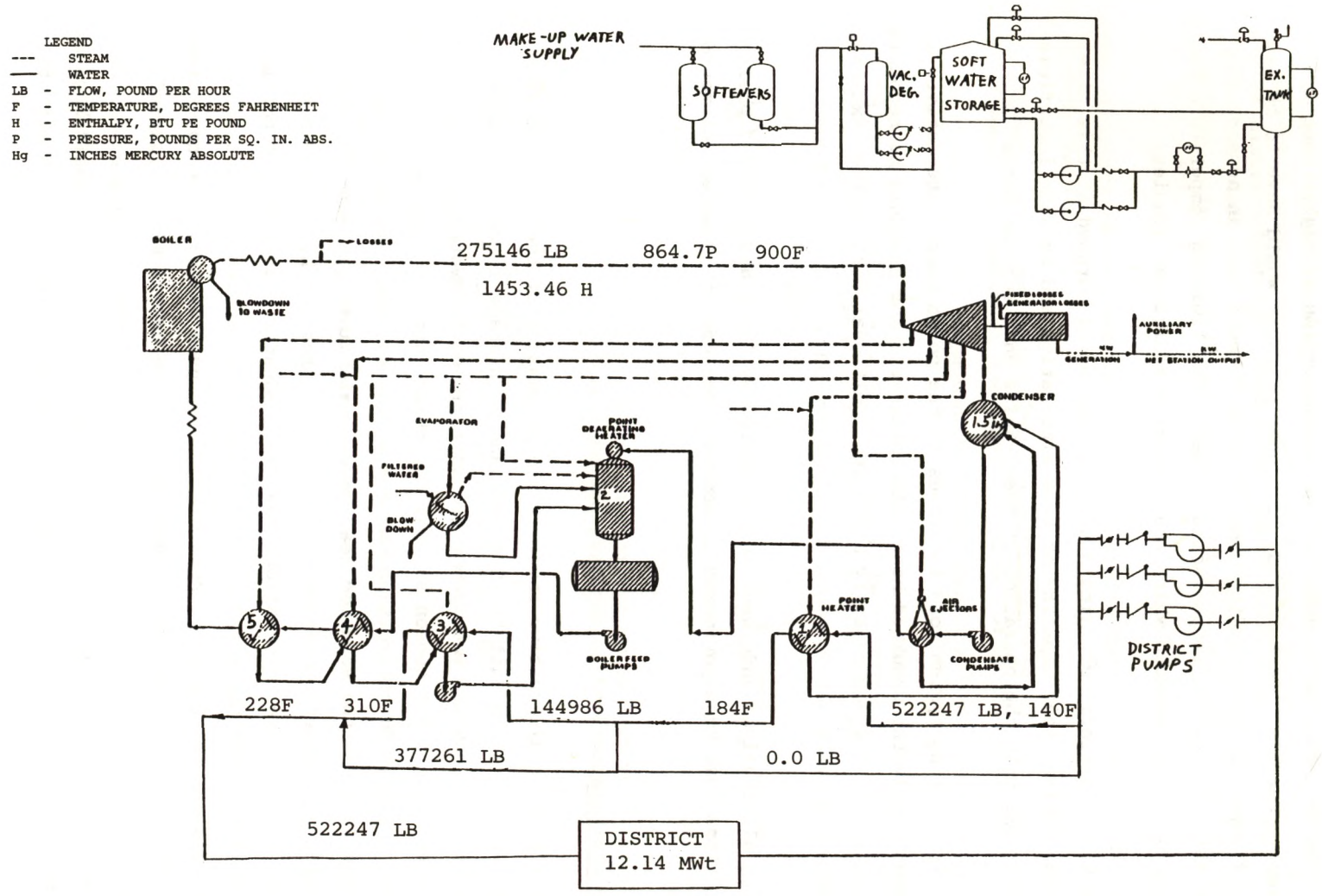


FIGURE 3-6 DISTRICT HEATING MODIFICATION ALTERNATIVE 1A, UNIT 5

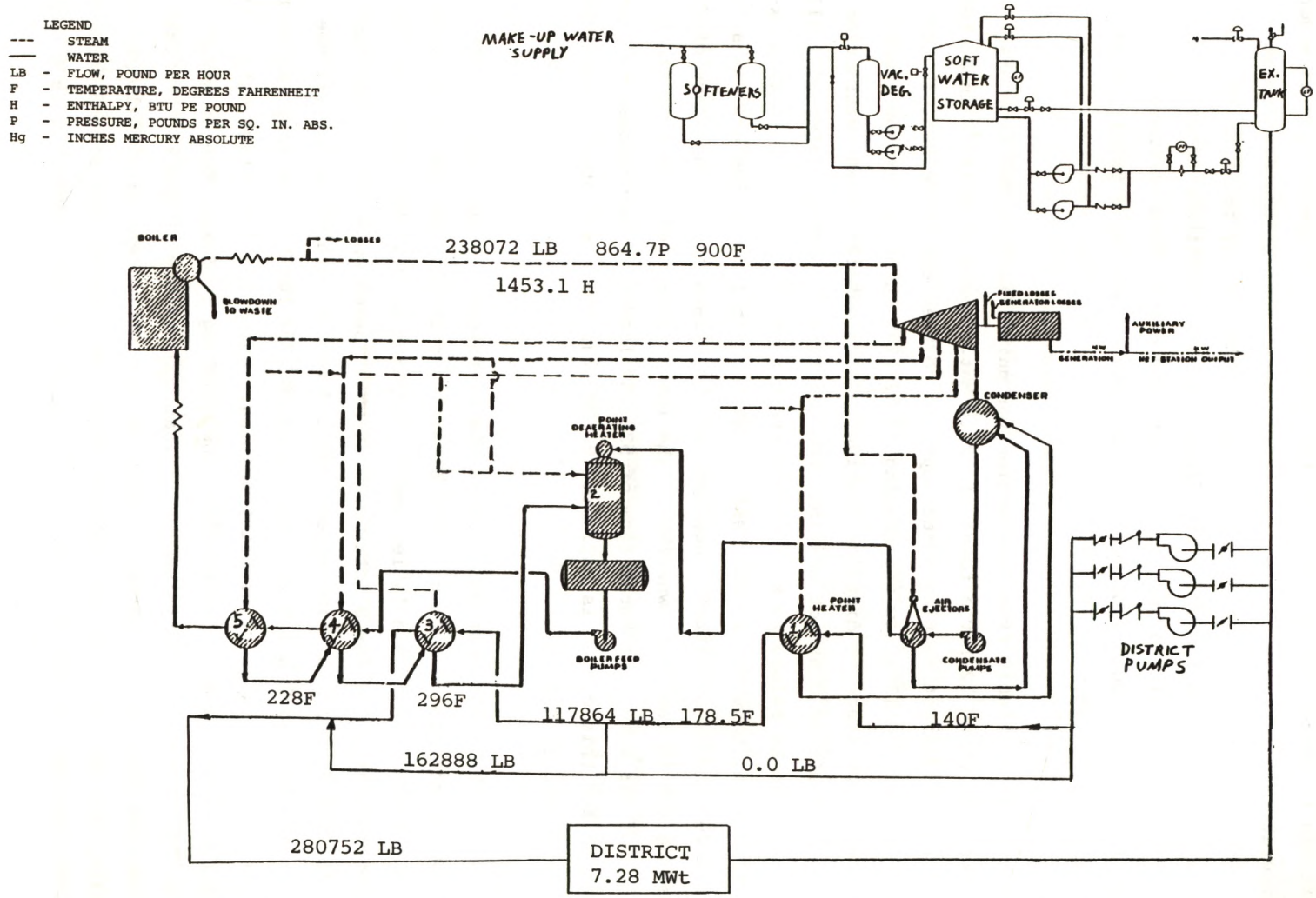


FIGURE 3-7 DISTRICT HEATING MODIFICATION ALTERNATIVE 1B, UNIT 6

of the second district heater to determine the final district heating water conditions.

As a result of removing the selected feedwater heaters from the feedwater cycle, the downstream feedwater heaters still in the cycle are now operating with lower inlet temperatures. This results in increased extractions to the downstream heaters. The increased extraction results in a higher energy transfer rate in these heaters and a minimal drop in the final feedwater condition entering the steam generator. In addition, due to the increased extractions at these heaters, less steam is passed through subsequent turbine stages and, as a result, less electricity is generated.

The district heat available from this option for unit 5 is 6.74 MWt from stage 16 and 5.40 MWt from stage 12 for a total of 12.14 MWt. Based on a 140^{o}F inlet temperature for the district heating water supplied to the 16th stage heater, the full load extraction will allow the heating of 522,247 lb/hr to a temperature of 184^{o}F for the first stage of district heating. Using the 12th stage extraction for the second stage of district heating, the existing feedwater heater will allow the 184^{o}F water to be raised to a final temperature of 310^{o}F. The full load extraction flow rate, however, is only sufficient to heat 144,986 lbs/hr. As a result, 377,261 lbs/hr of district heating water bypasses the second stage of district heating and is remixed downstream. The result after remixing is a final temperature of 228^{o}F for the total flow of 522,247 lbs/hr. The decrease in electrical output for this option is estimated to be 4.45 MWe. A sketch of alternate 1A is shown in Figure 3-6.

Alternative 1B. This alternative involves the by-passing of the 12th and 16th stage feedwater heaters on unit 6. This alternative is the same as option 1A for unit 5. The district heat available from this option is 3.17 MWt from stage 16 and 4.1 MWt from stage 12 for a total of 7.28 MWt. Based on a 140^{o}F inlet temperature for the district heating water supplied to the 16th stage heater, the full load extraction will allow the heating of 280,752 lbs/hr to a temperature of 178.5^{o}F for the first stage of district heating. Using the 12th stage extraction for the second stage of district heating, the existing feedwater heater will allow the 178.5^{o}F water to be raised to a final temperature of 296^{o}F. The full load extraction flow rate, however, is only sufficient to heat 117,864 lbs/hr. As a result, 162,888 lb/hr of district heating water bypasses the second stage of district heating and is remixed downstream. The result after remixing is a final

temperature of 228°F for the total flow of 280,752 lbs/hr. The decrease in electrical output for this option is estimated to be 1.2 MWe. A sketch of alternate 1B is shown in Figure 3-7.

Alternative 2. The second turbine cycle modification alternative is to increase extraction steam flow at the 12th and 16th stages, of the uprated unit 5, by replacing the respective diaphragms, and deliver this increased extraction to new district heat exchangers. The new district heat exchangers are outside the feedwater cycle. The condensed extraction steam is returned to the cycle into the open heater. The criteria used to determine the increased extraction was to set a maximum extraction nozzle velocity of 300 feet per second. For this modification, all of the existing feedwater heaters were maintained in service. At the points where the maximum extraction was taken, the extraction flow to the feedwater heater was maintained the same as in the original balance and the additional flow was delivered to the new district heater. For this alternative, the inlet and outlet district heating water temperatures were set and the flow rate necessary to condense the extraction steam was calculated. An inlet and outlet district heating water temperature of 140°F and 250°F, respectively, has been used.

Based on the velocity criteria of 300 ft/sec., the extraction flow available from the 16th stage for district heating is 24,453 lbs/hr at a pressure of 12.85 psia with an enthalpy of 1134 Btu/lb. It is estimated that with a district heating condenser designed to operate at a pressure of 11.5 psia with a condensate drain temperature of 200°F, a district heating load of 7.75 MWt could be supplied in the first stage of heating. The available extraction flow rate from the 12th stage is 39,820 lbs/hr. The increased 12th stage extraction is estimated to have a pressure of 73.2 psia and an enthalpy of 1250 Btu/hr. With a second stage district heating condenser designed to operate at 42 psia, and a condensate outlet of 270°F, it is estimated that an additional district heating load of 11.79 MWt could be supplied. The total district heat load from the two stages is 19.5 MWt. The corresponding district heating flow rate is 601,114 lb/hr. The decrease in electrical output for this option is estimated to be 5.7 MWe.

The result of the increased extraction at the selected stages is that less steam is available for extraction at the low pressure stages of the turbine and, therefore, less heat is transferred to the feedwater in the low pressure heaters. This reduction in feedwater temperature results in increased extraction in the high pressure feedwater heaters with the end result being the final feedwater

temperature entering the boiler is only reduced slightly. A sketch of alternative 2, for unit 5, is shown in Figure 3-8.

Alternative 4. This alternative involves the installation of a new 55 MW turbine at the Steele Street Station. A feasibility study performed by General Electric Company for the Board of Public Utilities, City of Jamestown, determined that the largest single purpose turbine-generator that could be installed in the Steele Street Station without major structural changes was a 55 MWe capacity machine. The new district heating turbine alternative is based on installing a 55 MWe dual purpose district heating machine in place of the single purpose machine. The dual purpose machine would have a full load electric only capacity of 55 MW and a full load heating only capacity of 80 MWt. The 80 MWt load would be supplied to two district heating condensers. The load is split equally between these two condensers and serves to heat district water from 140°F to 250°F. The coincident electrical load at the maximum heating capacity of 80 MWt would be approximately 40 MWe. If the turbine was installed for a peak load of 80 MWt, it would run at an average load of approximately 36 MWt based on the load duration curve for Jamestown. This would correspond to an electric load of approximately 46 MWe.

The district heating turbine would be installed in the same location proposed for the 55 MWe single purpose machine, in place of the existing Unit 4 machine. The district heating turbine would require all the turbine-generator accessories and related steam cycle equipment required by the single purpose machine plus the necessary district heating additions. The district heating additions include the extraction steam system for the district heating condensers, the drain system for the district heating condensers, the district circulating water system and the district heating water make-up and treatment system.

Equipment and Piping Selection

Alternative 1A. Bypassing the 12th and 16th stage feedwater heaters on unit 5, requires no changes to the extraction steam system. Preliminary investigation shows that the extraction lines to the 8th stage and 12th stage heaters can handle the increased extraction flow associated with this alternative. The condensate system requires modification to allow district heating water to be passed through the 12th and 16th stage feedwater heaters. The district water system piping that must be integrated with the feedwater system is 8 inch nominal size. Three district circulating pumps are required and are located upstream from the

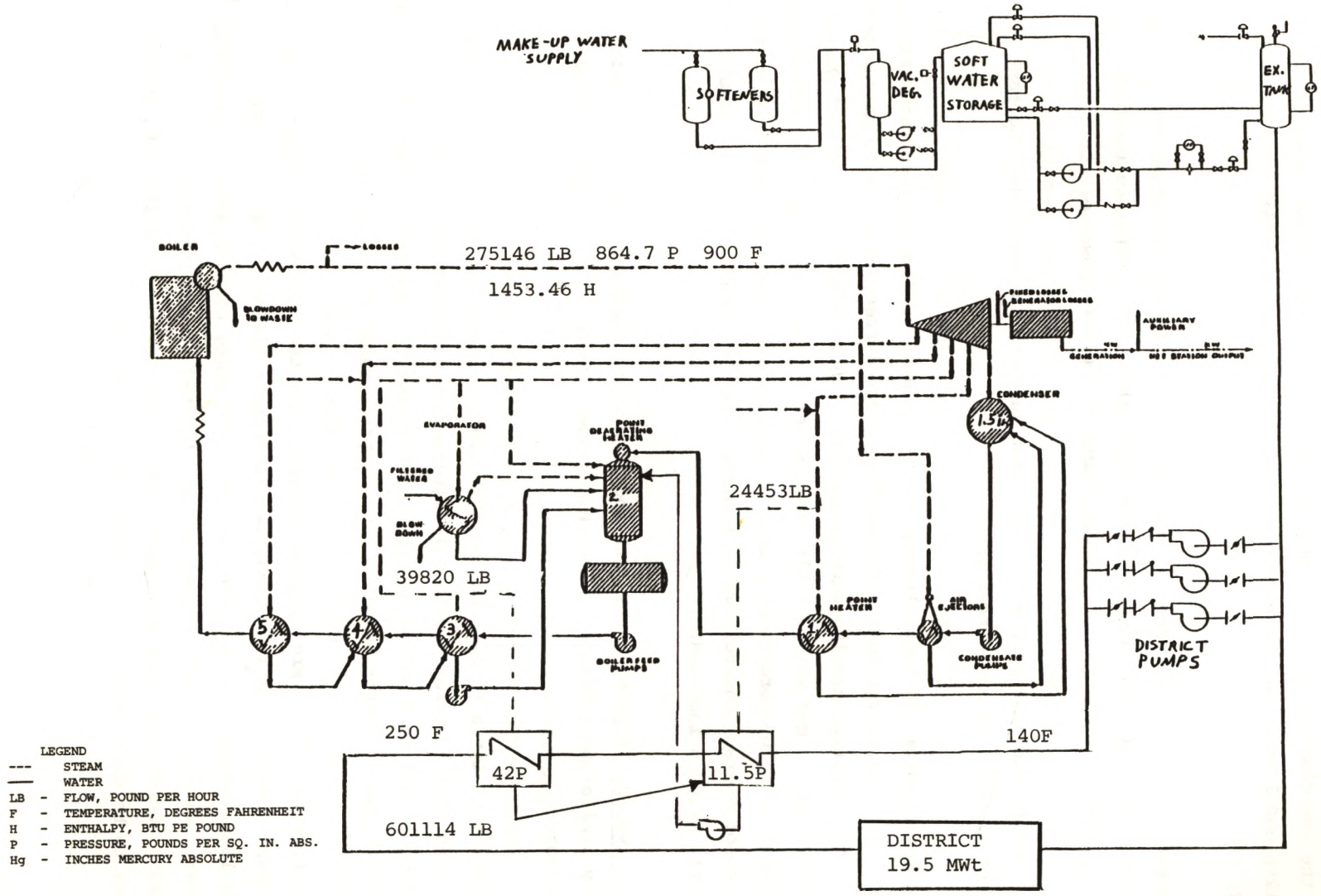


FIGURE 3-8 DISTRICT HEATING MODIFICATION ALTERNATIVE 2, UNIT 5

16th stage heater. The individual pump suction and discharge lines are 6 inches nominal diameter. The bypass lines installed around the 12th and 16th stage heaters are 8 inch nominal diameter. Line size butterfly valves are located in both the new district heating lines and the existing condensate lines to allow the 12th and 16th stage heaters to be used for heating condensate or district water.

The district water pumps used are 50 percent capacity and are rated for 550 gpm. The pumps are horizontal with split casing design. The pumps are rated for a system pressure of 150 psi. They are driven by 60 horsepower electric motors.

An expansion head tank with a 77 cubic foot capacity is required. The tank is 3.5 feet in diameter and 8 feet long.

The make-up system for this alternative is sized to produce treated water at a rate of 11.0 gpm to compensate for system losses corresponding to about one percent of the district heating water flow rate. There are two 100 percent capacity soft water pumps, one 16,400 gallon soft water storage tank, one 11.0 gpm vacuum degasifier, two 100 percent capacity vacuum pumps and two 100 percent capacity zeolite softeners. The soft water storage tank dimensions are 14 ft. diameter by 14 ft. high is included.

Alternative 1B. Bypassing the 12th and 16th stage feedwater heaters on unit 6, is very similar to alternative 1A. No changes are required in the extraction steam system.

The extraction lines to the 8th and 12th stage heaters can handle the increased extraction flow associated with this alternative. The condensate system requires modification to allow district heating water to be passed through the 12th and 16th stage feedwater heaters. The district water system piping that is integrated with the feedwater system is 6 inch size. Three district circulating pumps are required and are located upstream from the 16th stage heater. The individual pump suction and discharge lines are 4 inches nominal diameter. The bypass line installed around the 12th and 16th stage heaters are 6 inch nominal diameter. Line size butterfly valves are located in both the new district heating lines and the existing condensate lines to allow the 12th and 16th stage heaters to be used for heating condensate or district water.

The district water pumps used are 50 percent capacity and are rated for 300 gpm. The pumps are horizontal with split casing design. They are rated for a system pressure of 150 psi. They are driven by 35 horsepower electric motors.

The expansion tank for alternative 1B is identical to the expansion tank for alternative 1A.

The make-up system for alternative 1B is assumed to be identical to the make-up system for alternative 1A. This assumption is made because of the relatively small make-up required. The result of this assumption is that the make-up system for alternative 1B is rated for approximately two percent of the district heating system flow rate.

Alternative 2. Maximum extraction from the uprated unit 5 requires the installation of two, two pass district heating condensers. The district heating load is split approximately 60/40 between the high and low pressure condensers. The two heat loads are 11.8 MWt and 7.8 MWt respectively. The high pressure condenser has a total surface area of 1200 sq. ft. and the low pressure condenser has a surface area of 1400 sq. ft. Both condensers have 1 inch diameter 90-10 CuNi tubes. The high pressure condenser is approximately 30 feet long and 30 inches in diameter. The low pressure condenser is approximately 35 feet long and 30 inches in diameter.

At 100 percent heat load, the maximum high pressure and low pressure district heating condenser drain flow is 64,274 lb/hr. The drains from the high pressure condenser are normally cascaded to the low pressure condenser and all drains are then pumped forward to the deaerator. Two 100 percent capacity, 140 gpm vertical can type pumps are used. The pumps have a design head of 72 feet. If the low pressure condenser is not in service, the high pressure drains are cascaded to the main condenser.

The district water system uses three 50 percent capacity, 700 gpm circulating pumps. The pumps have horizontally split casings. The pumps are rated for a system pressure of 150 psi. They are driven by 100 horsepower electric motors.

The expansion head tank has a capacity of 77 cu. ft. It is 3.5 feet in diameter and 8 feet long.

The make-up system components are sized to produce treated water at 14 gpm to compensate for system losses corresponding to about one half percent of the district heating water flow rate. There are two 100 percent capacity soft water pumps, one 20,160 gallon soft water storage tank, one 14 gpm vacuum degasifier, two 100 percent capacity vacuum degasifier pumps and two 100 percent capacity zeolite softeners. The soft water storage tank dimensions are 15 feet diameter by 16 feet high.

The district water piping is 8 inch nominal size with 6 inch individual pump suction and discharge lines. The lines were sized not to exceed a maximum velocity of 12 feet per second.

The extraction piping from the 12th stage exhaust to the high pressure district heating condenser is 8 inch in diameter carbon steel pipe. The extraction piping from the 16th stage exhaust to the low pressure district heating condenser is 12 inch carbon steel pipe.

Alternative 4. The new district heating turbine alternative requires the selection and installation of a new cogeneration district heating turbine rated for 55 MW electric output and 80 MW thermal output. The turbine will be designed to operate with throttle conditions of 1000 PSIG, 900^{o}F and a full load flow of 534,450 lbs/hr. The turbine will incorporate two district heating extractions. One district heating extraction will supply the high pressure district heating condenser which will operate at 42 psi. The second district heating extraction will supply the low pressure district heating condenser which will operate at 15 psi. The high pressure district heating extraction will have a shell pressure of approximately 240 psi and an enthalpy of approximately 1300 but/lbm. The extraction line to the high pressure district heating condenser will be 8 inches in diameter and will carry superheated steam at a full load rate of 129,000 lbs/hr. The low pressure district heating extraction will have a shell pressure of approximately 46 psia and an enthalpy of approximately 1175 btu/lbm. The extraction line to the low pressure district heating condenser will be 18 inches in diameter and will carry saturated steam at a full load rate of 138,000 lbs/hr.

The two district heating condensers are shell and tube type heaters, each having two passes. The heat load is split equally between the two condensers, thus each district heating condenser has a design load of 40 MWt. The district heating condensers each contain approximately 4,580 square feet of heat transfer area.

They measure approximately 5 feet in diameter and are 28 feet long. The design is based on 1 inch diameter 90-10 CuNi tubes.

At 100 percent heat load, the maximum high pressure and low pressure district heating condenser drain flow is 267,000 lbs/hr. The drains from the high pressure condenser are normally cascaded to the low pressure condenser and all drains are then pumped forward to the deaerator. Two 50% capacity, 275 gpm vertical can type pumps are used. The pumps have a design head of 72 feet. If the low pressure condenser is not in service, the high pressure drains are cascaded to the main condenser.

The district water system uses three 50 percent capacity, 2600 gpm circulating pumps. The pumps have horizontally split casings. The pumps are rated for a system pressure of 150 psi. They are driven by 300 horsepower electric motors.

The expansion head tank has a capacity of 77 cu. ft. The tank is 3.5 ft. in diameter and 8 feet long.

The make-up system components are sized to produce treated water at 26 gpm to compensate for system losses corresponding to about one half percent of the district heating water flow rate. There are two 100 percent capacity soft water pumps, one 38,000 gallon soft water storage tank, one 26 gpm vacuum degasifier, two 100 percent capacity vacuum degasifier pumps and two 100 percent capacity zeolite softeners. The soft water storage tank dimensions are 18 feet diameter by 20 feet high.

The district water piping is 14 inch nominal size with 10 inch individual pump suction and discharge lines. The lines were sized not to exceed a maximum velocity of 12 feet per second.

The technical characteristics of the different district heating retrofit alternatives are presented in table 3-3.

Costs for Modification Alternatives

Table 3-4 presents the estimated costs for district heating modification alternatives 1A, 1B, 2 and 4. All figures represent installed costs. Piping costs are based on estimated piping lengths determined from approximate equipment location. A preliminary site visit determined that sufficient space is available for new

equipment and that additional building area is not required. For alternate 4, costs are only presented for items related to the district heating system. The turbine modification costs represent the estimated difference in price associated with a district heating turbine, not the complete cost of the turbine. A 25 percent increase for consideration of engineering and construction management costs, as well as contingency, has been included.