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CONFIDENTIAL

DISTRICT HEATING & COOLING PROJECT

Burlington, Vermont

Prepared for:

Burlington Electric Department
Burlington, Vermont

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SECTION 1
EXECUTIVE SUMMARY

The objective of this project was to perform a technical/economic study related to the implementation of a district energy system in Burlington, VT. The study was performed by Joseph Technology Corporation for the Burlington Electric Department (BED). Six core customers have been identified by BED. The McNeil Generating Station (a 50 MW wood-fired electric power plant located approximately one and a half miles away from the core customers) was selected as the energy source.

The report presents the results of the technical and economic assessment of district heating to be supplied from the McNeil Generating Station to six potential customers, district cooling options and the construction of a new cogeneration plant near the core customers.

The six prospective customers are:

- *University of Vermont*
- *Medical Center Hospital of Vermont*
- *Trinity College*
- *University Health Center*
- *Mater Christi School*
- *American Red Cross Building*

The total peak heat demand of the system is 180 MMBtu/hr and potential annual sale of heat is 502,160 MMBtu per year. The present customer on-site cost of heat was estimated and it varied from \$9.23 to \$29.41 per MMBtu.

Three alternatives for district heating supply from the McNeil Station to the six core customers have been assessed. One alternative is to supply high temperature (380°F) hot water (HTHW) pumped to customers through an underground piping system. This HTHW must be converted to steam if the customer heating system is steam based, or to low temperature hot water (LTHW) through heat exchangers if the customer has a hot water heating system.

Table 1-1
Potential Savings to District Heating Customers for
HTHW Supply Alternative

Customer	*Projected Heat Sales*	*Present Cost of Heat*	*Breakeven Cost of DH* (First Year)	*Potential Savings*	*Hook-Up Cost*	*Simple Payback*
	MMBtu	$/MMBtu	$/MMBtu	$/year	$	months
University of Vermont	306,246	9.23	~~7.27~~ 8.43	$600,242	$546,750	11
Medical Center Hospital of Vermont	87,184	9.40	7.27	$185,702	$96,000	7
University Health Center	16,900	17.90	7.27	$179,647	$25,000	2
Trinity College	17,700	13.34	7.27	$107,439	$32,000	4
Mater Christi School	3,646	21.82	7.27	$53,049	$21,000	5
Red Cross Building	984	29.41	7.27	$21,786	$10,500	6
	432,660 (-7%)		This is the same	1,147,865	731,250	7.5

Table 1-2
Potential Savings to District Heating Customers for
Steam Supply Alternative

Customer	*Projected Heat Sales*	*Present Cost of Heat*	*Breakeven Cost of DH* $8.06	*Potential Savings*	*Hook-Up Cost*	*Simple Payback*
	MMBtu	*$/MMBtu*	*$/MMBtu*	*$/year*	$	months
University of Vermont	306,246	9.23	6.95	$698,241 358,307	$76,000	2
Medical Center Hospital of Vermont	87,184	9.40	6.95	$213,601	$16,000	1
University Health Center	16,900	17.90	6.95	$185,055	$17,000	2
Trinity College	17,700	13.34	6.95	$113,103	$29,000	3
Mater Christi School	3,646	21.82	6.95	$54,216	$34,000	8
Red Cross Building	984	29.41	6.95	$22,101	$17,000	10
				1,286,317	189,000	17 mos

The conversion of the McNeil Station to cogeneration operation with district heat supply is the most feasible option at the present time. A stand-alone cogeneration facility for UVM and MCHV (with electric capacity of 3 MW or 7 MW) with district heat supply could be feasible. However, this will result in further reduction of the capacity factor of the McNeil Station. At the present time the McNeil Station should remain the primary electric source for the city of Burlington. Therefore, the cogeneration plant can be built in the future, should the electric demand of the customers in Burlington increase. This cogeneration plant would supply electricity and district energy to future customers in conjunction with the existing UVM boiler plant.

The implementation schedule for the district heating development in Burlington, VT is presented in Table 1-4. It is recommended proceed with detailed feasibility studies of building retrofits of the six major customers to district heating. At the same time the dispatch of the McNeil Station in the NEPOOL system should be thoroughly analyzed.

SECTION 2
ASSESSMENT OF POTENTIAL CUSTOMERS

The University of Vermont

Background

University of Vermont (UVM) is located in Burlington, the state's largest city with a population of about 38,000. The university has 8,000 undergraduate and 1,500 graduate students.

General Arrangement

The buildings were erected from 1791 to 1993 and their height varies from one to five stories. Main Street goes all across the campus and divides it into northern and southern halves. Academic and administrative buildings are primarily located in the northern area while residential facilities are located in the southern part. The campus has two major groups of residential facilities: one near Main Street and the other in the most remote southern area. The university athletic complex includes a swimming pool, six tennis courts, hockey arena and basketball courts located in the southern part of the campus. The central boiler plant is in the northern part of the campus in the same building with Royall Tyler Theatre.

Central Boiler Plant

UVM has its own DH system with the central boiler plant and a combination of steam and hot water distribution lines. The annual heating load of the UVM is presented in Figure 2-1. The central boiler plant is equipped with four steam generators, each with generation capacity of 40,000 lb/hr at 220 psig. Two boilers were installed in 1972 and were retubed during last three years; they are in good condition. The two remaining boilers were put into service in 1979 and are also in good condition. During the winter all four boilers operate with a total peak load of 130,000-140,000 lb/hr. The plant has no backup and the university is currently considering purchasing another 40,000 lb/hr boiler. HTHW is produced in a cascade type direct contact heat exchanger. A two phase mixture (combination of steam and water) goes to three distribution pumps. This causes cavitation which wears the pumps and increases the maintenance cost.

Gas, the primary fuel for the central plant, is purchased at an interruptible rate. Buying gas at this rate allows the university to pay a lower price but always, especially during severe winter, opens the possibility for interruption of the gas supply. This requires the university to keep a secondary supply of #2 oil with ½% of sulfur content which is preheated by steam. There are two oil storage tanks with the capacity of 50,000 gallons each, built between 1976 and 1979. Both tanks are "single wall" and in a good condition. Total gas consumption by the central plant from July 1992 to June 1993 was 3,940,140 ccf (approximately 394,000 MMBtu of fuel input) and total oil consumption for the same period was 196,380 gallons (approx. 27,500 MMBtu of fuel input). All boilers have 2 year old combustion controls and are equipped with dual fuel burners with pneumatic controls. The boilers are equipped with economizers providing the following temperatures (inlet/outlet): flue gas - 680/370°F , feedwater - 240/320°F. The central plant is shut down for two or three weeks during the summer for maintenance.

The University has also a number of satellite boilers located in major complexes. Those boilers are installed in Given Medical Building (3, only 2 work), Tupper Hall (2), Patrick Gymnasium (4) and Christie Hall (1). All these boilers fire #2 oil and their capacity is sufficient to keep some major facilities from freezing in an emergency. The Living & Learning complex has one hot water boiler and the Waterman building, which is totally independent, runs one 40 psig steam boiler firing #6 oil. All these boilers are relatively small and not manned.

University District Heating System

The steam and hot water distribution systems are generally divided by Main Street. HTHW is pumped through the southern part of the campus and then either flashed to low pressure steam (LPS) at 12-15 psig or passed through heat exchangers to heat the water in the buildings. The HTHW supplied from the central plant at totaled on an annual basis and then divided by the annual heat production to provide a unit heating cost. The O&M cost data was provided by UVM.

__Capital Component.__ The capital component is equivalent to the replacement cost of the boiler plant. The peak load is taken as an equivalent of 130,000 lb/hr of steam load. To annualize the capital cost, amortization of the cost is estimated over the 20 year life of 4 existing boilers and a backup boiler. The cost of money is assumed at 8.5%. Thus, the capital component represents the payment on the investment should UVM build an identical plant and borrow money for this purpose. The annual cost is then divided by the annual Btu's produced by the boilers. These amounts are shown in Table 2-1.

__Operation & Maintenance.__ The numbers shown in the table were based on the UVM 1993 records.

__Boiler Fuel.__ The amount of fuel used was reported by UVM; steam generation was estimated. The amount of steam generated is slightly larger than that used in the plant. During the periods when plant is firing oil, there are some losses due to the production of steam, such as pre-heating the fuel oil and providing steam for the atomization burners on the boiler. Neither of these steam uses is incurred when the boilers operate on natural gas.

__Total Annual Composite Cost.__ The cost of heat generated by the UVM central boiler plant is presented in Table 2-1. The total annual composite cost is $2,825,791 for a unit cost of $9.23/MMBtu.

Medical Center Hospital of Vermont

Background

The Medical Center Hospital of Vermont (MCHV) is served by a steam boiler plant that burns either gas or #6 fuel oil. The hospital occupies sixteen buildings built between 1889 and 1987. The largest building is the eight story McClure Building which has an area of 264,868 sq ft while the second largest is the Baird Building (139,394 sq ft). The rest of the buildings range from 19,000 to 60,000 sq ft.

Space Heating System

Heating of the hospital is provided by steam and hot water. The total annual load is presented in Figure 2-2. Approximately 40% of the total area is heated only by steam using steam radiators and fin tube baseboard terminal equipment, 40% of the facilities use both steam and hot water radiators and baseboards, while only 20% is hot water heated. The years of equipment installation range from 1950 to 1991 except for the Brown North Building which has steam radiators installed in 1907. There are also central air ducts with steam coils inside and steam and hot water fan coils.

Central Boiler Plant

The hospital has four boilers located in a basement. Two Wicks boilers began service in 1966 and now are primary boilers. Each has the capacity of 20,000 lb/hr and generates steam at 80 psig. The two remaining boilers were installed in 1941 and 1949. The 1941 boiler is presently out of service; the 1949 boiler is only for backup and has a capacity of 13,000 lb/hr. All three functioning boilers are dual fuel with the capability to fire natural gas and #2 oil.

Cost of Heat

The gas consumption by the hospital in 1993 was 1,186,400 ccf and cost $418,545. The oil cost for the same year was $21,726. These numbers as well as all O&M costs of running the boiler plant were provided by the hospital during the survey. The customer cost of heat per million Btu is presented in the Table 2-2.

Trinity College

Background.

Trinity College is an educational facility located in the north-east part of Burlington at Colchester and East Avenue. It has about 1000 students. The college occupies six major buildings which vary in size from 15,000 to 36,200 sq ft and it also has five small dorms with a total area of 10,500 sq ft The first building was erected in 1939 and the latest in 1985.

Heating System

A central boiler plant has two Hurst hot water boilers installed in 1992 with the capacity of 100 BHP each. Both boilers are in a good condition and unmanned. Presently, three major buildings with the total area of 89,000 sq ft are supplied with heat from the central plant. Those buildings are Mercy Hall, McAuley Hall and Thomas A. Farrel Family Library. Hot water is pumped from the plant to the buildings through 6" pipes. The supply temperature is 190°F and return is 150-160°F. Hot water fin tube baseboards are used in these buildings. The domestic hot water is heated by gas heaters in Mercy and McAuley halls, and by electricity in the library. The rest of the buildings are heated individually. The total heating load of Trinity College is shown in Figure 2-3.

Ira Allen Building. The Ira Allen building (19,000 sq ft) has two steam boilers firing #2 oil and generating steam at 5 psig. Both boilers were installed in the basement in 1958 and are in fair condition. The building is heated by steam while domestic hot water is heated by electricity. This building has a two pipe steam system and terminal equipment includes central air ducts with steam coils (UVM part) and steam fin tube baseboards.

Mann Hall. Mann Hall was built in 1939. This is a four story building with an area of 36,000 sq ft There are office spaces, a gymnasium and an auditorium in the building. Mann Hall has its own gas fired steam boiler with the capacity of 3.37 MMBtu/hr, installed in the basement. The boiler was introduced to service in 1991 and is in good condition. The building has two pipe steam system and steam fin tube baseboards are used as terminal equipment. A number of steam traps in the building need to be replaced.

Hunt Hall - Five Dorms. These five three story residential facilities, built in 1973 have a total area of 10,500 sq ft. The heating system is electric with electric baseboards. There is one storage tank for domestic hot water in each building which is also electrically heated.

Delehanty Hall. Delehanty Hall is a primarily residential building with only 25% of the space occupied by offices. It has a total area of 35,000 sq ft. The building has one tank for domestic hot water. All heating including domestic hot water is provided by electricity. There are electric fan coils in the building used for heating only. The college plans to convert this building to hot water heating.

The maximum heat demand of the entire college, provided that Hunt and Delehanty Halls are converted to hot water heating, is estimated at 7.6 MMBtu/hr. The maximum total heating capacity of two existing hot water boilers is 12 MMBtu/hr.

Current Production Cost For Heating

Annual heating production cost is defined as the sum of three cost components: boiler fuel, operations and maintenance (O&M) and capital component. Each cost component is totaled on an annual basis and then divided by the annual heat production to provide a unit heating cost. The O&M cost data was partially provided by Trinity College, data obtained from similar facilities was also used.

Table 2-3
Trinity College Cost of Heat

Peak Load, MMBtu/hr	7.6
Total Useful Heat Consumption, MMBtu	17,700

1992/93 Annual Expenditures for the Trinity College	*Miscellaneous*	*Item or Cost Description*	*Total Annual Cost ($)*	*Unit Cost ($/MMBtu)*
FUEL		**(MMBtu)**		
Annual Fuel Usage (MMBtu)		27,798	$167,182	$9.45
Gas	**(ccf)**			
Central Plant	135,000	13,500	$57,024	
All Buildings Individually	103,104	10,310	$43,551	
Total	*238,104*	*23,810*	***$100,575***	
Oil	**(Gal)**			
Ira Allen Bldg.	*10,096*	*1,413*	***$6,260***	
Electricity	**(kWh)**			
All Buildings for Heating and DHW	*754,336*	*2,574*	*$60,347*	
			8¢/KwH -	seems low
CAPITAL COMPONENT				
Total Boiler Capacity, BHP				
Central Plant		360		
All Buildings		120		
Capital Cost Allowance for Continuing Operations for the Next 20 years			$288,000	
Total Cost of the Boiler Plants			***$288,000***	
Annual Capital Component (assuming 8.5% interest rate, 20 years)			$30,433	
MAINTENANCE/OPERATIONS (NON-FUEL)				
Labor Cost*			$6,000	
Annual Service Contracts			$17,500	
Annual Chemicals			$2,500	
Annual Parts Cost			$3,500	
Annual Insurance			$1,000	
Annual Water & Sewer			$8,000	
Total Non-Fuel			$68,933	$3.89
TOTAL ANNUAL COST			$236,115	$13.34

* - Labor Cost assumed 15% of the total work time of 1 person

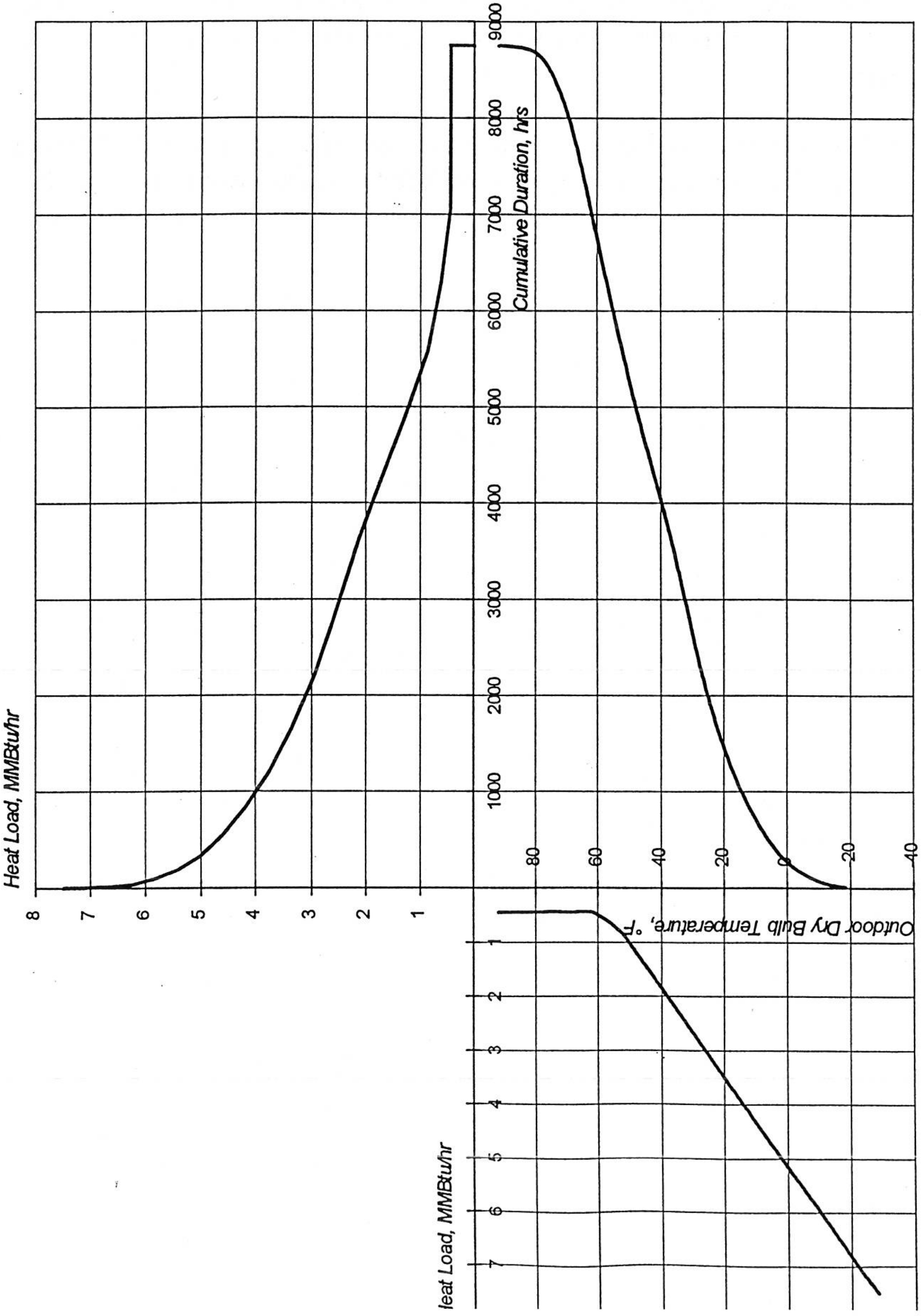


Figure 2-4. Heat Load Duration Curve for University Health Center

Table 2-4
University Health Center Cost of Heat

Peak Load, MMBtu/hr 7.5
Total Useful Heat Consumption, MMBtu 16,902

1992/93 Annual Expenditures for the University Health Center	*Miscellaneous*	*Item or Cost Description*	*Total Annual Cost ($)*	*Unit Cost ($/MMBtu)*
FUEL		**(MMBtu)**		
Annual Fuel Usage (MMBtu)		15,727'	$142,988	$8.46
Gas	(ccf) 154,500	15,450	$65,261	
Oil	(Gal) 1,980	277	$1,000	
Electricity (Heat Pumps) *needs to be confirmed*	kWh 678,999	4,635	$76,727	11.3 ¢/kWH
CAPITAL COMPONENT				
Total Boiler Capacity, BHP		327		
Capital Cost Allowance for Continuing Operations for the Next 20 years			$261,600	
Total Cost of the Boiler Plant			$261,600	
Annual Capital Component (assuming 8.5% interest rate, 20 years)			$27,644	
MAINTENANCE/OPERATIONS (NON-FUEL)				
Labor Cost			$115,000	
Annual Service Contracts			$1,500	
Annual Chemicals			$2,500	
Annual Parts Cost			$3,000	
Annual Insurance			$5,000	
Annual Water & Sewer			$5,000	
Total Non-Fuel			$159,644	$9.45
TOTAL ANNUAL COST			$302,631	$17.90

'-conventional fuel only

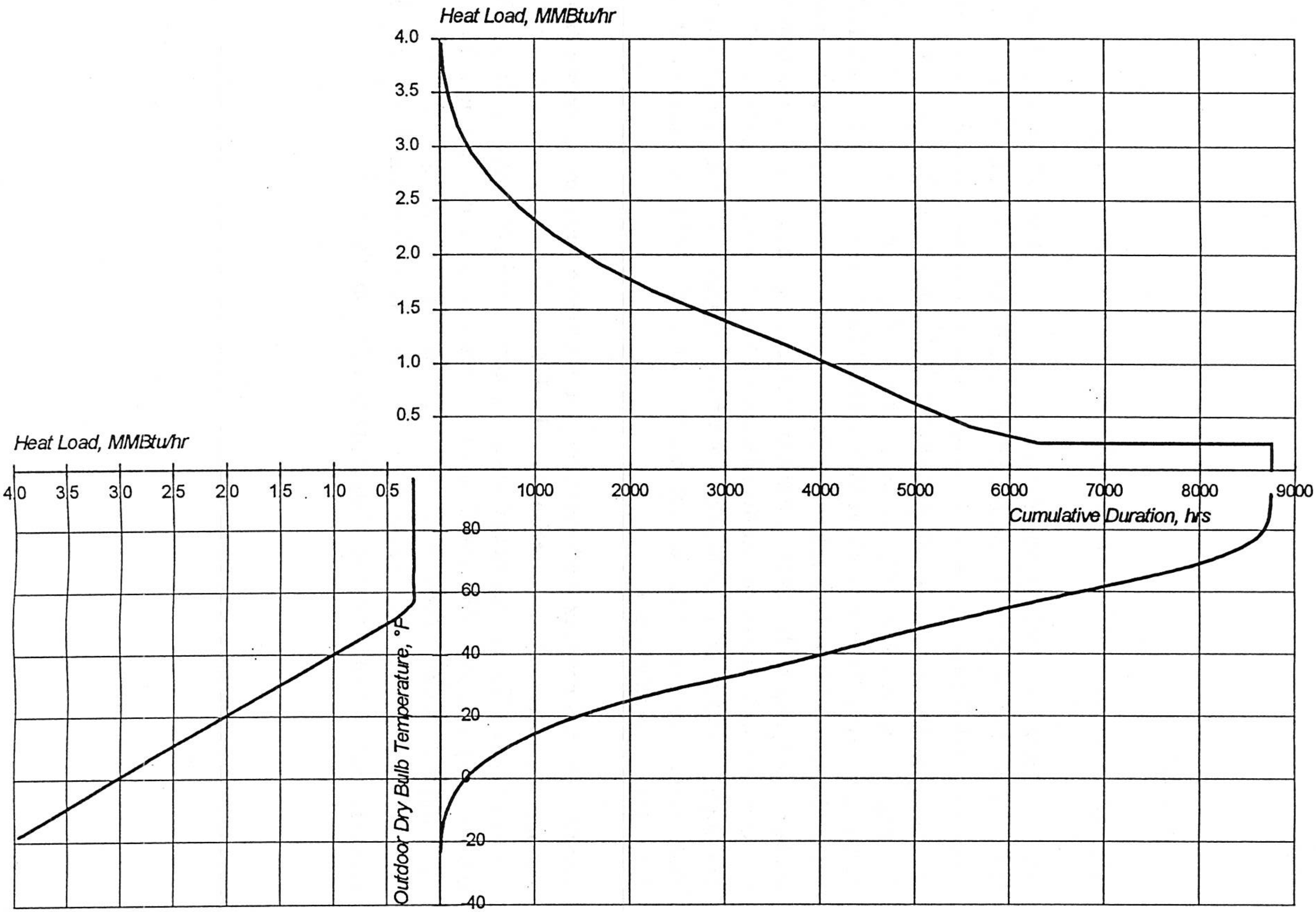


Figure 2-5. Heat Load Duration Curve for "Sisters of Mercy of America/Mater Christi School"

Table 2-5
Sisters of Mercy of America Cost of Heat

Peak Load, MMBtu/hr 3.6
Total Useful Heat Consumption, MMBtu 3,646

1992/93 Annual Expenditures for the Sisters of Mercy of America	*Miscellaneous*	*Item or Cost Description*	*Total Annual Cost ($)*	*Unit Cost ($/MMBtu)*
FUEL		**(MMBtu)**		
Annual Fuel Usage (MMBtu)		4,711	$72,715	$19.94
Gas	**(ccf)** 30,430	3,043	$17,313	
Electricity for Heating	kWh 488,765	1,668	$55,402	
CAPITAL COMPONENT				
Total Boiler Capacity, BHP		36		
Capital Cost Allowance for Continuing Operations for the Next 20 years			$28,800	
Total Cost of the Boiler Plant			$28,800	
Annual Capital Component (assuming 8.5% interest rate, 20 years)			$3,043	
MAINTENANCE/OPERATIONS (NON-FUEL)				
Labor Cost			$0	
Annual Service Contracts			$1,500	
Annual Chemicals			$500	
Annual Parts Cost			$0	
Annual Insurance			$800	
Annual Water & Sewer			$1,000	
Total Non-Fuel			$6,843	$1.88
TOTAL ANNUAL COST			$79,558	$21.82

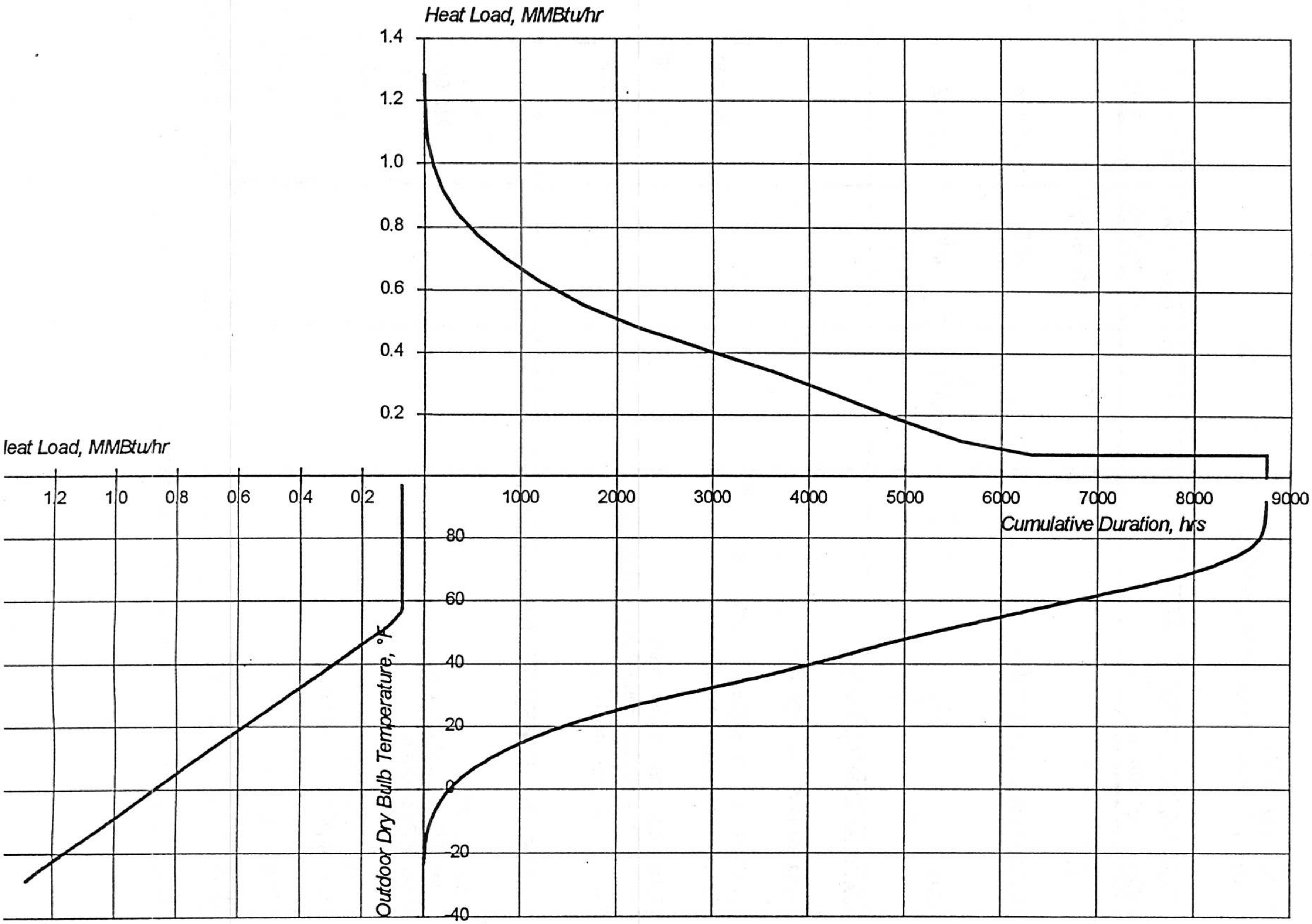


Figure 2-6. Heat Load Duration Curve for "American Red Cross" Building

SECTION 3
MCNEIL GENERATING STATION

Background

The McNeil Generation Station, a wood fired electric generation plant, began commercial operation in June 1984. The station is jointly-owned by the Burlington Electric Department (50%), Central Vermont Public Service (20%), Vermont Public Power Supply Authority (19%) and Green Mountain Power (11%). There are 45 people employed.

Generating Unit

The station is equipped with a single boiler/single turbine generating unit. The Zurn steam boiler generates 500,000 lb/hr at 1,275 psig. Medium-low NOx burners provide efficient boiler operation on gas fuel. The flue gas temperature leaving the economizer is 300°F.

A single casing BBC turbine has a steam throttle pressure of 1,275 psig and a temperature of 950°F. The turbine has five extraction points of which two high pressure extractions #4 and #5 are available for DH. The maximum thermal load that can be obtained from extraction #5 is 213 MMBtu/hr and, from extraction #4 96 MMBtu/hr.

At full-load, the normal claim capacity of the plant is 50 MW while the gross generation is 55 MW. The generator is rated at 60 MW maximum output and the unit is able to sustain maximum claim capacity of 53 MW for 6 hours in winter and 52 MW in summer. According to BBC the turbine is able to operate using 5% overpressed live steam. During the last year the capacity factor of the station did not exceed 20-26%. If the station provides DH to outside customers it must be dispatched based on thermal load requirements.

SECTION 4
DISTRICT HEATING ALTERNATIVES

High Temperature Hot Water Supply

Description

The total annual heating load demand of all six customers is shown in Figure 4-1. The total peak demand of the proposed DH system is estimated at 180 MMBtu/hr. The major portion of this load is UVM which requires about 130 MMBtu/hr of the peak load.

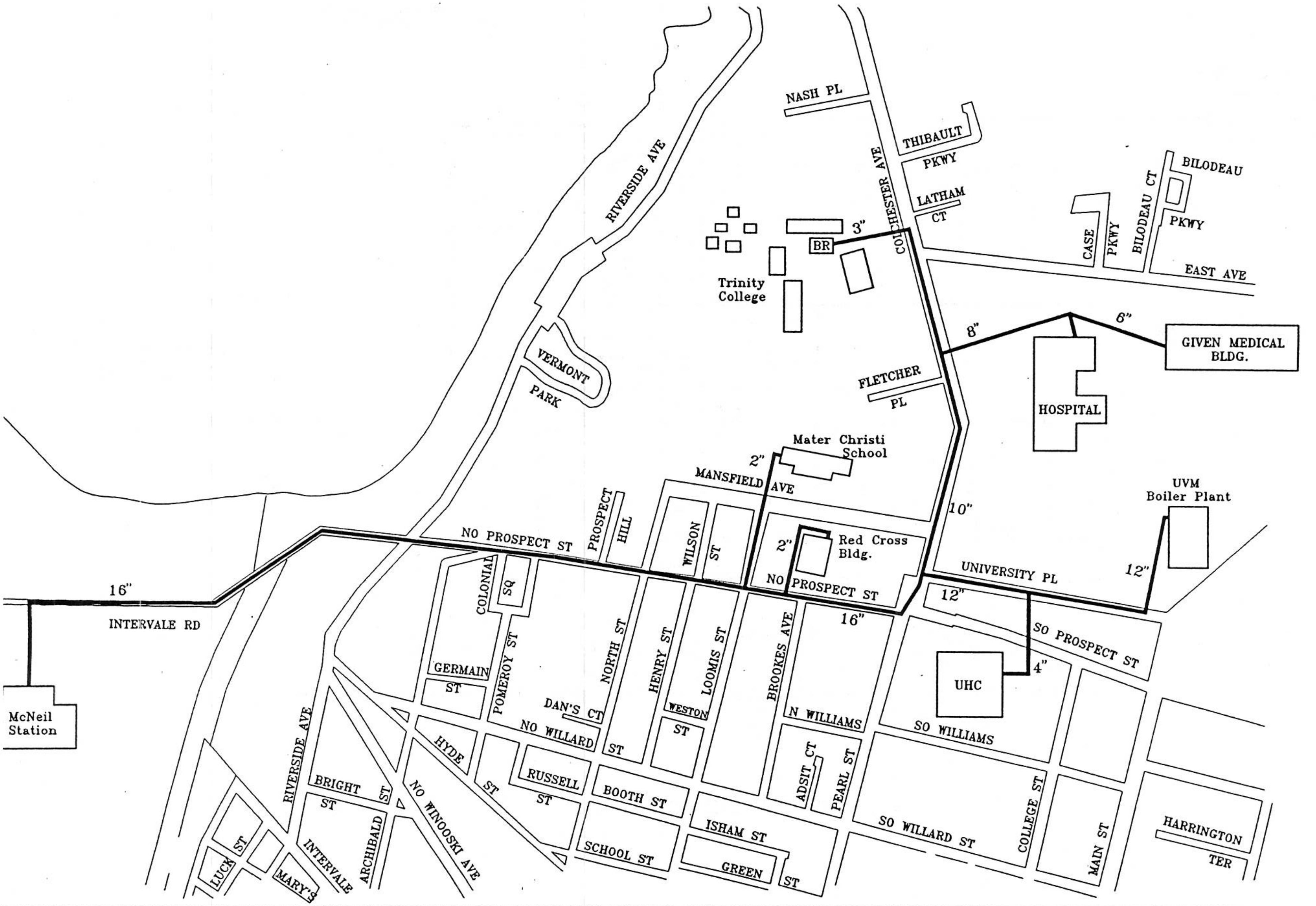
One alternative is to supply the total peak demand from the McNeil Station in the form of HTHW pumped to the customers through the underground piping system shown in Figure 4-2. At the customer sites this HTHW must be converted to steam if the customer heating system is steam based, or to LTHW through heat exchangers if the customer has a hot water heating system. The backup will be provided by the UVM boiler plant.

The parameters of the water supplied from the McNeil station are determined by UVM, which requires high temperature hot water at 375°F for its heating system. Taking into account the transmission losses, the temperature of the hot water leaving the station should be at least 380°F. In order to provide this temperature, the #5 turbine extraction will be used. During the OFF-peak period, especially in the summer, the temperature of the hot water will be reduced. In this case, the use of the #4 extraction becomes possible. To provide for this possibility, an interconnection between the #4 and #5 extractions is provided. Switching to the #4 extraction would permit an increase in the cogeneration rate and obtain a higher electric output from the turbine.

The flow diagram of the proposed HTHW DH system is shown in Figure 4-3. The return DH water is heated in two surface type steam-to-water heat exchangers to be installed at the power plant. The heat exchangers are supplied with steam from turbine extractions #5 or #4. An additional steam line directly from the boiler with a pressure reducing/station is used for steam supply and backup in case of turbine

Desuperheating

Figure 4-2. DISTRICT HEATING UNDERGROUND HTHW PIPING DIAGRAM



outage. The heat exchangers can operate in parallel or series. When the pressure in turbine extraction #5 is high enough to heat the DH water to 380°F a parallel arrangement is used. When the turbine runs on partial load and does not have enough pressure in the #5 extraction to heat the DH water to 380°F, the heat exchangers operate in a serial arrangement and steam from the boiler after the pressure reducing station is used to provide the necessary heat to the second heat exchanger. The steam line size permits supply of 100% load from the main steam line if the turbine is down and heat supply is required. The first DH exchanger remains connected to the turbine extraction and heats the water using extraction steam as much as possible. The DH exchangers are sized so that each of them could handle 100% DH flow rate and 70% of the total heat load.

Three 50% capacity DH pumps installed on the return line are equipped with one variable and two constant speed drives, with the capability to switch the variable speed drive between pumps. This arrangement provides enough flexibility to supply the full range of required DH loads.

All makeup water and a side stream of the return water will pass through a water softener and a deaerator. The deaerator will also serve as an expansion tank for the system.

Modifications and Dispatch of the McNeil Station

The modifications required to the power plant for this alternative include installation of two heat exchangers, construction of the additional steam line from the boiler with the pressure reducing station, installation of the DH pumps and controls for all equipment. The DH piping construction and modification of the existing condensate lines are also required.

In order to supply DH the power plant has to be dispatched based on the customers' demand. The data quantifying the McNeil Station electric output and generation for the last five years have been obtained from the station personnel. Since the dispatch schedule of the plant for the years 1995-2005 is uncertain, it was assumed that an average (for the past five years) monthly generation would be used in the present analysis.

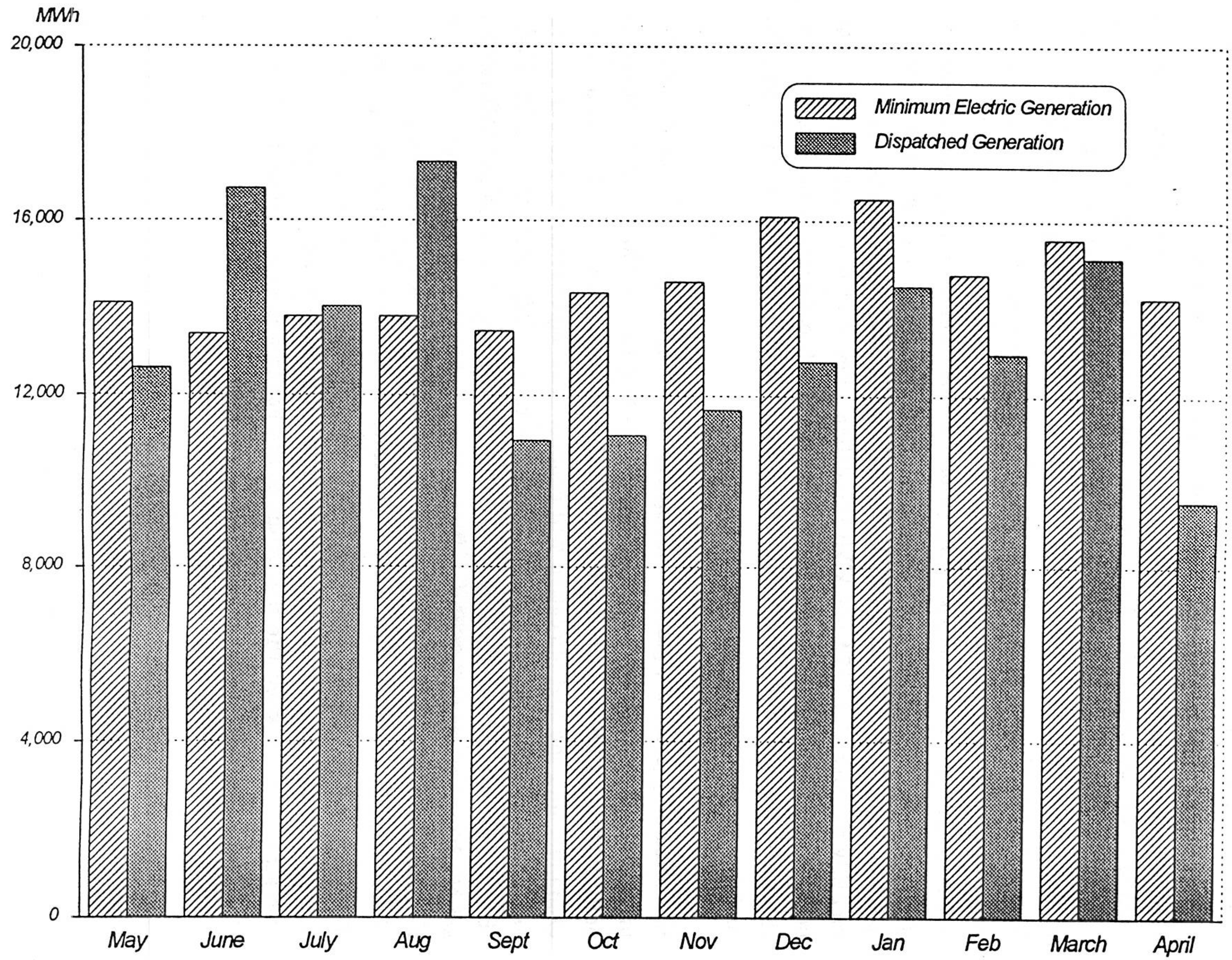


Figure 4-4. Minimum Electric Generation of McNeil Power Plant in District Heating Mode

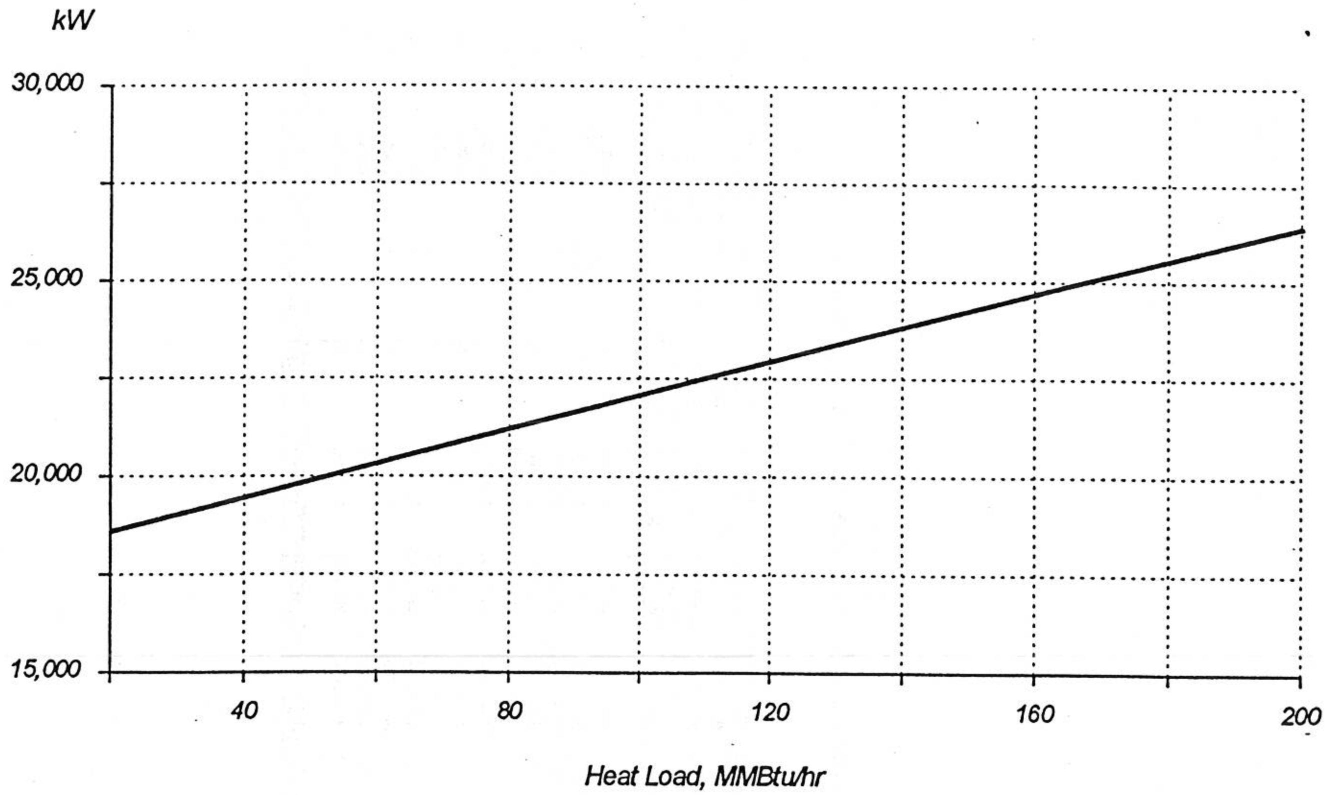


Figure 4-5. Minimum Electric Output of the Turbine in District Heating Mode

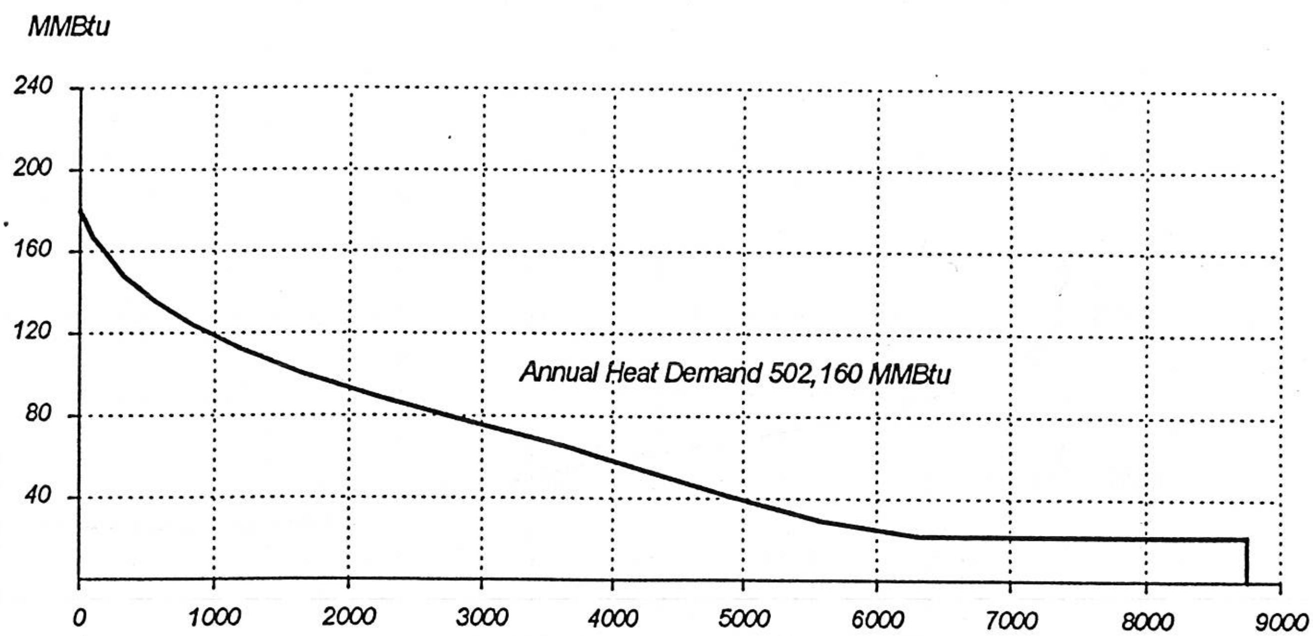


Figure 4-6. Total Heating Load

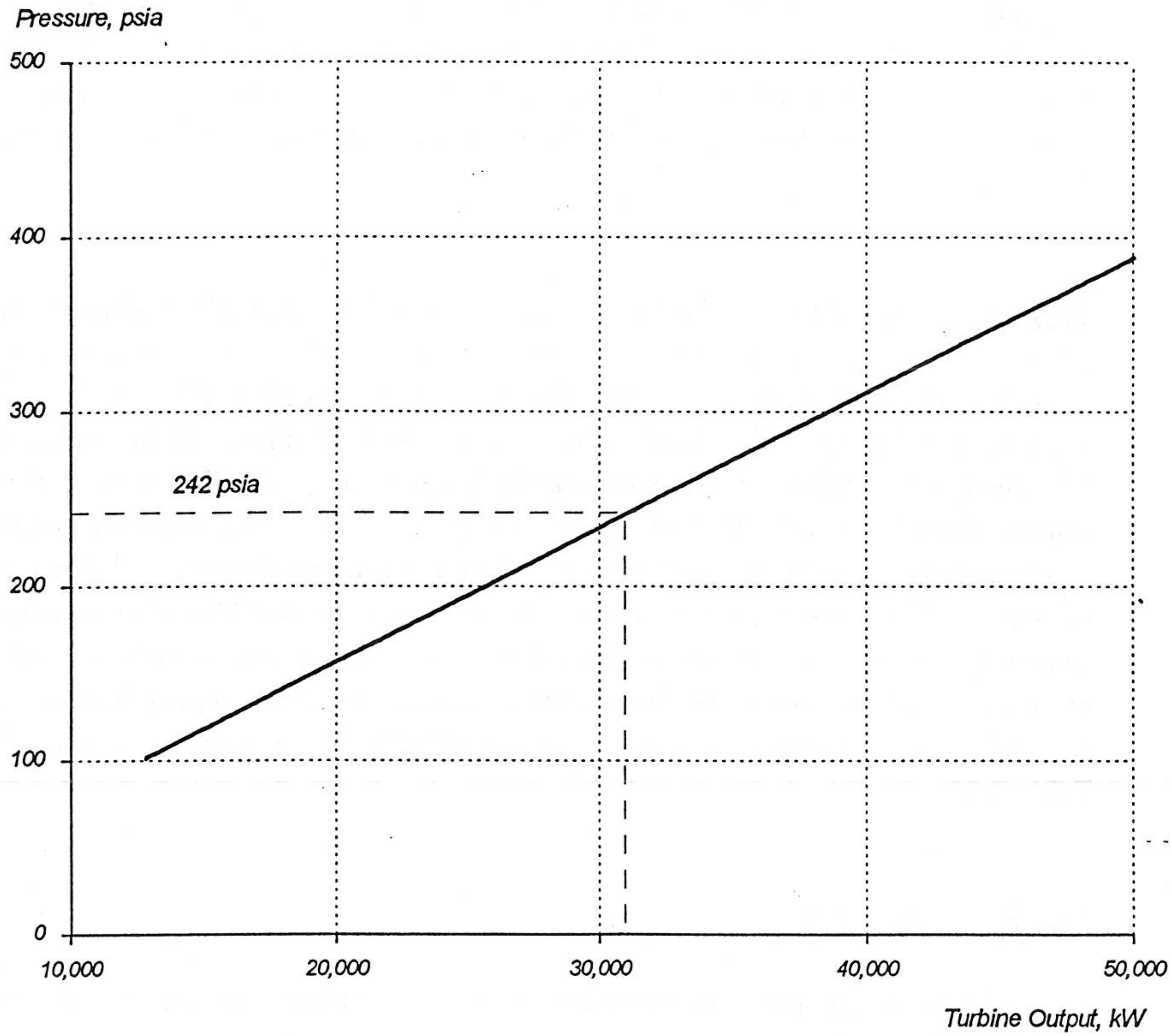


Figure 4-8. Pressure in #5 Turbine Extraction at Partial Loads

Shouldn't this be 150?

Table 4-2
Preliminary Capital Cost Estimate

McNeil Station Retrofit to High Temp HW District Heating

Items	*~~Size (ea)~~*	*No.*	*Total Cost*
Primary Heat Exchanger (DHE-1)	50 MMBtu	1	$150,000
Secondary Heat Exchanger (DHE-2)	50 MMBtu	1	$150,000
Heat Exchanger Support Steel			$45,000
District Heating Pumps (w/ 1 variable speed)	150 hp	3-50%	$170,000
Pressurizing Pumps	10 hp	2-100%	$20,000
Condensate Return Pumps	10 hp	2-100%	$30,000
Pump Concrete Pads			$10,000
Motor Control Panel			$45,000
Power Wiring			$35,000
District Heating Deaerator		1	$35,000
Storage Reservoir		1	$50,000
Deaerator Support Steel			$20,000
Makeup Water Softener		1	$20,000
New Piping, Fittings, Insulation and Manual Valves, Demolition			$720,000
Hot Water Central Control System			$35,000
Plant Btu Meter (Magnetic)	14"	1	$18,000
Unit Control Modifications			$75,000
Extraction Line Isolation Valve	18"	1	$24,000
Extraction Line Non Return Check	18"	1	$34,000
Extraction Line Drain Valves	3"	2	$12,000
Extraction Steam Control Valve	18"	1	$28,000
Heat Exchanger Drain Control Valves	6"	2	$28,000
Boiler Steam Control Valves	18"	2	$70,000
Heat Exchanger HW Temp Control	14"	4	$70,000
Deaerator Steam Control Valves	4"	1	$7,000
Deaerator Makeup Control Valve	2"	2	$5,000
Deaearator Sidestream Control Valve	2"	2	$8,000
Pressurizing Pump Recirc Control Valve	2"	2	$9,000
Condensate Pump Control Valve	4"	2	$17,000
Instrumentation/ Misc Controls/ Wiring			$125,000
UVM Boiler Plant Modifications			$300,000
SUBTOTAL			$2,365,000
Engineering, Construction			$355,000
Contingency (10% of Total)			$237,000
TOTAL			$2,957,000

Based on the above assumptions the breakeven price of heat has been developed. It should be noted that leasing costs of the UVM boiler plant were assumed at $30,000 per year. This cost is recommended as a start for negotiations considering that a major source of air pollution will be almost eliminated. The continuous NO_x and CO_2 emissions from the UVM boiler plant may be expensive for UVM in the near future, should the boiler plant continue operating as is. The externality costs are rated on MMBtu of useful heat basis per year. A plant producing 100,000 MMBtu of useful heat can be a subject to fine up to $41,000 (for NO_x emission) and $186,000 (for CO_2 emission). The UVM plant produces about 300,000 MMBtu's of useful heat, therefore the externality costs may be substantial. This may affect the leasing fee.

No additional personnel was anticipated at the McNeil Station. The UVM plant is intended to be automated to the greatest extent. It will serve as a backup and will operate only a few weeks per year. Therefore, two persons have been allocated to perform startup and routine maintenance.

The economic analysis of HTHW alternative is presented in Table 4-4. The breakeven price of heat for this alternative was calculated for every year during the 20 year period, and for 1996 this price would be $7.27 per MMBtu. In other words, if BED sells heat at this price to all potential customers, BED will still be able to pay principal and interest accrued on bonds and cover all the expenses including the 3.5% city operating fee.

Table 4-4 (continued)
ECONOMIC ANALYSIS

McNeil Station - District Heating Mode

432,660 / 502,160 = 86.2

ANNUAL QUANTITIES

Start of Evaluation	1996	
Unit Costs	1996	Escalation
Capital Costs		0.0%
Penalty for Must Run, $/kWh	0.00817	4.0%
Fuel Price, $/MMBtu	1.93	4.0%
Makeup Water - $/1000 cuft	6.00	4.0%
Heat Sold - $/MMBtu	n/a	
Labor Rate, $/man.yr	45,000	4.0%
Aux. Power Price, $/kWh	0.045	4.0%

Heat Source -	Cogeneration
Disp. (exist.) Gen-n, MWh/yr	159,560,170
Must Run Generation, kWh/yr	22,351,816
Pumping Power, kWh/yr	492,162
Fuel Allocated for DH, MMBtu/yr	444,394
Add-l Fuel to meet Disp.,MMBtu/yr	97,196
District Heat Output (MMBtu/yr)	502,160
Labor Force, man.yr	2

Property Tax - %	0
Insurance Rate - %	2.00
Cost of Capital - %	6.00
Investment ($1000)	0
City Operation Fee - %	3.5
Incremental O&M - %	0.5

Year	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
A. Annual Quantities										
1. District Heat - MMBtu/yr	502,160	502,160	502,160	502,160	502,160	502,160	502,160	502,160	502,160	502,160
2. Chilled Water - MWh/yr	0	0	0	0	0	0	0	0	0	0
3. Must Run Generation - kWh/yr	22,351,816	22,351,816	22,351,816	22,351,816	22,351,816	22,351,816	22,351,816	22,351,816	22,351,816	22,351,816
4. Fuel Allocated for DH - MMBtu/yr	444,394	444,394	444,394	444,394	444,394	444,394	444,394	444,394	444,394	444,394
5. Add-l Fuel to meet Disp.- MMBtu/yr	97,196	97,196	97,196	97,196	97,196	97,196	97,196	97,196	97,196	97,196
6. Pumping Power, kWh/yr	492,162	492,162	492,162	492,162	492,162	492,162	492,162	492,162	492,162	492,162
7. Must Run Gen. Adjusted - kWh/yr	21,859,654	21,859,654	21,859,654	21,859,654	21,859,654	21,859,654	21,859,654	21,859,654	21,859,654	21,859,654
8. Makeup Water - 1000cuft	2,727	2,727	2,727	2,727	2,727	2,727	2,727	2,727	2,727	2,727
9. Labor Force - man.yr	2	2	2	2	2	2	2	2	2	2
B. Unit Costs										
1. Heat Sales -$/MMBtu	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
2. Penalty for Must Run Generation-$/kWh	0.008	0.008	0.009	0.009	0.010	0.010	0.010	0.011	0.011	0.012
3. Aux. Power Price - $/kWh	0.045	0.047	0.049	0.051	0.053	0.055	0.057	0.059	0.062	0.064
4. Makeup Water - $/1000 cuft	6.00	6.24	6.49	6.75	7.02	7.30	7.59	7.90	8.21	8.54
5. Fuel - $/MMBtu										
Wood	1.93	2.01	2.09	2.17	2.26	2.35	2.44	2.54	2.64	2.75
Oil	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nat. Gas	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6. Labor - $/man.yr	45,000	46,800	48,672	50,619	52,644	54,749	56,939	59,217	61,586	64,049

Year	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
A. Annual Quantities										
1. District Heat - MMBtu/yr	502,160	502,160	502,160	502,160	502,160	502,160	502,160	502,160	502,160	502,160
2. Chilled Water - MWh/yr	0	0	0	0	0	0	0	0	0	0
3. Must Run Generation - kWh/yr	22,351,816	22,351,816	22,351,816	22,351,816	22,351,816	22,351,816	22,351,816	22,351,816	22,351,816	22,351,816
4. Fuel Alloc-d for DH - MMBtu/yr	444,394	444,394	444,394	444,394	444,394	444,394	444,394	444,394	444,394	444,394
5. Add-l Fuel to meet Disp.- MMBtu/yr	97,196	97,196	97,196	97,196	97,196	97,196	97,196	97,196	97,196	97,196
6. Pumping Power, kWh/yr	492,162	492,162	492,162	492,162	492,162	492,162	492,162	492,162	492,162	492,162
7. Must Run Gen. Adjusted - kWh/yr	21,859,654	21,859,654	21,859,654	21,859,654	21,859,654	21,859,654	21,859,654	21,859,654	21,859,654	21,859,654
8. Makeup Water - 1000cuft	2,727	2,727	2,727	2,727	2,727	2,727	2,727	2,727	2,727	2,727
9. Labor Force - man.yr	2	2	2	2	2	2	2	2	2	2
B. Unit Costs										
1. Heat Sales -$/MMBtu	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
2. Penalty for Must Run Generation-$/kWh	0.012	0.013	0.013	0.014	0.014	0.015	0.015	0.016	0.017	0.017
3. Aux. Power Price - $/kWh	0.07	0.07	0.07	0.07	0.08	0.08	0.08	0.09	0.09	0.09
4. Makeup Water - $/1000 cuft	8.88	9.24	9.61	9.99	10.39	10.81	11.24	11.69	12.15	12.64
5. Fuel - $/MMBtu										
Wood	2.86	2.97	3.09	3.21	3.34	3.48	3.61	3.76	3.91	4.07
Oil	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nat. Gas	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6. Labor - $/man.yr	66,611	69,275	72,046	74,928	77,925	81,042	84,284	87,656	91,162	94,808

Steam Supply from the McNeil Station

The second option is to supply steam directly from the McNeil Station to each customer. The flow diagram of the station in this case presented in Figure 4-9. The need for DH exchangers is eliminated but the system requires installation of additional equipment for the returned condensate treatment, especially a condensate polishing system to make it possible to introduce the condensate back into the cycle. The preliminary cost estimate of the power plant retrofit to steam DH is presented in Table 4-6.

The distribution piping system, presented in Figure 4-10, will be similar to HTHW alternative while requiring smaller piping for the condensate return line. However, a number of condensate traps and manholes have to be installed in the system. The preliminary cost estimate of this steam distribution piping system is presented in Table 4-7.

In the case of UVM, 180 psig steam will enter the customer's system header. The reduction in steam pressure at UVM from the existing 220 psig to 180 psig will require booster pumps on the HTHW system to prevent it from flashing. UVM has presently a problem if they must shut down the boilers for maintenance or in case of a forced outage. In this case the HTHW system has to be cooled to below 212°F or isolated to maintain 220 psig pressure on it. Even when they isolate the HTHW system, some water flashes to steam in the piping. New booster pumps pressurizing the return line will eliminate this problem.

The feasibility analysis of the steam DH system was performed using the same assumptions as for HTHW alternative. The complete economic analysis is presented in Table 4-8. The breakeven cost of heat obtained from this analysis was $6.95 per MMBtu.

Table 4-6
Preliminary Capital Cost Estimate
McNeil Station Retrofit to Steam District Heating

Items	*Size (ea)*	*No.*	*Total*
Condensate Collection Pumps	10 hp	2-100%	$30,000
Pump Concrete Pads			$10,000
Motor Control Panel			$6,000
Power Wiring			$10,000
Condensate Transfer Pumps	10 hp	2-100%	$30,000
Pump Concrete Pads			$10,000
Motor Control Panel			$6,000
Power Wiring			$10,000
Condensate Collection Tank	10,000 gal	1	$23,000
Tank Foundation			$5,000
Condensate Transfer Tank	1,000 gal	1	$5,000
Tank Foundation			$5,000
Water Treatment System	375 gpm		$1,425,000
New Piping, Fittings, Insulation and Manual Valves, Demolition			$450,000
Unit Control Modifications			$75,000
Extraction Line Isolation Valve	18"	1	$24,000
Extraction Line Non Return Check	18"	1	$34,000
Extraction Line Drain Valves	3"	2	$12,000
Extraction Steam Control Valve	18"	1	$28,000
Boiler Steam Control Valves	18"	2	$70,000
Instrumentation/ Misc Controls/ Wiring			$125,000
UVM Boiler Plant Modifications			$300,000
SUBTOTAL			$2,693,000
Engineering, Construction			$404,000
Contingency (10% of Total)			$269,000
TOTAL			$3,366,000

Table 4-7

Preliminary Capital Cost Estimate

Steam District Heating

Items	*Size (each)*	*Number*	*Total*
Underground Steam Piping			
Steam Straight Pipe with Casing	16"	6024'	$1,927,680
Steam Straight Pipe with Casing	12"	1900'	$425,600
Steam Straight Pipe with Casing	10"	2688'	$322,560
Steam Straight Pipe with Casing	6"	300'	$30,000
Steam Straight Pipe with Casing	3"	900'	$54,000
Steam Straight Pipe with Casing	2"	1100'	$55,000
Cond. Straight Pipe with Casing	8"	6024'	$903,600
Cond. Straight Pipe with Casing	6"	1900'	$190,000
Cond. Straight Pipe with Casing	5"	2688'	$215,040
Cond. Straight Pipe with Casing	3"	300'	$18,000
Cond. Straight Pipe with Casing	2"	900'	$36,000
Cond. Straight Pipe with Casing	1"	1100'	$39,600
Steam Elbows with Casing	16"	81	$259,200
Steam Elbows with Casing	12"	19	$42,560
Steam Elbows with Casing	10"	36	$43,200
Steam Elbows with Casing	6"	2	$2,000
Steam Elbows with Casing	3"	14	$8,640
Steam Elbows with Casing	2"	18	$8,800
Condensate Elbows with Casing	8"	40	$48,000
Condensate Elbows with Casing	6"	10	$10,000
Condensate Elbows with Casing	5"	18	$14,400
Condensate Elbows with Casing	3"	1	$600
Condensate Elbows with Casing	2"	2	$800
Condensate Elbows with Casing	1"	5	$1,800
Total trench feet		12912'	
Manholes/500'	6x8x7	52	$1,032,960
Traps, valves, pump for Manhole		52	$361,536
Gland Seals/Anchor (2/ manhole)	16"	12	$38,554
Gland Seals/Anchor (2/ manhole)	12"	4	$9,120
Gland Seals/Anchor (2/ manhole)	10"	5	$6,451
Gland Seals/Anchor (2/ manhole)	8"	12	$14,458
Gland Seals/Anchor (2/ manhole)	6"	4	$6,600
Gland Seals/Anchor (2/ manhole)	5"	5	$4,301
Gland Seals/Anchor (2/ manhole)	3"	2	$1,097
Gland Seals/Anchor (2/ manhole)	2"	4	$1,600
Gland Seals/Anchor (2/ manhole)	1"	2	$660
End Seals (2/ customer)		14	$12,600
Subtotal for Mechanical (Piping)			$6,147,016
Trench Excavation	16"	6024'	$1,207,800
Trench Excavation	12"	1900'	$257,400
Trench Excavation	10"	2688'	$228,800
Trench Excavation	6"	300'	$19,800
Trench Excavation	3, 2, 1"	2000'	$79,200
Site Restoration	16"	6024'	$40,700
Site Restoration	12"	1900'	$466,400
Site Restoration	10"	2688'	$490,600
Site Restoration	6"	300'	$244,200
Site Restoration	3, 2, 1"	2000'	$79,200
Subtotal for Civil (Piping)			$3,114,100
SUBTOTAL:			$9,261,116
Engineering & Construction Management (15% of Total)			$1,389,000
Contingency (10% of Total)			$926,000
TOTAL:			$11,576,116

Table 4-8 (continued)
ECONOMIC ANALYSIS

McNeil Station - Steam District Heating

ANNUAL QUANTITIES

Start of Evaluation	1996		Heat Source -	Cogeneration	Property Tax - %	0
Unit Costs	1996	Escalation	Disp. (exist.) Gen-n, MWh/yr	159,560,170	Insurance Rate - %	2.00
Capital Costs		0.0%	Must Run Generation, kWh/yr	22,351,816	Cost of Capital - %	6.00
Penalty for Must Run, $/kWh	0.00817	4.0%	Pumping Power, kWh/yr	0	Investment ($1000)	0
Fuel Price, $/MMBtu	1.93	4.0%	Fuel Allocated for DH, MMBtu/yr	444,394	City Operation Fee - %	3.5
Makeup Water - $/1000 cuft	6.00	4.0%	Add-l Fuel to meet Disp.,MMBtu/yr	97,196	Incremental O&M - %	0.5
Heat Sold - $/MMBtu	n/a		District Heat Output (MMBtu/yr)	502,160		
Labor Rate, $/man.yr	45,000	4.0%	Labor Force, man.yr	2		
Aux. Power Price, $/kWh	0.045	4.0%				

Year	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
A. Annual Quantities										
1. District Heat - MMBtu/yr	502,160	502,160	502,160	502,160	502,160	502,160	502,160	502,160	502,160	502,160
2. Chilled Water - MWh/yr	0	0	0	0	0	0	0	0	0	0
3. Must Run Generation - kWh/yr	22,351,816	22,351,816	22,351,816	22,351,816	22,351,816	22,351,816	22,351,816	22,351,816	22,351,816	22,351,816
4. Fuel Allocated for DH - MMBtu/yr	444,394	444,394	444,394	444,394	444,394	444,394	444,394	444,394	444,394	444,394
5. Add-l Fuel to meet Disp.- MMBtu/yr	97,196	97,196	97,196	97,196	97,196	97,196	97,196	97,196	97,196	97,196
6. Pumping Power, kWh/yr	0	0	0	0	0	0	0	0	0	0
7. Must Run Gen. Adjusted - kWh/yr	22,351,816	22,351,816	22,351,816	22,351,816	22,351,816	22,351,816	22,351,816	22,351,816	22,351,816	22,351,816
8. Makeup Water - 1000 cuft	736	736	736	736	736	736	736	736	736	736
9. Water Treated - 1000 cuft	4,909	4,909	4,909	4,909	4,909	4,909	4,909	4,909	4,909	4,909
10. Labor Force - man.yr	2	2	2	2	2	2	2	2	2	2
B. Unit Costs										
1. Heat Sales -$/MMBtu	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
2. Penalty for Must Run Generation-$/kWh	0.008	0.008	0.009	0.009	0.010	0.010	0.010	0.011	0.011	0.012
3. Aux. Power Price - $/kWh	0.045	0.047	0.049	0.051	0.053	0.055	0.057	0.059	0.062	0.064
4. Makeup Water - $/1000 cuft	6.00	6.24	6.49	6.75	7.02	7.30	7.59	7.90	8.21	8.54
5. Water Treatment - $/1000 gal	2.00	2.08	2.16	2.25	2.34	2.43	2.53	2.63	2.74	2.85
6. Fuel - $/MMBtu										
Wood	1.93	2.01	2.09	2.17	2.26	2.35	2.44	2.54	2.64	2.75
Oil	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nat. Gas	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7. Labor - $/man.yr	45,000	46,800	48,672	50,619	52,644	54,749	56,939	59,217	61,586	64,049

Year	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
A. Annual Quantities										
1. District Heat - MMBtu/yr	502,160	502,160	502,160	502,160	502,160	502,160	502,160	502,160	502,160	502,160
2. Chilled Water - MWh/yr	0	0	0	0	0	0	0	0	0	0
3. Must Run Generation - kWh/yr	22,351,816	22,351,816	22,351,816	22,351,816	22,351,816	22,351,816	22,351,816	22,351,816	22,351,816	22,351,816
4. Fuel Alloc-d for DH - MMBtu/yr	444,394	444,394	444,394	444,394	444,394	444,394	444,394	444,394	444,394	444,394
5. Add-l Fuel to meet Disp.- MMBtu/yr	97,196	97,196	97,196	97,196	97,196	97,196	97,196	97,196	97,196	97,196
6. Pumping Power, kWh/yr	0	0	0	0	0	0	0	0	0	0
7. Must Run Gen. Adjusted - kWh/yr	22,351,816	22,351,816	22,351,816	22,351,816	22,351,816	22,351,816	22,351,816	22,351,816	22,351,816	22,351,816
8. Makeup Water - 1000 cuft	736	736	736	736	736	736	736	736	736	736
9. Water Treated - 1000 cuft	4,909	4,909	4,909	4,909	4,909	4,909	4,909	4,909	4,909	4,909
10. Labor Force - man.yr	2	2	2	2	2	2	2	2	2	2
B. Unit Costs										
1. Heat Sales -$/MMBtu	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
2. Penalty for Must Run Generation-$/kWh	0.012	0.013	0.013	0.014	0.014	0.015	0.015	0.016	0.017	0.017
3. Aux. Power Price - $/kWh	0.07	0.07	0.07	0.07	0.08	0.08	0.08	0.09	0.09	0.09
4. Makeup Water - $/1000 cuft	8.88	9.24	9.61	9.99	10.39	10.81	11.24	11.69	12.15	12.64
5. Water Treatment - $/1000 gal	2.96	3.08	3.20	3.33	3.46	3.60	3.75	3.90	4.05	4.21
6. Fuel - $/MMBtu										
Wood	2.86	2.97	3.09	3.21	3.34	3.48	3.61	3.76	3.91	4.07
Oil	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nat. Gas	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7. Labor - $/man.yr	66,611	69,275	72,046	74,928	77,925	81,042	84,284	87,656	91,162	94,808

Low Temperature Hot Water Supply

In this option LTHW is supplied from the McNeil Station at maximum of 250°F and returned to the plant at about 160°F.

The flow diagram for LTHW DH is the same as for the HTHW alternative (shown in Figure 4-3) except for the heating medium flowrates. The cost of the power plant retrofit is presented in Table 4-10.

The preliminary cost estimate for the LTHW distribution system is presented in Table 4-11. The cost of the piping system in this case is significantly lower than for the two other alternatives which lowers the total cost of the project. The economic analysis of the LTHW alternative is presented in Table 4-12. The breakeven cost of heat in this case is $5.47 per MMBtu.

Implementation Schedule

An implementation schedule for the project has been prepared. It includes detailed retrofit analysis of the customer buildings, development contracts with customers, financing of the selected alternative and the modifications of the McNeil Station, and underground piping design and construction. It is anticipated that the system may start commercial operation in October of 1996. The preliminary schedule of the project implementation is presented in Table 4-13.

Table 4-11

Preliminary Capital Cost Estimate

Low Temp. HW District Heating System

Items	*Size (each)*	*Number*	*Total*
Underground LTHW Piping			
LTHW Straight Pipe with Casing	16"	14928'	$2,452,085
LTHW Straight Pipe with Casing	10"	3840'	$420,406
LTHW Straight Pipe with Casing	2"	2200'	$56,570
LTHW Straight Pipe with Casing	4"	900'	$38,372
LTHW Straight Pipe with Casing	12"	1104'	$150,100
LTHW Straight Pipe with Casing	8"	1536'	$122,219
LTHW Straight Pipe with Casing	6"	600'	$34,262
LTHW Straight Pipe with Casing	3"	900'	$30,056
Total Trench feet		13004'	
Valves for Isolation		10	$140,000
Anchors		5	$70,000
End Seals & valves (2/ customer)		14	$33,600
Subtotal for Mechanical (Piping)			$3,547,671
Trench Excavation	16"	14928'	$858,000
Trench Excavation	10"	3840'	$147,400
Trench Excavation	2"	2200'	$19,800
Trench Excavation	4"	900'	$13,200
Trench Excavation	12"	1104'	$52,800
Trench Excavation	8"	1536'	$42,900
Trench Excavation	6"	600'	$12,100
Trench Excavation	3"	900'	$11,000
Site Restoration	16"	14928'	$367,400
Site Restoration	10"	3840'	$62,700
Site Restoration	2"	2200'	$8,800
Site Restoration	4"	900'	$5,500
Site Restoration	12"	1104'	$22,000
Site Restoration	8"	1536'	$18,700
Site Restoration	6"	600'	$5,500
Site Restoration	3"	900'	$4,400
Subtotal for Civil (Piping)			$1,652,200
SUBTOTAL			$5,199,871
Engineering & Construction Management (15% of Total)			$780,000
Contingency (10% of Total)			$520,000
TOTAL:			$6,499,871

Table 4-12 (continued)

ECONOMIC ANALYSIS

McNeil Station - Low Temp HW District Heating

ANNUAL QUANTITIES

Start of Evaluation	1996		Heat Source -	Cogeneration	Property Tax - %	0
Unit Costs	1996	Escalation	Disp. (exist.) Gen-n, MWh/yr	159,560,170	Insurance Rate - %	2.00
Capital Costs		0.0%	Must Run Generation, kWh/yr	22,351,816	Cost of Capital - %	6.00
Penalty for Must Run, $/kWh	0.00817	4.0%	Pumping Power, kWh/yr	492,162	Investment ($1000)	0
Fuel Price, $/MMBtu	1.93	4.0%	Fuel Allocated for DH, MMBtu/yr	444,394	City Operation Fee - %	3.5
Makeup Water - $/1000 cuft	6.00	4.0%	Add-l Fuel to meet Disp.,MMBtu/yr	97,196	Incremental O&M - %	0.5
Heat Sold - $/MMBtu	n/a		District Heat Output (MMBtu/yr)	502,160		
Labor Rate, $/man.yr	45,000	4.0%	Labor Force, man.yr	2		
Aux. Power Price, $/kWh	0.045	4.0%				

Year	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
A. Annual Quantities										
1. District Heat - MMBtu/yr	502,160	502,160	502,160	502,160	502,160	502,160	502,160	502,160	502,160	502,160
2. Chilled Water - MWh/yr	0	0	0	0	0	0	0	0	0	0
3. Must Run Generation - kWh/yr	22,351,816	22,351,816	22,351,816	22,351,816	22,351,816	22,351,816	22,351,816	22,351,816	22,351,816	22,351,816
4. Fuel Allocated for DH - MMBtu/yr	444,394	444,394	444,394	444,394	444,394	444,394	444,394	444,394	444,394	444,394
5. Add-l Fuel to meet Disp.- MMBtu/yr	97,196	97,196	97,196	97,196	97,196	97,196	97,196	97,196	97,196	97,196
6. Pumping Power, kWh/yr	492,162	492,162	492,162	492,162	492,162	492,162	492,162	492,162	492,162	492,162
7. Must Run Gen. Adjusted - kWh/yr	21,859,654	21,859,654	21,859,654	21,859,654	21,859,654	21,859,654	21,859,654	21,859,654	21,859,654	21,859,654
8. Makeup Water - 1000cuft	2,727	2,727	2,727	2,727	2,727	2,727	2,727	2,727	2,727	2,727
9. Labor Force - man.yr	2	2	2	2	2	2	2	2	2	2
B. Unit Costs										
1. Heat Sales -$/MMBtu	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
2. Penalty for Must Run Generation-$/kWh	0.008	0.008	0.009	0.009	0.010	0.010	0.010	0.011	0.011	0.012
3. Aux. Power Price - $/kWh	0.045	0.047	0.049	0.051	0.053	0.055	0.057	0.059	0.062	0.064
4. Makeup Water - $/1000 cuft	6.00	6.24	6.49	6.75	7.02	7.30	7.59	7.90	8.21	8.54
5. Fuel - $/MMBtu										
Wood	1.93	2.01	2.09	2.17	2.26	2.35	2.44	2.54	2.64	2.75
Oil	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nat. Gas	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6. Labor - $/man.yr	45,000	46,800	48,672	50,619	52,644	54,749	56,939	59,217	61,586	64,049

Year	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
A. Annual Quantities										
1. District Heat - MMBtu/yr	502,160	502,160	502,160	502,160	502,160	502,160	502,160	502,160	502,160	502,160
2. Chilled Water - MWh/yr	0	0	0	0	0	0	0	0	0	0
3. Must Run Generation - kWh/yr	22,351,816	22,351,816	22,351,816	22,351,816	22,351,816	22,351,816	22,351,816	22,351,816	22,351,816	22,351,816
4. Fuel Alloc-d for DH - MMBtu/yr	444,394	444,394	444,394	444,394	444,394	444,394	444,394	444,394	444,394	444,394
5. Add-l Fuel to meet Disp.- MMBtu/yr	97,196	97,196	97,196	97,196	97,196	97,196	97,196	97,196	97,196	97,196
6. Pumping Power, kWh/yr	492,162	492,162	492,162	492,162	492,162	492,162	492,162	492,162	492,162	492,162
7. Must Run Gen. Adjusted - kWh/yr	21,859,654	21,859,654	21,859,654	21,859,654	21,859,654	21,859,654	21,859,654	21,859,654	21,859,654	21,859,654
8. Makeup Water - 1000cuft	2,727	2,727	2,727	2,727	2,727	2,727	2,727	2,727	2,727	2,727
9. Labor Force - man.yr	2	2	2	2	2	2	2	2	2	2
B. Unit Costs										
1. Heat Sales -$/MMBtu	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
2. Penalty for Must Run Generation-$/kWh	0.012	0.013	0.013	0.014	0.014	0.015	0.015	0.016	0.017	0.017
3. Aux. Power Price - $/kWh	0.07	0.07	0.07	0.07	0.08	0.08	0.08	0.09	0.09	0.09
4. Makeup Water - $/1000 cuft	8.88	9.24	9.61	9.99	10.39	10.81	11.24	11.69	12.15	12.64
5. Fuel - $/MMBtu										
Wood	2.86	2.97	3.09	3.21	3.34	3.48	3.61	3.76	3.91	4.07
Oil	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nat. Gas	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6. Labor - $/man.yr	66,611	69,275	72,046	74,928	77,925	81,042	84,284	87,656	91,162	94,808

SECTION 5
CUSTOMER RETROFIT AND POTENTIAL SAVINGS

Customer Site Retrofit

The six potential customers were analyzed to estimate the cost of connecting a DH system to their existing heating system. For each customer prices for the three different district options: high temperature hot water (HTHW), steam, and low temperature hot water (LTHW) have been developed. All options are based on the heat supply from the modified McNeil Station. The customer site retrofit costs are preliminary. A separate study would be required for the detailed analysis of the retrofits.

High Temperature Hot Water Supply

UVM. The UVM requirement for 375°F HTHW can be fulfilled by pumping HTHW from the McNeil station directly into their piping system. An expansion tank for all the water in the system will be installed at the McNeil Station. The tank will maintain a high enough pressure so that the water will not flash. Presently UVM uses an excess pressure of 35 psi.

Two 100% HTHW to steam heat exchangers will be required at the UVM central plant to generate the 120 psig steam they require for the north part of their campus. A schematic diagram of this arrangement is shown in Figure 5-1. Additional heat exchangers must be installed in Given Medical Building to generate the 5 psig steam needed there. The piping interconnection and heat exchangers are estimate to cost $546,750. The price includes cost for heat exchangers to generate 120 psi steam from the HTHW. The temperatures of the two mediums are within 30° of each other, thus requiring large surface area heat exchangers. Space is not a concern since the heat exchangers can be installed above the cascade heater which could be kept as a backup.

Medical Center Hospital of Vermont. It is proposed to connect the district HTHW to a steam reboiler in which steam can be generated at 80 psig to match the existing system. This is shown in Figure 5-2. Only one reboiler will be required if an existing conventional boiler can be kept as emergency backup. The hook-up cost is estimated at $96,000.

University Health Center. The present heating system is low pressure steam which is converted to hot water before it is used for heating. There is a separate boiler to serve the 50 psi autoclave load. As backup, the main boilers can supply 50 psig, which is then reduced everywhere except at the autoclave load. Therefore it is proposed to connect the district HTHW to the main boiler header. HTHW can then be converted to low temperature water in all of the existing heat exchangers. A separate steam generator can be installed to produce 50 psig steam for the autoclave load. The total retrofit cost is estimated at $25,000.

Trinity College. Using HTHW in place of a hot water boiler will require a heat exchanger and control valve. The existing boilers can be left for backup. A schematic is shown in Figure 5-3. The cost is estimated at $32,000. The equipment will fit in the existing boiler room.

Mater Christi School. Using HTHW in place of a hot water boiler will require a heat exchanger and control valve. The existing boilers can be left for backup. The cost is estimated at $21,000 The equipment will fit in the existing boiler room.

Red Cross Building. Using HTHW in place of a hot water boiler will require a heat exchanger and control valve. The existing boilers can be left for backup. The cost is estimated at $10,500. The equipment will fit in the existing boiler room.

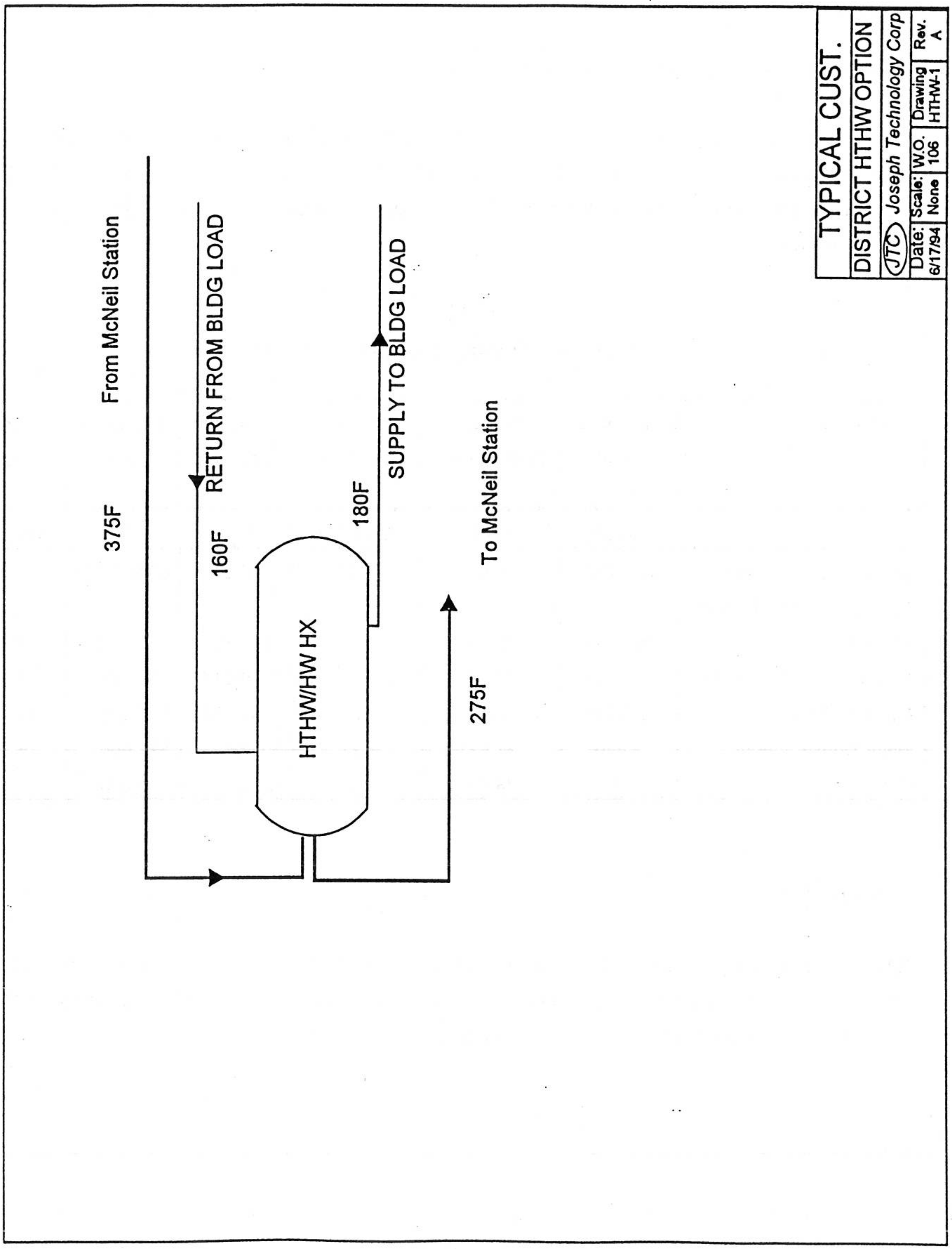

From McNeil Station
375F
RETURN FROM BLDG LOAD
160F
180F
SUPPLY TO BLDG LOAD
HTHW/HW HX
275F
To McNeil Station
TYPICAL CUST.
DISTRICT HTHW OPTION
JTC Joseph Technology Corp
Date: 6/17/94
Scale: None
W.O. 106
Drawing HTHW-1
Rev. A

Figure 5-3

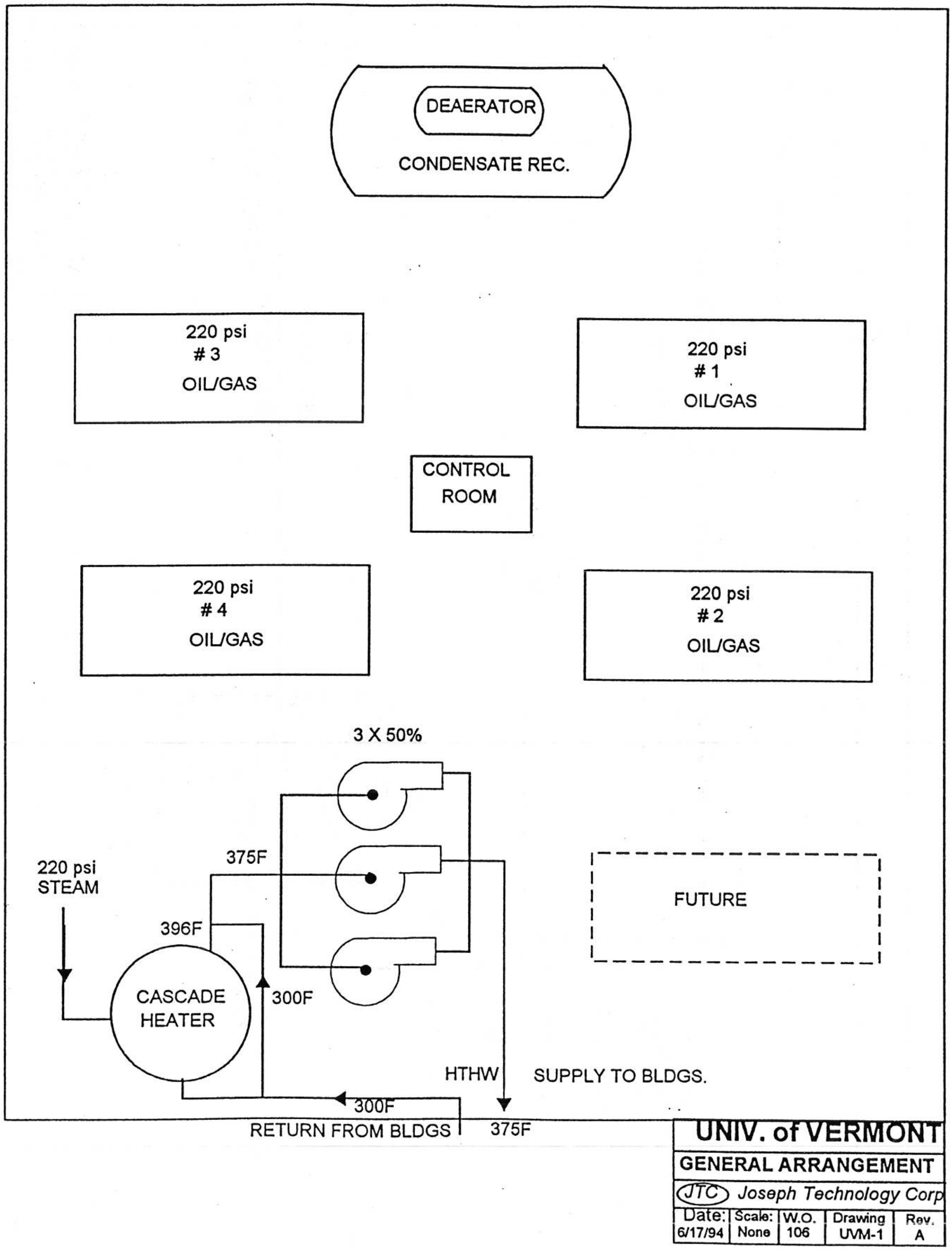

DEAERATOR
CONDENSATE REC.
220 psi
3
OIL/GAS
220 psi
1
OIL/GAS
CONTROL
ROOM
220 psi
4
OIL/GAS
220 psi
2
OIL/GAS
3 X 50%
220 psi
STEAM
375F
396F
CASCADE
HEATER
300F
FUTURE
HTHW
SUPPLY TO BLDGS.
300F
RETURN FROM BLDGS
375F
UNIV. of VERMONT
GENERAL ARRANGEMENT
JTC Joseph Technology Corp
Date: 6/17/94
Scale: None
W.O. 106
Drawing UVM-1
Rev. A

Figure 5-4

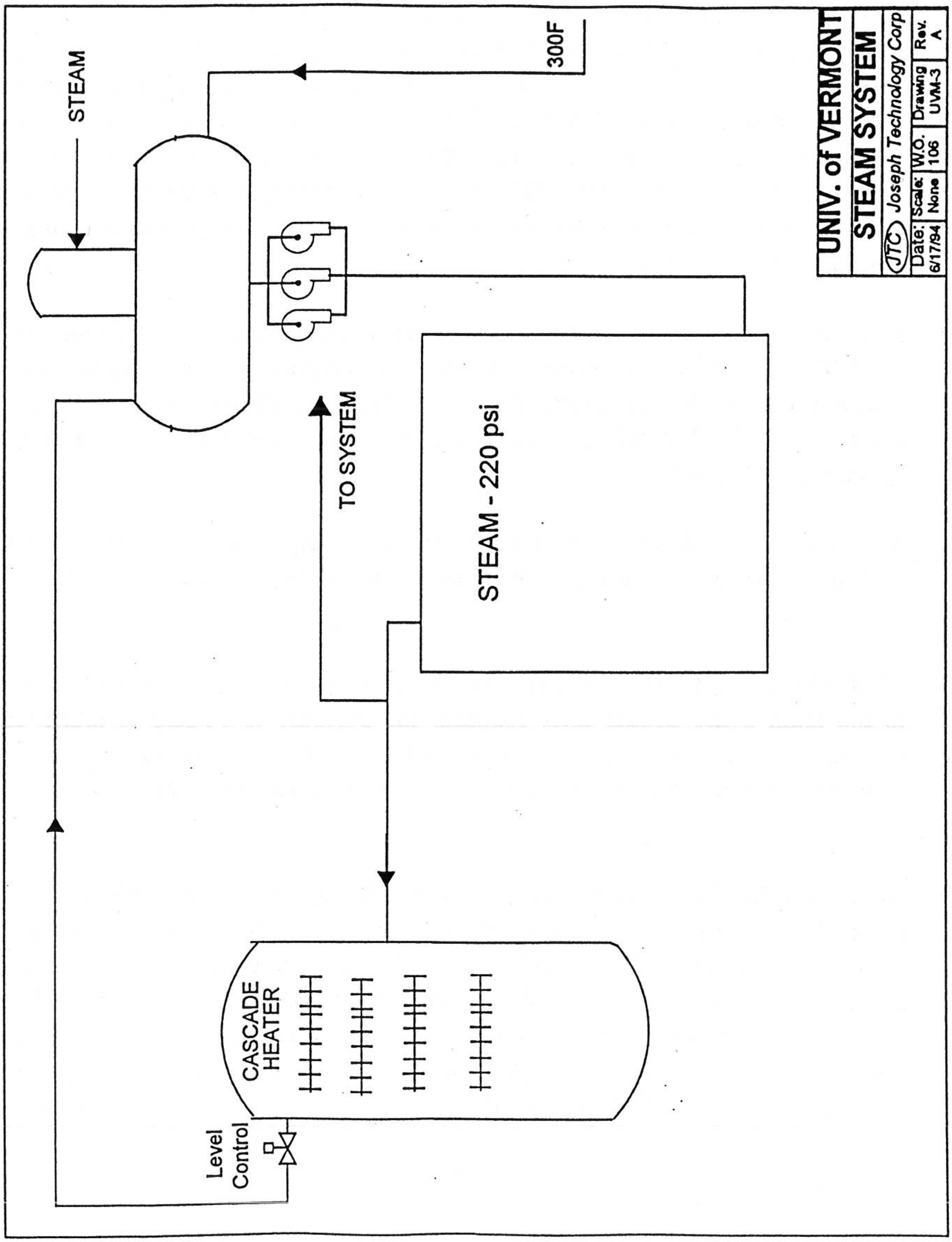
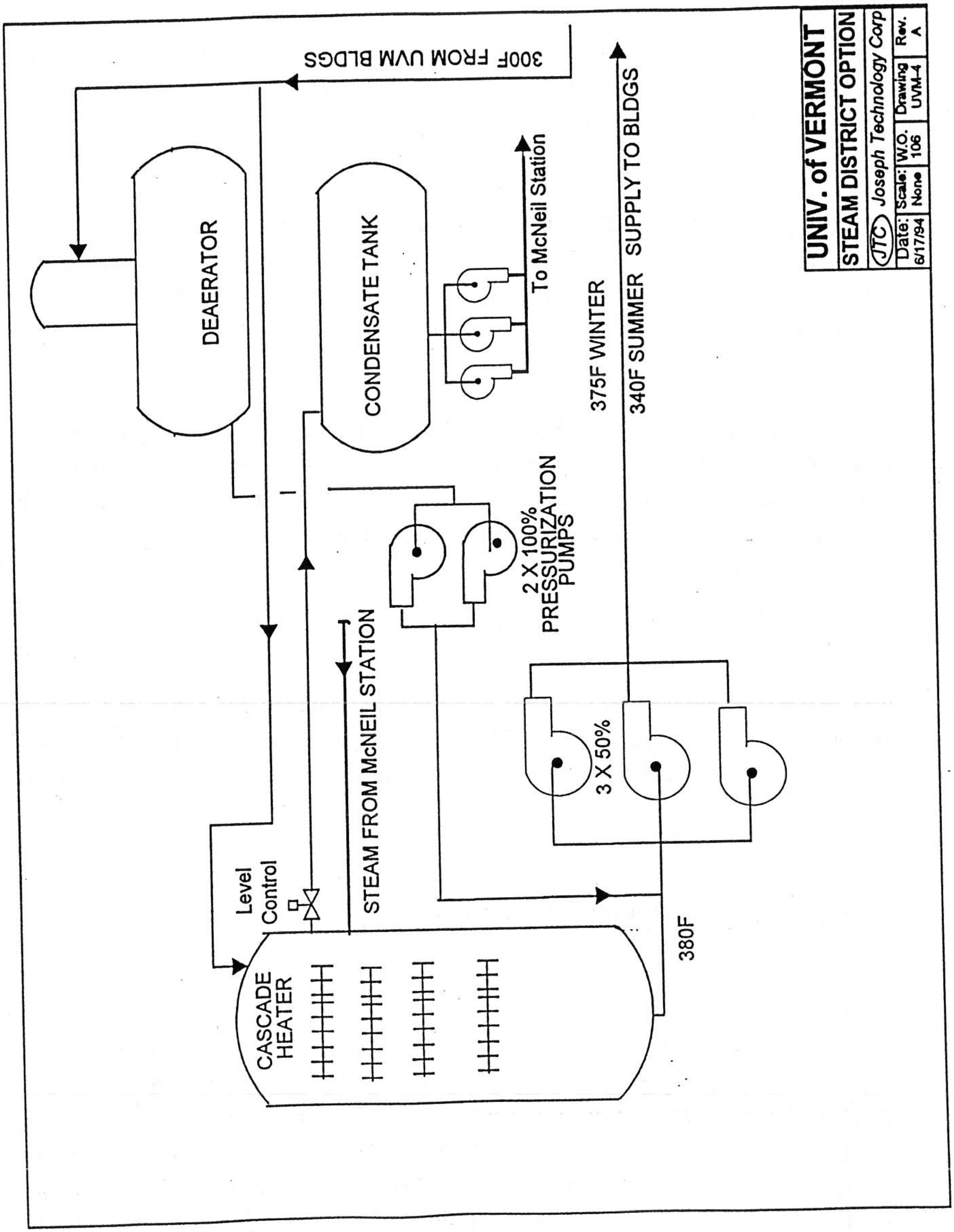

STEAM
300F
TO SYSTEM
STEAM - 220 psi
CASCADE HEATER
Level Control
UNIV. of VERMONT
STEAM SYSTEM
JTC Joseph Technology Corp
Date: 6/17/94
Scale: None
W.O. 106
Drawing UVM-3
Rev. A

Figure 5-6



UNIV. of VERMONT
STEAM DISTRICT OPTION
JTC Joseph Technology Corp
Date: 6/17/94
Scale: None
W.O. 106
Drawing UVM-4
Rev. A
300F FROM UVM BLDGS
DEAERATOR
CONDENSATE TANK
To McNeil Station
375F WINTER
340F SUMMER
SUPPLY TO BLDGS
2 X 100% PRESSURIZATION PUMPS
3 X 50%
STEAM FROM McNEIL STATION
Level Control
CASCADE HEATER
380F

Figure 5-7

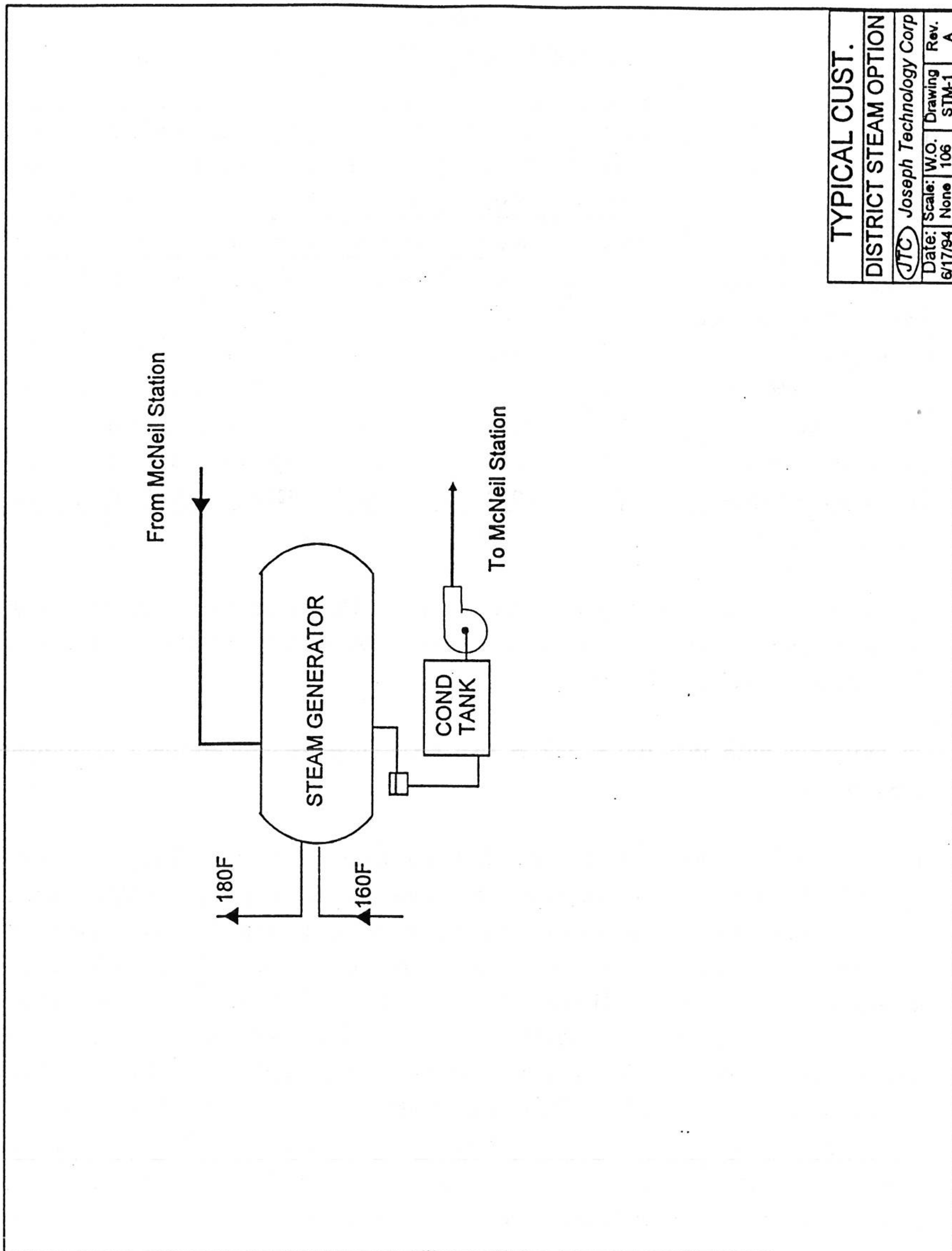

TYPICAL CUST.
DISTRICT STEAM OPTION
JTC Joseph Technology Corp
Date: 6/17/94
Scale: None
W.O. 106
Drawing STM-1
Rev. A
From McNeil Station
To McNeil Station
STEAM GENERATOR
COND TANK
180F
160F

Figure 5-8

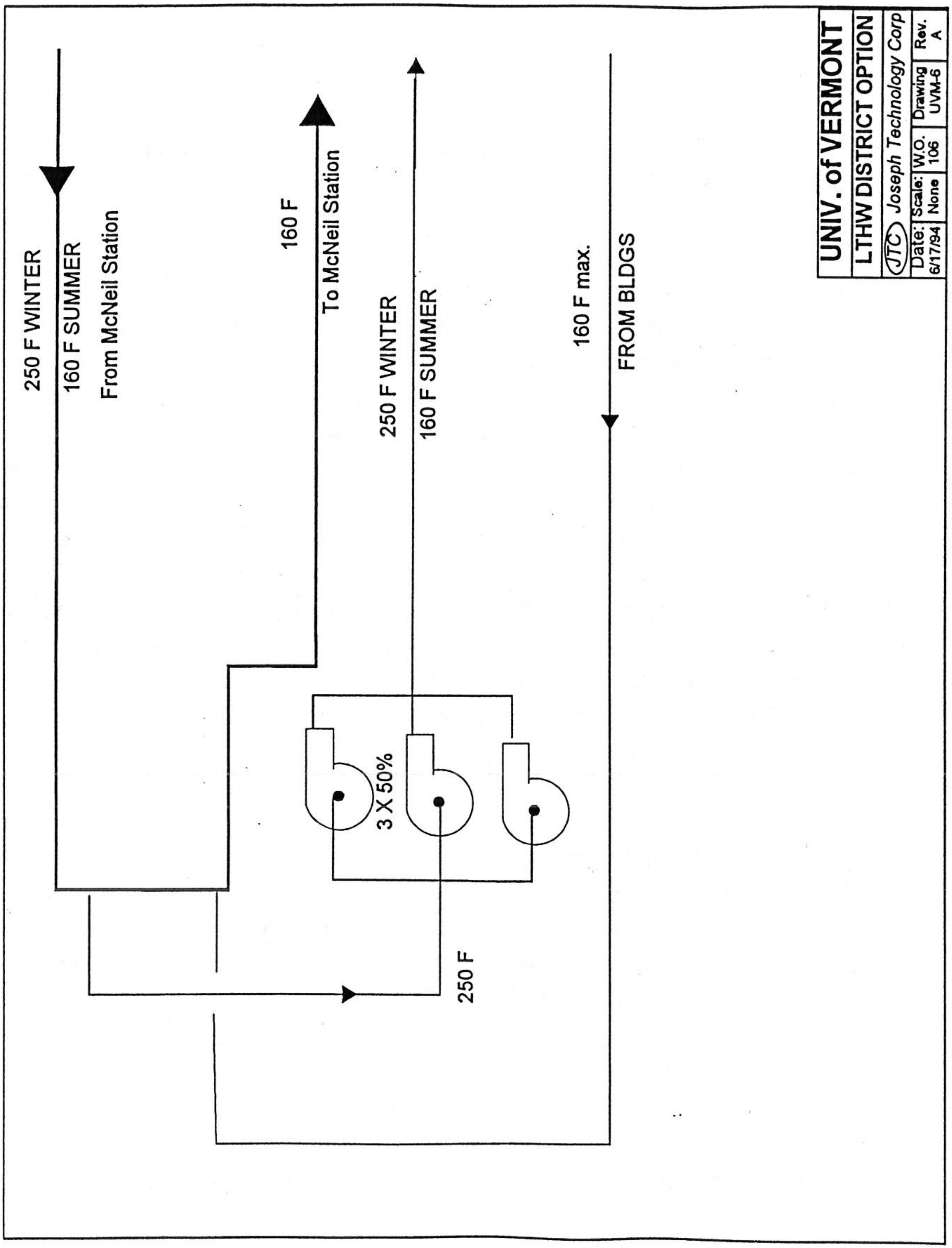

UNIV. of VERMONT
LTHW DISTRICT OPTION
JTC Joseph Technology Corp
Date: 6/17/94
Scale: None
W.O. 106
Drawing UVM-6
Rev. A
250 F WINTER
160 F SUMMER
From McNeil Station
160 F
To McNeil Station
250 F WINTER
160 F SUMMER
160 F max.
FROM BLDGS
3 X 50%
250 F

Figure 5-9

heating. There is a separate boiler to serve the 50 psi autoclave load. As backup, the main boilers can supply 50 psi, which is then reduced everywhere except at the autoclave load. Therefore it is proposed to connect the district LTHW to the main boiler header. A separate steam to LTHW heat exchangers can then be added to enable the boilers to serve as backup. The main boilers can be also used as backup to the autoclave boiler through the dedicated piping already in place. The hook-up cost is estimated at $57,000.

Trinity College. The use of LTHW in place of a hot water boiler will require a heat exchanger and control valve. The existing boilers can be left as emergency backup units. A schematic is shown in Figure 5-10. The cost is estimated at $26,000. The equipment will fit in the existing boiler room.

Mater Christi School. The use of LTHW in place of a hot water boiler will require a heat exchanger and control valve. A schematic is shown in Figure 5-10. The existing boiler can be left for backup. The cost is estimated at $21,500. The equipment will fit in the existing boiler room.

Red Cross Building. The use of LTHW in place of a hot water boiler will require a heat exchanger and control valve. A schematic is shown in Figure 5-10. The existing boiler can be left for backup. The cost is estimated at $10,500. The equipment will fit in the existing boiler room.

Potential Savings and a Simple Payback

The customers' present cost of heat and potential savings are estimated by using the minimum breakeven cost of heat for BED and presented in Table 5-3. The table also presents the hook-up cost for the customers and a simple payback on the investment.

Table 5-3
Potential Savings to DH Customers

Customer	Projected Heat Sales	Present Cost of Heat	Breakeven Cost of DH	Potential Savings	Hook-Up Cost	Simple Payback
	MMBtu	$/MMBtu	$/MMBtu	$/year	$	months
University of Vermont	306,246	9.23	~~5.47~~ 6.35	$1,151,485	$175,000	2
Medical Center Hospital of Vermont	87,184	9.40	5.47	$342,633	$216,000	8
University Health Center	16,900	17.90	5.47	$210,067	$57,000	4
Trinity College	17,700	13.34	5.47	$139,299	$26,000	4
Mater Christi School	3,646	21.82	5.47	$59,612	$21,500	5
Red Cross Building	984	29.41	5.47	$23,557	$10,500	6

Red Cross Building

The Red Cross Building has a central hot and chilled air distribution ductwork system. There are two electric centrifugal chillers. They are 100 tons each and were installed in 1976. One is backup to the other and is still in "like new" condition.

Trinity College

Trinity College has only a few window units.

Mater Christi School

The Mater Christi Schools have a number of window units.

Thus, the most prospective customers for the chilled water system are MCHV and Medical Given building which is a part of UVM. The total anticipated peak cooling load of those two facilities is about 2,000 tons. The existing cooling loads are summarized in the Table 7-1.

Table 7-1
Cooling Loads of the Potential Customers

Customer	Installed Capacity, ton	Year of Installation	Chiller Type
MCHV	3x270 2x310	1989 1983	centrifugal, electric
UVM	1000*	N/A	centrifugal, electric
UHC**	40 160	1969 1978	reciprocating reciprocating
Red Cross	200	1976	centrifugal, electric
Trinity College	No central chilling at the facility. Window units only		
Mater Christi School	No central chilling at the facility. Window units only		

* - Given Medical Building only

**- Cooling load is supplied by heat pumps boilers or at the McNeil Station would drive the two-stage steam absorption chillers which have an average coefficient of performance (COP) of 1.0. This COP means that 12,000 Btu of steam produce 1 ton-hr of cooling. The electric centrifugal chillers have the COP of up to 5.86 which means that 0.6 kW can produce 1 ton of cooling. In order to reduce electric demand charges the central cooling plant should include both absorption and electric centrifugal chillers.

The supply of chilled water from a central plant also requires a piping system for chilled water supply and return. Taking into account the existing load and a possible future expansion the pipe size would be 18-20 inches. Considering the low cooling load utilization factor in Burlington, it does not appear feasible to run additional two-pipes for district cooling and install chillers at the McNeil Station or another location.

Cooling Load Supply from McNeil Station

Another possibility of cooling load supply is by means of HTHW or steam generated at the McNeil Station. This option would require generation of chilled water in steam or HTHW absorption chillers, located at the customer sites. The two core customers, UVM (at Given Medical Building) and MCHV, already have electric centrifugal chillers which supply all the cooling demand with the sufficient backup capacity. This cooling option would require them to replace those chillers. Therefore, this alternative does not appears to be feasible at this time. It can be considered later in case of system expansion or major customer equipment renovation.

Interconnection of the Existing Cooling Systems

The total combined load of Medical Center Hospital of Vermont and Given Medical Building is about 2,000 ton. Interconnection of the existing chillers is suggested. A tunnel connecting the MCHV and Given Medical Building on UVM's campus simplifies interconnection.

SECTION 7
COGENERATION ALTERNATIVES

Introduction

This section addresses the feasibility of constructing a cogeneration plant to provide district energy to six potential customers and electricity to two major customers. Three cogeneration alternatives have been considered.

- Conversion of the existing McNeil single purpose power plant to cogeneration.
- Construction of a gas turbine cogeneration plant at the McNeil site.
- Construction of a stand-alone gas turbine cogeneration plant at a customer site.

The conversion of the existing McNeil Station to cogeneration is presented in Section 5. The single purpose McNeil Station is to be modified to serve six district heating customers.

Construction of a gas turbine plant at the McNeil site does not appear to be feasible at the present time. McNeil has sufficient thermal capacity to serve all six customers and additional load as well, should the downtown be hooked-up. Modification of the McNeil Station for cogeneration requires much smaller capital investment compare with the installation of a gas turbine unit. Therefore, this alternative is considered not feasible.

The third alternative appears to be more attractive and it is presented below in more details.

Stand-Alone Cogeneration Plant

Two assumptions have been made with respect to this alternative to establish the sizing criteria for the cogeneration plant consisting of two units.

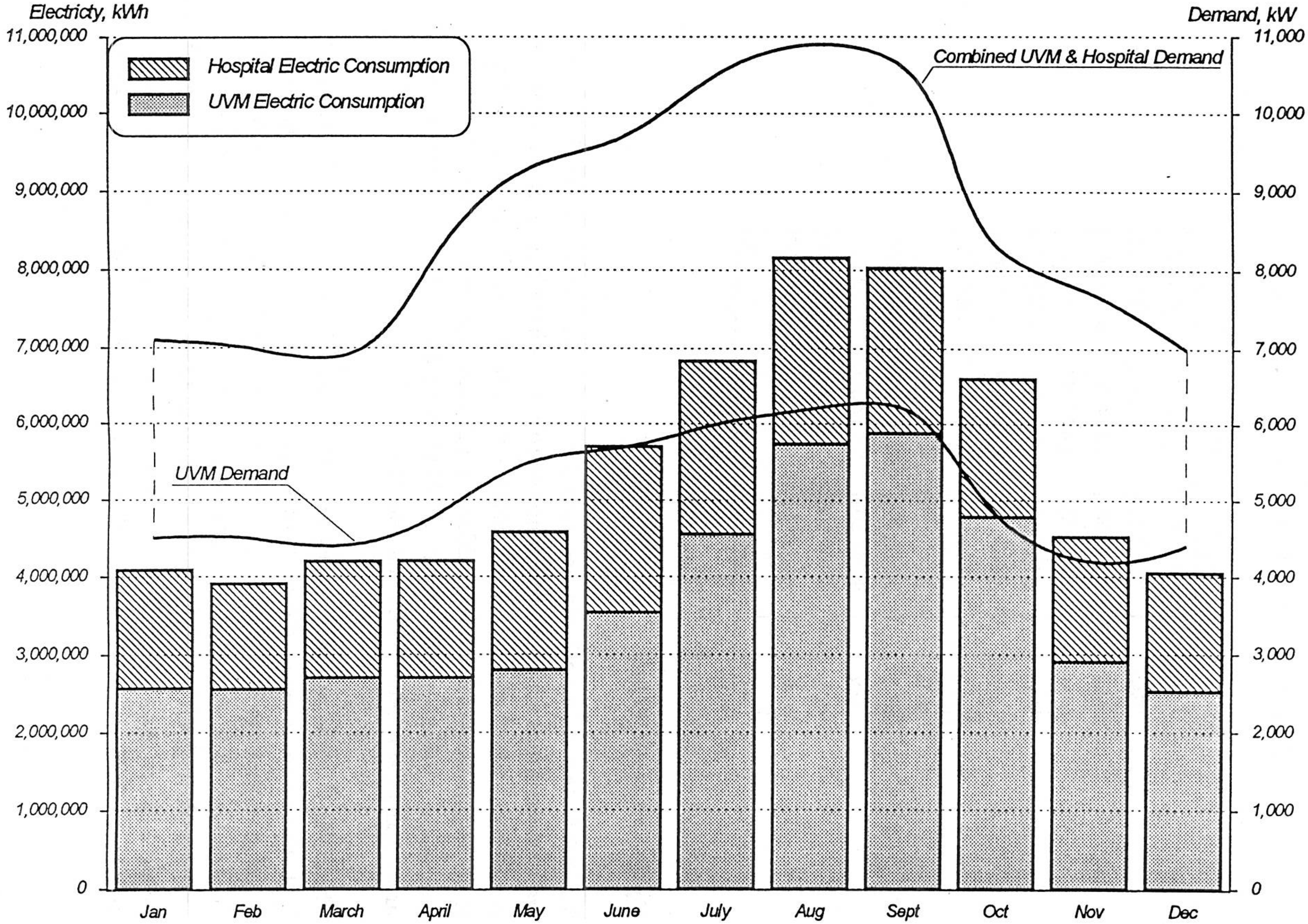


Figure 7-1. Combined UVM and MCHV Electric Consumption and Demand

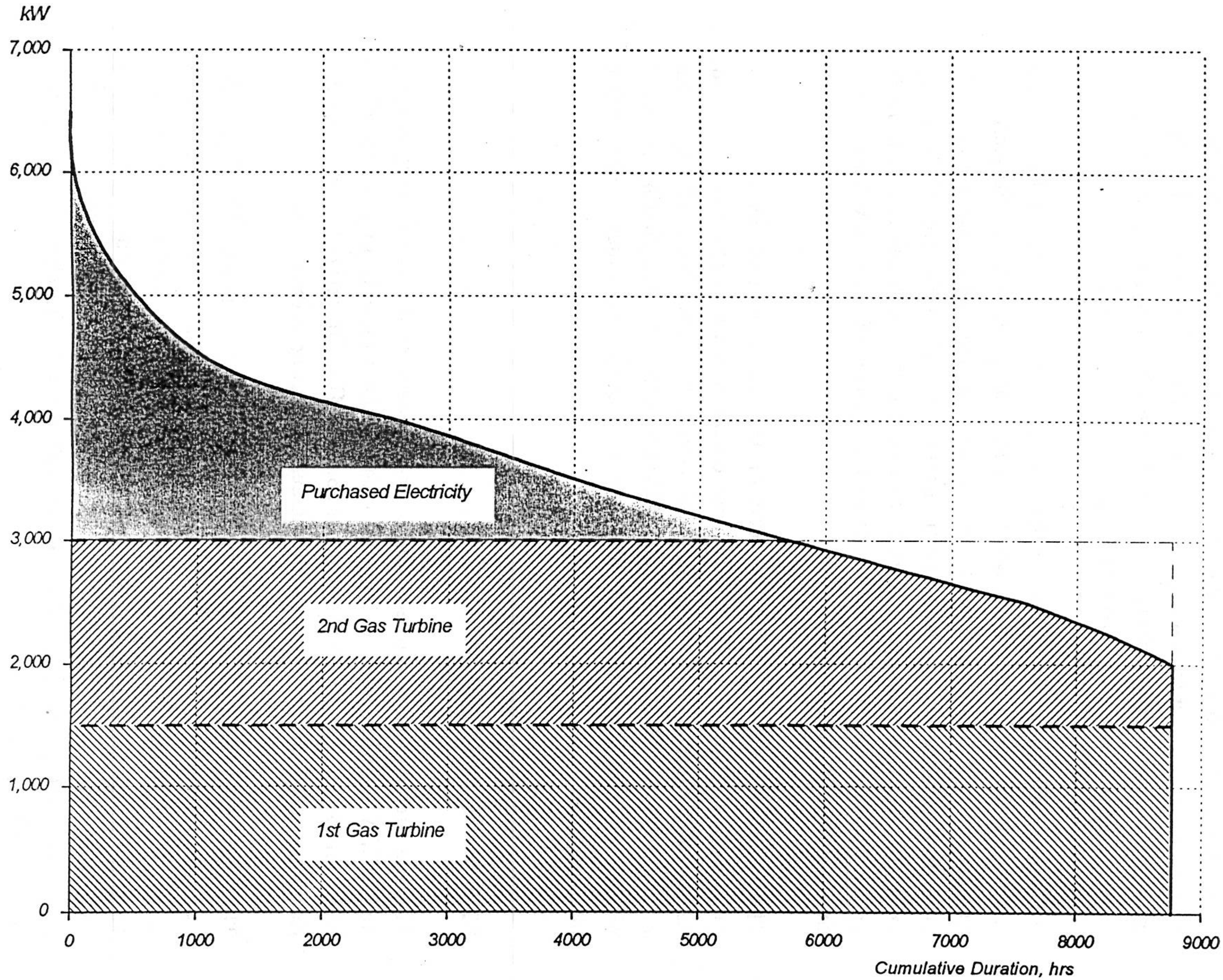


Figure 7-2. University of Vermont Electric Load Duration
Option #1 (UVM only, 2x1,500 kW Gas Turbines)

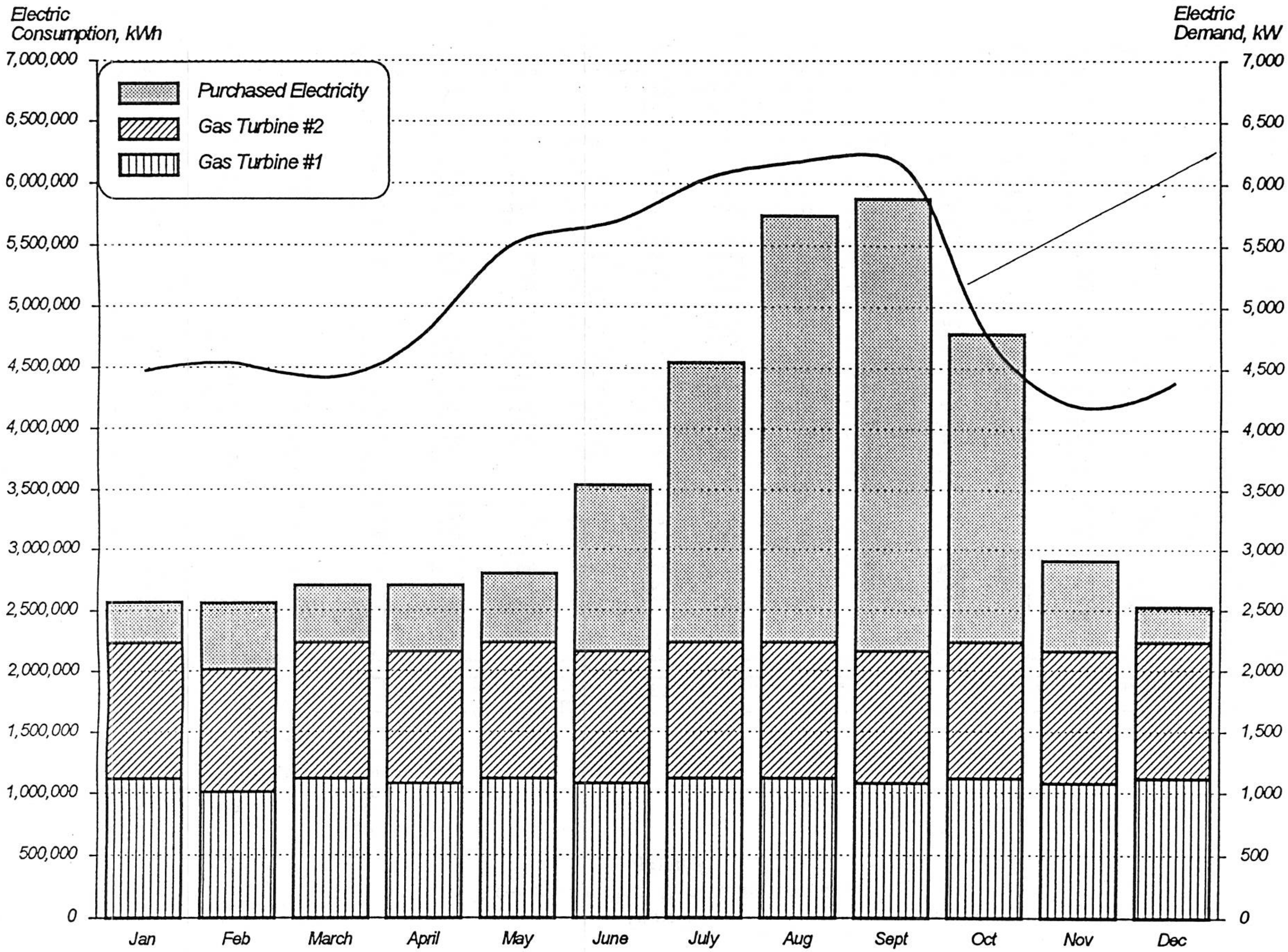


Figure 7-3. UVM Electricity Allocation and Electric Demand. Option #1 - (2x1,500 kW Gas Turbines)

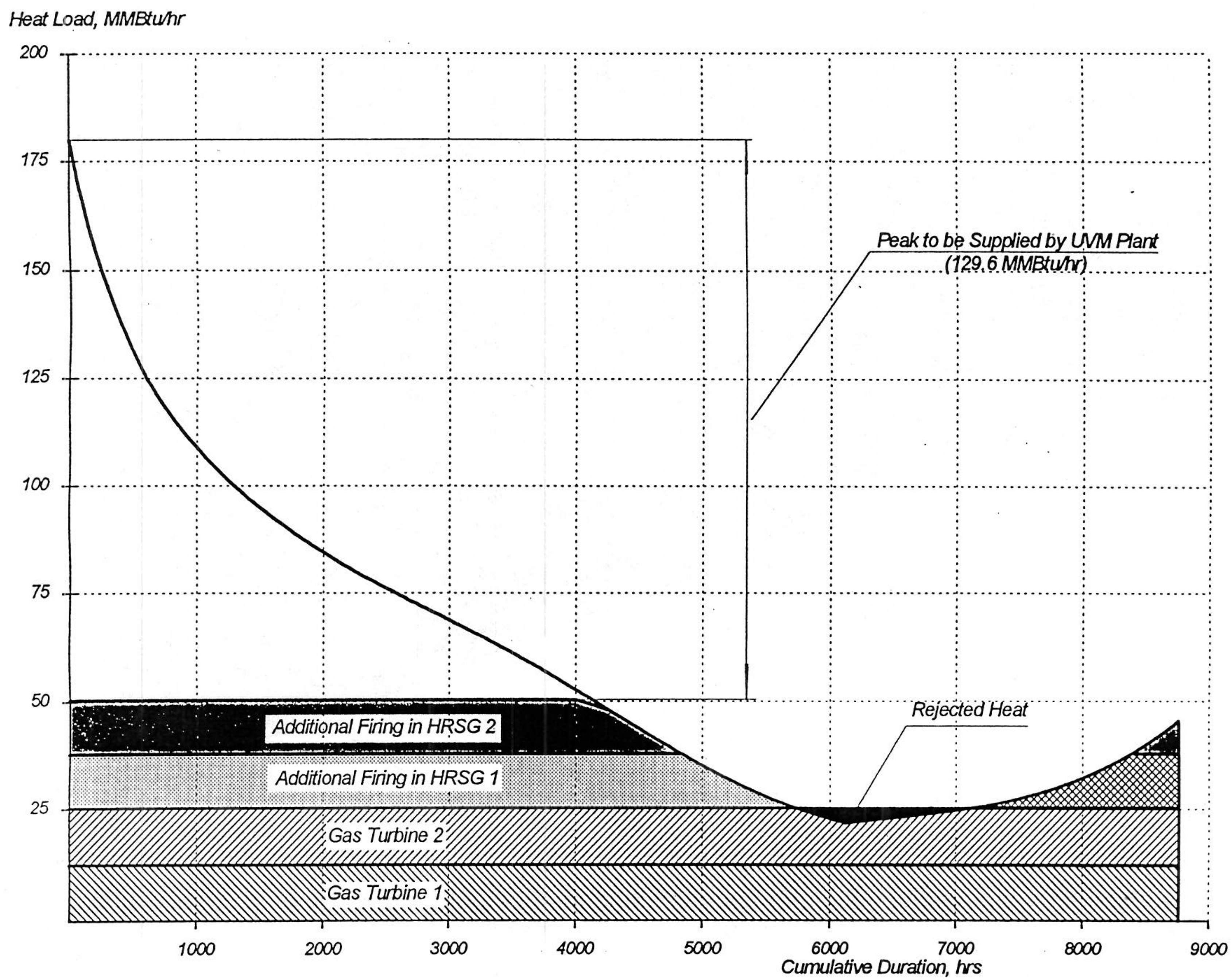


Figure 7-4. Heating & Cooling Load Supply by Gogeneration Plant
Option #1 (2x1,500 kW Gas Turbines)

The performance analysis is shown in Table 7-3 and the heating and cooling load supply is shown in Figure 7-6. In this case, the cogeneration plant with supplementary firing in HRSG's is able to supply about 95 MMBtu/hr of thermal load, while the UVM plant would have to supply only 85.4 MMBtu/hr. That provides a sufficient backup capacity. A large quantity of thermal energy is rejected during the season when both heating and cooling demands are low.

This option appears to be more attractive because it would supply a major portion of both electric and thermal requirements with a minimal electric purchase and use of the UVM plant. The electric and heat generation allocation for both options are presented in Table 7-4.

Unit Cost

The fuel component includes the fuel input to the gas turbines and HRSG's, and fuel to be burnt in the auxiliary peaking boiler (UVM plant). The fuel price was assumed to be $3.2/MMBtu.

Table 7-4
Electric and Heat Generation Allocation for the Proposed Cogeneration Plant

	Option #1	***Option #2***
Customer(s)	UVM	UVM, MCHV
Installed Capacity, kW	2x1,500	2x3,500
Gas Turbine #1, kWh	13,140,000	30,660,000
Gas Turbine #2, kWh	11,414,300	24,819,000
Purchase, kWh	18,685,700	9,334,100
Total, kWh	43,240,000	64,813,100
Heat Output, MMBtu	379,187	570,570
Total Fuel Input, MMBtu	531,523	938,311

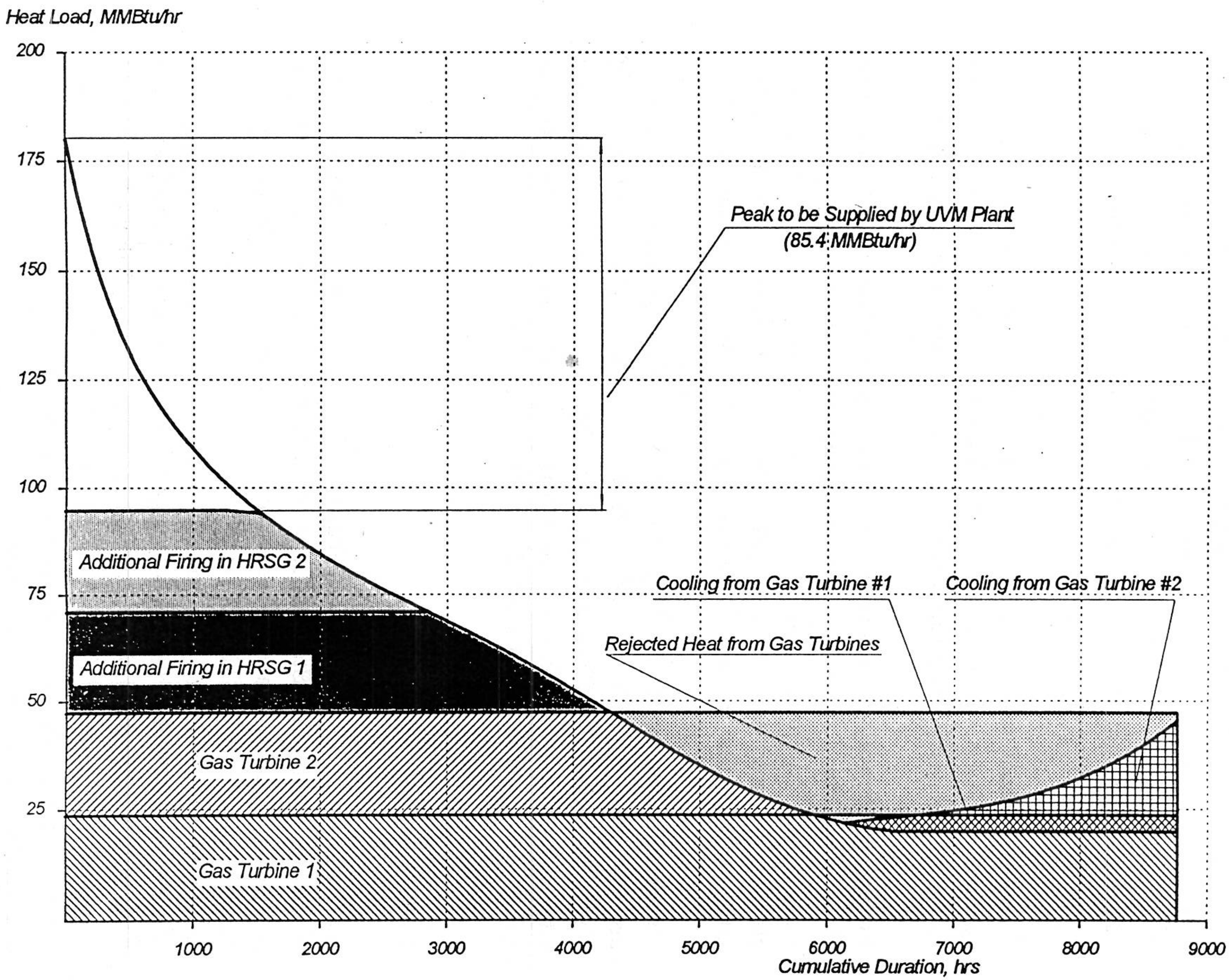


Figure 7-6. Heating & Cooling Load Supply by Gogeneration Plant Option 2 (2x3,500 kW Gas Turbines)

Table 7-5
Cogeneration Plant - Option #1. Unit Cost.

Peak Heating Load, MMBtu/hr	180.0	*Purchased Backup Power*	
Installed Electric Capacity, kW	3,000	Demand $/kW/mo	$20.13

Total Useful Heat Required, MMBtu	526,160
Total Electric Generation, kWh	24,554,333

Annual Expenditures for the Cogeneration Plant	*Miscellaneous*	*Item or Cost Description*	*Total Annual Cost ($)*	*Heat Cost ($/MMBtu)*	*Electric Cost (¢/kWh)*
FUEL	(ccf)	(MMBtu)			
Annual Fuel Usage					
Fuel Input to GT's	3,450,000	345,000	$1,104,000		
Fuel Input to HRSG's	1,866,000	186,600	$597,120		
Fuel Input to PB's	2,099,614	209,961	$671,877		
Total Fuel Input	7,415,614	741,561	$2,372,997		
CAPITAL COMPONENT					
Gas Turbine Plant					
Capital Cost of the GT Plant	$4,500,000				
Annual Capital Component (assuming 8.5% interest rate, 20 years)			$475,519		
Piping Network (UVM Plant to all Customers)					
Installed Cost	$3,000,000				
Annual Capital Component (assuming 8.5% interest rate, 20 years)			$317,013		
Peaking Boiler Plant					
Required Peaking Capacity, MMBtu/hr	130				
Installed	130				
Needs to be Installed (Backup), MMBtu/hr	35				
Capital Cost of PB plant (Utilized part of the UVM Plant)	$3,945,481				
Annual Capital Component (assuming 8.5% interest rate, 20 years)			$416,923		
MAINTENANCE/OPERATIONS (NON-FUEL)					
Backup Power Purchase Demand, kW	1,500		$362,340		
O&M Costs (3% of Capital Investment)			$343,364		
Electric Interconnection			$80,000		
TOTAL ANNUAL COST			$4,368,156	$5.35	6.3

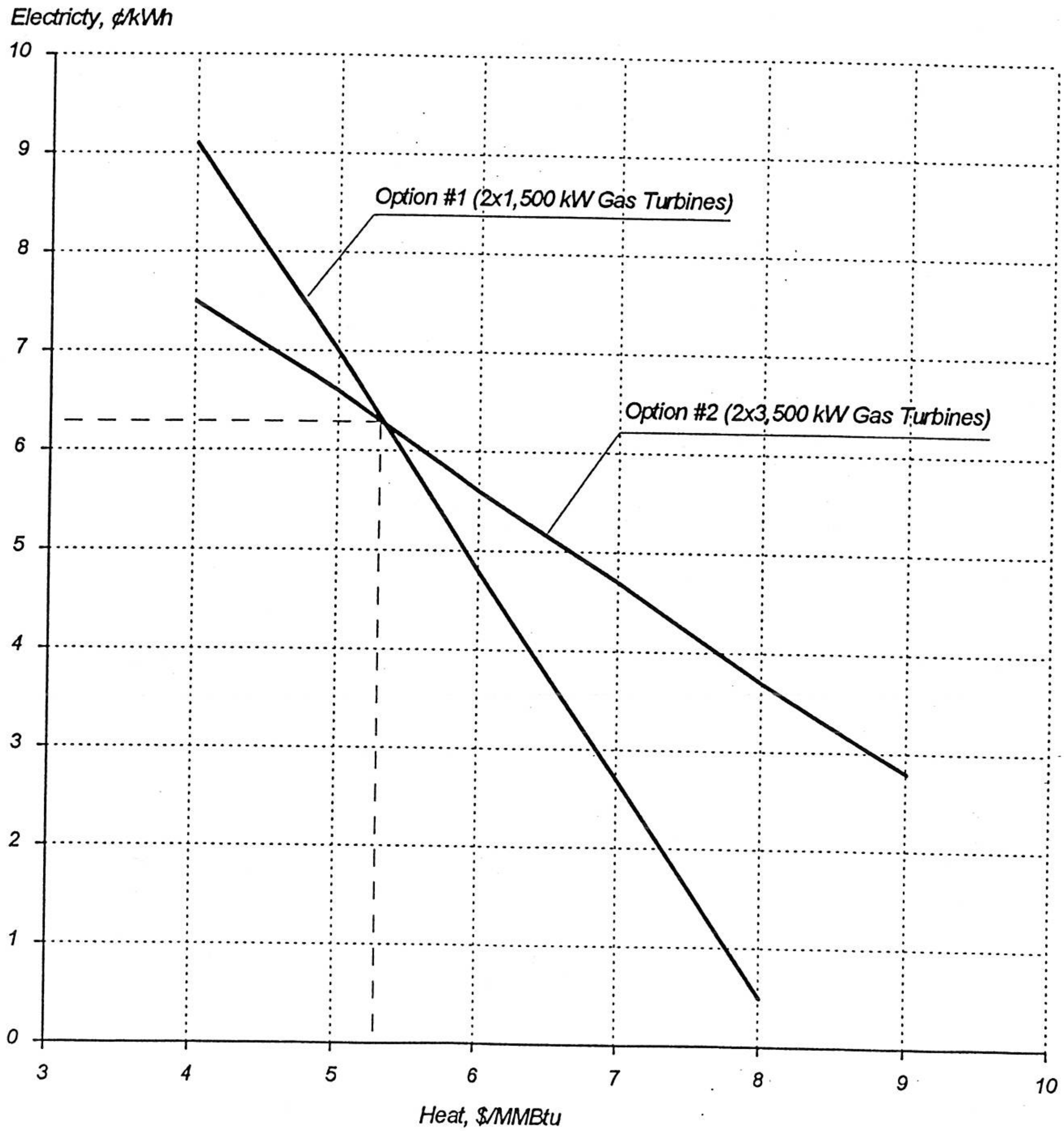


Figure 7-7. Correlation between Breakeven Cost of Heat and Electric Cost