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ENERGY

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COGENERATION

GRID CONNECTED INTEGRATED COMMUNITY ENERGY SYSTEM

Phase II, Final Stage 2 Report

Preliminary Design of Cogeneration Plant

March 22, 1978

Work Performed Under Contract No. EC-77-C-02-4210

University of Minnesota
Physical Plant
Minneapolis, Minnesota

and

Helmick & Lutz Company
Engineers
Minneapolis, Minnesota

U. S. DEPARTMENT OF ENERGY

Division of Buildings and Community Systems

MASTER

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GRID CONNECTED INTEGRATED COMMUNITY ENERGY SYSTEM

PHASE II FINAL STAGE 2 REPORT

PRELIMINARY DESIGN OF COGENERATION PLANT

March 22, 1978

UNIVERSITY OF MINNESOTA PHYSICAL PLANT
319 15th AVE. S.E.
MINNEAPOLIS, MINNESOTA 55455
612-373-4521

Prepared For
The U.S. Department of Energy
Under Contract No. EC-77-C-02-4210

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South East Generating Station

Helmick & Lutz

PRELIMINARY DESIGN OF COGENERATION PLANT

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The following materials represents the Phase II, Stage 2 preliminary design for Grid-ICES by the University's Prime Consultant, Helmick and Lutz Company.

HELMICK & LUTZ COMPANY
ENGINEERS
1315 GLENWOOD AVENUE
MINNEAPOLIS, MINNESOTA 55405
TELEPHONE 377-5070

March 22, 1978

University of Minnesota
Physical Plant Maintenance & Operations
Room 200 Shops Building
319 15th Avenue Southeast
Minneapolis, Minnesota 55455

Attention: Mr. W. E. Soderberg
Director

Re: Grid Connected Integrated Community Energy System
Phase II Stage 2 and three Options.

Gentlemen:

This report presents the Final Design Description of the Grid ICES, including the Basic Plan and three Options.

Capital costs and operating benefits are summarized as follow.

<u>Basic Plan</u>	<u>1978</u>	<u>Escalated Cost</u>
Estimated Cost, Steam Generation	\$16,918,000	\$17,873,000
Electric Generation	<u>2,634,000</u>	<u>2,819,000</u>
Total	\$19,552,000	\$20,692,000
Cost Benefit, Western Coal	\$ 1,698,431	\$ 2,107,244
Electric Power	702,630	911,135
<u>Option I, Add-On Customers</u>		
Estimated Cost	\$ 1,828,000	\$ 1,956,000
Added Western Coal Cost	421,178	521,493
Benefit, Added Generation	39,673	50,734
Displaced Fuel (Gas and Oil)		
Indirect Benefit	554,975	885,643
Equivalent Saving	2,900,000 gal., oil (69,000 barrels)	
<u>Option II, Pyrolysis</u>		
Estimated Cost	\$ 7,700,800	\$ 8,240,000
Annual Fuel and Electric Benefit	304,424	346,646

<u>Option III, Hot Water</u>	<u>1978</u>	<u>Escalated Cost</u>
Estimated Cost	\$ 1,930,000	\$ 2,065,000
Annual Benefit	142,914	184,744

Implementation of the Energy System includes installation of coal unloading for partial unit train shipments, rehabilitation of the Southeast Generating Station (including Pollution abatement facilities), interconnection of the Southeast Station to the University thermal system, and installation of a single automatic extraction non-condensing turbine-generator; all as described herein.

Yours very truly,

HELMICK & LUTZ COMPANY

George W. Burke

GWB:jmn

The Phase I Report, Grid-ICES, the Phase II Stage I, Preliminary Report and the Stage I Report Supplement developed the recommended Integrated Community Energy System at the University of Minnesota.

The Energy System consists of a Basic Plan and three Options as described below:

A. Basic Plan

1. The University of Minnesota as the Community.
2. Acquisition and rehabilitation of the Southeast Generating Station as the Grid Connected source utilizing Western sub-bituminous coal and providing electric power generation as the by-product of Community thermal load.
3. Northern States Power Company as the Grid Connected utility.

B. Option I - Add-On Customers

1. Expansion of the Community thermal load by extension of the University steam system.
2. Add-On Customers
 - a. St. Mary's Hospital
 - b. Fairview Hospital
 - c. Augsburg College

C. Option II - Pyrolysis

1. Addition to the Southeast Generating Station of solid waste disposal by the Pyrolysis method with waste heat recovery.
2. Pyrolysis unit to be the Andco-Torrax process to provide high temperature, sterile reduction of contaminated Hospital waste.
3. Waste heat recovery at high pressure boiler steam conditions to augment the Grid Connected source.

D. Option III - Hot Water Distribution

1. Conversion of a portion of the University steam distribution system to high temperature, hot water distribution.
2. A Demonstration system to provide maximum by-product electric generation, minimum thermal system losses, and maximum thermal system range.

This report presents the Preliminary Design Description of the energy system and identifies the quantitative benefits of the cost of fuel and the sale of electric power, enabling complete economic analysis by the University of Minnesota.

TABLE 1
QUANTITATIVE GAINS

The Basic Plan and each Option provide the following quantitative benefits in energy consumption.

Basic Plan

1. Electric generation -	40,566,000 KWH/year
2. Central station heat rate -	10,662 BTU/KWH
By-product heat rate -	4,619 BTU/KWH
	<hr/>
Saving per KWH -	6,043 BTU
Annual saving -	245,140 x 10 ⁶ BTU, or
Equivalent western coal -	13,787 tons

Option I - Add-on Customers

1. Incremental electric generation - 4,209,000 KWH
2. Annual electric saving - 25,435 x 10⁶ BTU, or
1,430 tons, western coal
3. Directly displaced customer fuel equivalent of 2,900,000 gal. of fuel oil

Option II - Pyrolysis Waste Disposal

1. Incremental electric generation - 3,458,000 KWH
2. Annual electric saving - 20,897 x 10⁶ BTU, or
1,175 tons, coal
3. Waste fuel saving per year - 311,802 x 10⁶ BTU, or
17,537 tons, coal

Option III - Hot Water Distribution

1. Incremental electric generation - 5,802,000 KWH
2. Annual saving - 35,061 x 10⁶ BTU, or
1,972 tons, coal

TABLE 1 (Continued)

Summary of Energy Consumption Reduction

1. Basic Plan	245,140 x 10 ⁶ BTU/year
2. Option I	25,435 x 10 ⁶ BTU/year
3. Option II	
a. Electric	20,897 x 10 ⁶ BTU/year
b. Fuel	311,802 x 10 ⁶ BTU/year
4. Option III	35,061 x 10 ⁶ BTU/year
<hr/>	
Total	638,335 x 10 ⁶ BTU/year

In addition to conservation of energy, the ICES provides the following benefits

1. Stabilizes community fuel cost with the use of abundant lower cost Western coal.
2. Reduces the amount of sulfur dioxide emissions by substitution of low sulfur Western coal for Eastern coal and No. 6 Fuel Oil.
3. Implementation of Option II, Pyrolysis, will provide for:
 - a. Environmentally sound disposal of contaminated hospital wastes.
 - b. 97% reduction of landfill area for 132 tons per day of waste material.

**GRID ICES
PROCESS DIAGRAM
COGENERATION OF ELECTRICITY
AS A BY-PRODUCT OF HEAT**

7
MINNEAPOLIS

**HELMICK & LUTZ
ENGINEERS**

MINNESOTA

UNIVERSITY
OF
MINNESOTA

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Basic Plan

The Minneapolis Campus is served by a central heating plant using coal, oil and gas fuels. Availability of natural gas has declined to the point that it will be discontinued. The cost of fuel oil requires its use as a standby fuel. Therefore, coal will become the primary fuel.

Coal used at the University has been Eastern or Mid-western coals secured in barge load lots. This fuel averages 12,726 BTU/lb and currently costs \$39.40 per ton (\$1.548 per 10^6 BTU). Barge shipment requires clam shell unloading, trucking of all coal and off Campus storage of winter fuel supply.

The University has negotiated an agreement to secure partial unit-train shipments of Western sub-bituminous coal (8,890 BTU/lb) at a cost of \$15.6427 per ton (\$.88 per 10^6 BTU). Utilization of this coal will require a new rail unloading system and a de-rating of existing coal fired boiler equipment. Coal delivery will be year around and the unloading system will permit conveyor delivery to on-site storage.

Current steam load will exceed existing boiler capacity on Western coal and expansion space is not available at the current plant site. Therefore, the University has purchased the "Southeast Generating Station" from Northern States Power Company. This station is 3,000 feet west of the University plant and has three usable boilers, two of which can be rehabilitated for coal firing. All electrical generating equipment has been removed and the available building space is adaptable for expansion to a cogenerating facility. It is particularly suited for by-product generation since the boiler equipment at Southeast is designed for steam generation at a nominal level of 450 psig 750° F, permitting consideration of a non-condensing turbine to supply the existing 175 psig and 15 psig distribution systems.

Accordingly the basic system plant has been developed as outlined below:

1. Interconnect the Southeast Generating Station and the Minneapolis Campus Heating Plant to form a Community energy center.
2. Install a rail, coal unloading system to permit use of low cost, low BTU, low sulphur Western coal as the primary fuel.
3. Rehabilitate the Southeast Station as a based loaded, coal fired plant with proper environmental controls.
4. Install a non-condensing turbine-generator to provide electric power as a by-product of the thermal load.
5. Enter into an agreement with Northern States Power Co. for the sale of the available electric power.

The Southeast Generating Station will have a capability of 236,000 pounds per hour steam rate on coal firing and would operate year around. An existing boiler, oil fueled, has a capability of 160,000 pounds per hour and would be used for standby capacity. All steam would be reduced to 180 and 20 pounds pressure through an automatic extraction non-condensing turbine. The reduced steam headers and a condensate return line would be interconnected to existing systems in the Minneapolis Heating Plant.

The University Heating Plant would operate six months each year (October through March) when thermal demand normally exceeds the capability of the Southeast Station. Existing coal fired equipment would operate at 180 psig nominal pressure into a common header system with the 180 psig extracted steam. A minimum pressure of 175 psig would be maintained to satisfy load requirements.

Option I - Add-On Customers

Adjacent to the West Bank Campus of the University are Fairview and St. Mary's Hospitals; across from the hospitals is Augsburg College.

The three institutions have agreed to join the energy community and would purchase steam from the system. Their heating systems, oil and gas fired, would be shut down and removed.

St. Mary's Hospital Heating Plant provides steam both for itself and Fairview. Steam is generated at 150 psig nominal with interruptible natural gas and No. 6 fuel oil.

Augsburg College operates three low pressure steam boiler rooms on interruptible natural gas and No. 4 or No. 5 fuel oil.

A connecting tunnel would be constructed from the nearest University building (Middlebrook Hall) to the vicinity of St. Mary's Heating Plant, Augsburg would be fed with direct buried steam and condensate line extensions.

Each steam customer would be separately metered and billed under contract agreements presented with this report.

Option II - Solid Waste Pyrolysis

The University presently operates two 50 ton per day incinerators for the disposal of its normal solid waste and all University Hospital contaminated waste. No alternate disposal means is available for the contaminated waste portion.

Operation of the incinerators is in violation with current standards for air quality and ash disposal.

Investigation of Hospital waste disposal in the Minneapolis-St. Paul Metropolitan Area indicates a great need for a system that would provide environmentally sound disposal of contaminated materials. A successfully developed system is offered by Andco-Torrax in the form of a gas generating pyrolysis unit followed by secondary combustion of the off-gas. Waste products from this system are a water cooled, sterile frit material and a hot gas with sufficient energy content for the generation of steam as a by-product.

Space exists in the Southeast Station to accommodate the Pyrolysis system and waste heat boiler. Based on a survey of Hospital waste availability, the unit size would be 132 tons per day. Input of 132 tons per day would be stabilized by receiving Municipal wastes to maintain level operation. This would result in the availability of 38,000 pounds per hour of steam at 450 psig 750° F from waste heat.

As a back-up facility to the Pyrolysis system, the existing incinerators would be up-graded to provide environmental compliance.

Complete design description of Pyrolysis is contained in Volume 4.

Option III - Hot Water Distribution

All buildings on the University West Bank Campus and a portion on the East Bank are heated by circulating hot water and cooled by steam adsorbtion generated chilled water, both systems tied to the high pressure steam (180 psig) system.

The primary heat exchanges could be changed or converted to a lower energy level, hot water system. Generation of hot water at the heating plant would use a higher ratio of turbine-generator exhaust steam, increasing by-product electric power.

Establishment of a hot water distribution loop would provide for more economic future load growth. Campus growth (new buildings) would be on the West Bank and multiple dwelling housing is adjacent to this campus area.

Hot water distribution, in addition to maximizing by-product generation, provides minimum system losses and maintenance, flexibility of design, and increases the range of thermal service.

GRID ICES
ELEVATED CONVEYOR/
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TYPICAL SECTION

TYPICAL ELEVATION

Three primary considerations of either the Basic Plan or combined Option I Plan are as follows:

- A. The minimum steam service pressure required at any use point of the high pressure system is 125 psig
- B. The existing low pressure system requires 10% of base system load at a minimum plant header pressure of 15 psig
- C. The existing boilers in the Southeast Generating Station are designed for feedwater temperature of 250° F, saturation temperature of 15 psig steam

The line diagram of the steam system was developed, identifying all load points, main sizes and distances between service risers. Pressure drop calculations at maximum use indicate a maximum pressure drop of 50 psig to any steam service. This will require maintaining a minimum header pressure of 175 psig at the University Heating Plant. This also corresponds to the lowest operating pressure of the existing 200 psig boilers.

Therefore, the extraction steam pressure level of the proposed turbine-generator is 180 psig nominal (adjustable over a 10% range) to serve the primary load at 175 psig.

Since the University Heating Plant will not operate during the summer season, the low pressure system must be either pressure reduced from 175 psig or supplied by a turbine back-pressure level of 20 psig. This level (20 psig) also corresponds to the required pressure for the deaerating heater on the Southeast Station feedwater supply. Therefore, the non-condensing exhaust of the turbine-generator is set at 20 psig nominal.

Interconnection of the Southeast Station to the University Heating Plant would consist of a 180 psig header, a 20 psig header and a condensate return line. All connected to the existing header distribution system to yield a commonly operated energy center. The total capacity of the system is tabulated on the following page.

Expected peak load range can be satisfied with coal produced steam, and oil fired capacity will be used only on a standby or emergency basis.

Electrical connection of the turbine-generator will be made to a new set of 13.8 KV 500 MVA switchgear, with two breaker positions connected to existing Northern States Power Company cables to their Main Street sub-station. Either of these circuits can be synchronized to receive the generated power.

Station auxiliaries of the Southeast Station will be connected to key interlocked double throw, primary selective switches enabling feed from either the existing University feeder system (normal) or from self-generated or NSP Main Street source.

TABLE 2

PLANT CAPABILITY

I. Southeast Generating Station (450 psig 750°F)

<u>Boiler No.</u>	<u>Coal (8890 BTU/#)</u>	<u>No. 2 Oil</u>
1	-	160,000 #/hr.
3	108,000 #/hr.	-
4	128,000 #/hr.	-
	<u>236,000 #/hr.</u>	<u>160,000 #/hr.</u>

Turbine-Generator (Capability)

Throttle Capability -	350,000 #/hr.
180 psig Extraction -	0 to 330,000 #/hr.
20 psig Exhaust -	8000 to 140,000 #/hr.
Turbine rating, pressure rise point -	7,500 KW
Turbine rating, max output -	12,750 KW
Generator rating -	12,500 KW 0.85 PF
	13,800 volts

II. University Heating Plant

<u>Boiler No.</u>	<u>Coal (8890 BTU/#)</u>	<u>Oil</u>
1 (Standby)	60,000 #/hr.	
2	60,000 #/hr.	
3	60,000 #/hr.	
4	75,000 #/hr.	
5	94,000 #/hr.	
6		200,000
12 (Standby)	<u>68,000 #/hr.</u>	
	417,000 #/hr.	<u>200,000 #/hr.</u>

III. Total System

	<u>Coal</u>	<u>Oil</u>
Southeast Station	236,000 #/hr.	160,000 #/hr.
University Plant	417,000	200,000
	<u>653,000 #/hr.</u>	<u>360,000 #/hr.</u>

Projected Peak Community Load -
 Expected Range = 505,000 to 555,000 #/hr.

All load data for the University Campus and the Add-On Customers have been reviewed and monitored over the past two years. Hourly load data, correlated to gross space and weather data, have been entered into computer memory. All added or projected space requirements have been entered through the year 1985.

Accordingly, computer printouts are available for any year, month or season on an integrated basis and are similarly available on a percent occurrence basis (Load Duration) or on a load trend basis.

Heat balance diagrams for each option or load configuration are presented. Balance formulation was made for each load or source configuration and computer programmed against load memory data. Computer printouts are available for in-plant and community steam flows, electric production, fuel consumption and transportation requirements--all available on an annual basis, monthly basis (minimum, average and peak), by user and by Option.

Estimated date of final implementation of the Grid-ICES is 1981. The following tables indicates the heat balance quantities for 1981 and identify the cost and benefits derived from the system. Dollar values are based on current (January, 1978) cost escalated as noted to effective costs of 1981.

A separate section in this volume presents the manner of heat balance and computer input, and presents a complete printout of system parameters by Option.

TABLE 3

HEAT BALANCE QUANTITIES
(ANNUAL BASIS - 1981)

	<u>BASIC PLAN</u>	<u>OPTION I</u>	<u>OPTION II</u>	<u>OPTION III</u>
# Steam Generated (10 ⁶)	1947.1	2272.6	2259.9	2281.8
Total Coal Use (Tons)	157,377	181,925	156,334	157,982
Total Solid Waste (Tons)	-	-	46,200	46,200
Total No. 2 Oil (Gals.)	-	-	179,470	179,470
Total Natural Gas (MCF)	-	-	17,232	17,232
Total Tons, Coal Ash	12,590	14,554	12,507	12,639
Total Tons, Frit	-	-	9,009	9,009
Gross MWH Generated	40,566	44,775	48,233	54,035
Peak KW - Winter	7332	7494	8462	9876
Summer	6390	6466	7434	9389
Ave. Peak (Capacity Credit)	6861	6980	7948	9632
Coal to Electric Generation (4619 BTU/KWH)	10,888	11,730	12,422	13,579
Net Coal to Steam Generation	146,489	170,195	143,912	144,403
In-Plant MWH (S.E. & U of M)	9,328	9,762	13,762	14,412
By-Product Power Rate	21.75	22.56	23.63	25.17
Thermal Capacity Utilization Factor	73.2%	77.5%	69%	72%

TABLE 4
SUMMARY OF UTILITY UNIT COSTS

	<u>1978</u>	<u>Escalate</u>	<u>1981</u>
<u>Coal (Per Ton)</u>			
Western, 8,890 BTU/#	\$ 16.78	7.4 %	\$20.78
Eastern, 12,726 BTU/#	\$ 42.31	7.4 %	\$52.42
<u>Natural Gas (MCF)</u>			
Interruptible	\$ 1.92	13 %	\$ 2.77
Firm, Process	\$ 2.60	13 %	\$ 3.75
<u>Fuel Oil</u>			
No. 2 Per Gal.	.4125¢	13 %	.5951¢
Per 10 ⁶ BTU	\$ 2.946	13 %	\$ 4.25
No. 6 Per 10 ⁶ BTU	\$ 2.678	13 %	\$ 3.864
<u>Ash Disposal</u>			
Coal Ash, Per Ton	\$ 6.12	6.15%	\$ 7.32
Frit, Per Ton	\$ 1.53	6.15%	\$ 1.83
<u>Electric Power</u>			
Per MWH	\$26.20	10 %	\$34.87
<u>Electric Power Sale</u>			
Capacity Credit (KW)	\$64		\$83
Energy (MWH)	\$11		\$14
<u>Water & Sewer</u>	.535/1000 gal.	10 %	.712

TABLE 5

FUEL AND ELECTRIC POWER COSTS

I. BASIC PLAN

	<u>1978</u>	<u>1981</u>
A. Steam Generation Cost		
1. Coal (\$16.78/Ton, 7.4% Esc.) 146,489 Tons	\$2,458,085	\$3,044,041
2. Ash Disposal (\$6.12/Ton, 6.15%) 12,590 Tons	77,051	88,221
3. Electric Power (\$26.20 MWH, 10%) 9,328 MWH	244,394	325,288
Total	<u>\$2,779,530</u>	<u>\$3,457,550</u>
B. Electric Generation Benefit		
1. Coal Cost 10,888 Tons	(\$ 182,700)	(\$ 226,252)
2. Capacity Credit (\$64 to \$83) 6861 KW	439,104	569,463
3. Energy Sale (\$11 to \$14) 40566 MWH	446,226	567,924
Total	<u>\$ 702,630</u>	<u>\$ 911,135</u>
C. Steam Generation, Fuel Benefit, Western Coal		
1. Equivalent Eastern Coal 80/83 x 17.78/25.452 x 146,489 = 98,634 Ton Ash (10%) = 9,863 Ton		
2. Eastern Coal Cost (\$42.31/Ton, 7.4%) 98,634 Ton 9,863 Ton	\$4,173,205 60,362	\$5,170,394 69,112
Total	<u>\$4,233,567</u>	<u>\$5,239,506</u>
3. Western Coal & Ash	<u>2,535,136</u>	<u>3,132,262</u>
4. Fuel Benefit	\$1,698,431	\$2,107,244

TABLE 5 (Continued)

II. OPTION 1 (Incremental Basis)

	1978	1981
A. Steam Generation Cost		
1. Coal (170,195 - 146,489)	\$ 397,787	\$ 492,611
2. Ash (14,554 - 12,590)	12,020	13,748
3. Electric (9762 - 9328)	11,371	15,134
Total	\$ 421,178	\$ 521,493
B. Electric Generation Benefit		
1. Coal (11,730 - 10,888)	(\$ 14,242)	(\$ 18,069)
2. Capacity (6980 - 6861)	7,616	9,877
3. Energy (44,775 - 40,566)	46,299	58,926
Total	\$ 39,673	\$ 50,734
C. Fuel Displacement at Hospitals and Augsburg		
1. Equivalent BTU = $23,706 \times 17.78 \times 80/83 \times 10^6$ = $406,258 \times 10^6$		
2. 60% Oil = 243,755 (No. 6 Oil)	\$ 652,776	\$ 941,869
40% Gas = 162,503 (Interruptible)	312,006	450,133
3. Displacement Total	\$ 964,782	\$1,392,002
4. Indirect Fuel Benefit	\$ 554,975	\$ 885,643
5. Displaced Fuel Equivalent		

In terms of No. 2 Oil - 2,902,000 Gallons, or
69,000 Barrels

TABLE 5 (Continued)

III. OPTION II (Incremental Basis)

	1978	1981
A. Steam Generation Benefit		
1. Coal (170,195 - 143,912)	\$ 441,029	\$ 546,161
2. Fuel Oil, Cost, 179,470 Gal.	(74,031)	(106,803)
3. Natural Gas Cost, 17,232 MCF	(44,803)	(64,620)
4. Elec. Cost (13,762 - 9762)	(104,800)	(139,480)
5. Ash Credit (14,554 - 12,507)	12,528)	14,329
6. Frit Charge 9,009 Ton	(13,784)	(16,847)
Total Benefit	\$ 216,139	\$ 232,740
B. Electric Generation Benefit		
1. Coal Cost (12,422 - 11,730)	(\$ 11,705)	(\$ 14,850)
2. Capacity Credit (7948 - 6980)	61,952	80,344
3. Energy (48,233 - 44,775)	38,038	48,412
Total Benefit	\$ 88,285	\$ 113,906

IV. OPTION III (Incremental)

A. Steam Generation Cost		
1. Coal (144,403 - 143,912)	\$ 8,305	\$ 10,437
2. Ash (12,639 - 12,507)	808	990
Total Cost	\$ 9,113	\$ 11,427
B. Electric Generation Benefit		
1. Coal Cost (13,579 - 12,422)	(\$ 19,571)	(\$ 24,829)
2. Capacity Credit (9632 - 7948)	107,776	139,772
3. Energy (54,035 - 48,233)	63,822	81,228
Total Benefit	\$ 152,027	\$ 196,171
C. Net Benefit	\$ 142,914	\$ 184,744

I. GENERAL

Four modes of operation were considered for the electric connection of the by-product generated power. This section summarizes the investigation of Phase II, Stage 1 and Stage 2.

- a. Parallel operation with Northern States Power Company with synchronizing at the existing 4th Street Switching Station (main service point of the East Bank Campus).
- b. Parallel operation with Northern States Power Company with synchronizing to the Main Street Substation, with the Southeast Station on the synchronized bus only. (Sale of surplus power.)
- c. Parallel operation with Northern States Power Company, including a wheelage agreement from Main Street to 4th Street and simultaneous demand interval metering. (Self use of all generated power.)
- d. Parallel operation of the generator only to Main Street. (Sale of all generated power.)

II. EXISTING EAST BANK ELECTRIC SYSTEM

All power to the East Bank (Main) Campus of the University of Minnesota is received at the 4th Street Switching Station from two separate Northern States Power sources. There are many occasions that these sources cannot be operated in parallel.

Each University of Minnesota 13.8 KV feeder is bifurcated to permit source selection as well as primary selective switching. The Hospital and Health Science feeders must provide ultimate service reliability.

All feeders are run in underground concrete duct banks, are branched to numerous loads and are tapered in the load direction. Few spare duct runs exist. No existing feeder cable has the capacity to carry the proposed electric generator.

The existing East Bank 4th Street Switching Station, with the last addition of power factor capacitors, completely occupies the space available. It is located approximately 6,000 feet from the Southeast Generating Station.

III. TECHNICAL AND PHYSICAL CONSIDERATIONS

Parallel operation into the East Bank 4th Street Switching Station is not recommended from a technical standpoint. To accommodate operation by selective paralleling to two different Utility sources based on system loading will require dual breakers for each twin bussed service gear. Considering that relay setting and system stability. Add to this the remote location and extreme length of generator feed, one can state that the cost of the installation, on top of operating difficulties, is too high for further consideration.

The original Southeast Plant was a generating station for Northern States Power. The existing electric tie from Southeast to the Main Street Substation still exists and was designed for synchronizing. Therefore, connection of the new generator and switchgear is simply a matter of connecting to the existing cables. Relaying and synchronizing are with known conditions.

IV. ECONOMICS

Northern States Power Company contract with the University of Minnesota is a "Large General Service" GKO 25 rate schedule. Current basic charges are as follows:

<u>A. Demand</u>	<u>October - May</u>	<u>June - September</u>
Excess	\$4.15/KW	\$5.05/KW

B. Energy

First 1,000 MWH = \$18.20/MWH
Excess MWH = \$14.50/MWH

C. Determination of Demand

1. Normal service - 15 minute interval, with minimum demand established at 80% of peak demand occurrence during June through September.
2. Parallel service (Standby or Supplementary) - 15 minute interval, with minimum demand equivalent to 80% of greatest excess demand over the agreed standby demand occurring in the previous eleven months.

On the basis of the above, the East Bank Campus loading was projected by month to include the effects of the Southeast Generating Station on total load and typical billings projected at current rates.

Results of these billing calculations are as follows:

A. Parallel Operation at 4th Street (not recommended)

1. Lowest possible annual bill - \$1,900,000. This assumes no turbine outages.
2. Probable billing range with one turbine outage each year.
 - a. Outage at minimum demand = \$2,133,000
 - b. Outage at maximum demand = \$2,254,000

B. Parallel Operation at Southeast Station

Probable Billing Range
Minimum = \$2,208,000
Maximum = \$2,210,000

C. Parallel Operation with Wheelage Agreement

Probable Billing Range
Minimum = \$2,199,000
Maximum = \$2,320,000

D. Sale of all Generated Power

Total Purchase cost	=	\$2,892,000
Total Sales	=	\$ 742,000
Annual Cost	=	\$2,150,000

V. CONCLUSIONS

On the basis of economics, simplicity of operation, and in conformance with existing rate schedules, the sale of all generated power is recommended.

It should be pointed out that this electrical arrangement does not preclude changing the mode of operation in the future. Should there be dramatic rate changes that would favor a wheelage agreement or other service agreements, they could be implemented at a future date.

UNIVERSITY OF MINNESOTA

1981 EAST BANK LOAD
GENERATION WHEELED BY N.S.P.

	MONTHLY BILLING			GENERATOR OUTAGE PENALTIES	
	<u>Net Load</u>	<u>Wheel</u>	<u>Total</u>	<u>Min Demand</u>	<u>Max Demand</u>
J	\$ 125,805	\$ 6,225	\$ 132,030	\$ 26,560	\$ 36,188
F	115,760	5,700	121,460	28,220	35,358
M	133,880	5,625	139,505	25,315	34,943
A	156,740	5,325	162,065	21,580	31,208
M	172,810	5,025	177,835	12,035	21,663
J	201,400	5,025	206,425	9,960	24,485
J	193,575	5,175	198,750	10,790	20,418
A	195,760	5,475	201,235	12,450	22,078
S	176,665	5,025	181,690	19,920	29,548
O	156,865	5,250	162,115	21,165	30,743
N	139,315	5,775	145,090	24,070	36,698
D	<u>126,510</u>	<u>6,150</u>	<u>132,660</u>	<u>26,145</u>	<u>35,773</u>
TOTAL	\$1,895,085	\$65,775	\$1,960,860	\$238,210	\$359,103

BILLING RANGE

Net Load-----	\$1,960,860	\$1,960,860
Penalty-----	<u>238,210</u>	<u>359,103</u>
Total-----	\$2,199,070	\$2,319,963

UNIVERSITY OF MINNESOTA

1981 EAST BANK CAMPUS LOAD

<u>MONTH</u>	<u>CAMPUS LOAD</u>		<u>ADD SE LOAD</u>		<u>TOTAL LOAD</u>		<u>SE GEN</u>		<u>NET LOAD</u>	
	<u>MWH</u>	<u>DEMAND</u>	<u>MWH</u>	<u>DEMAND</u>	<u>MWH</u>	<u>DEMAND</u>	<u>MWH</u>	<u>PEAK KW</u>	<u>MWH</u>	<u>DEMAND</u>
J	8700	19700	740	1500	9440	21200	4940	7500	4500	13700
F	7200	19200	670	1500	7870	20700	4120	6800	3750	13900
M	8700	19200	740	1500	9440	20700	4400	6700	5040	14000
A	8500	19700	720	1500	9220	21200	2930	6300	6290	14900
M	8700	21600	740	1500	9440	23100	2700	5900	6740	17200
J	9700	22100	720	1500	10420	23600	2950	5900	7470	17700
J	9800	22100	740	1500	10540	23600	3540	6100	7000	17500
A	10200	22100	740	1500	10940	23600	3650	6500	7290	17100
S	8700	19700	720	1500	9420	21200	2820	5900	6600	15300
O	9100	19700	740	1500	9840	21200	3570	6200	6270	15000
N	8800	19700	720	1500	9520	21200	4260	6900	5260	14300
D	8700	19700	740	1500	9440	21200	4920	7400	4520	13800
TOTAL					115,530		44,800		70,730	

*Min. Billing Demand = 14,160

DISTANCES

S.E. Steam Plant to N.S.P. Main Street Substation—2000ft.

S.E. Steam Plant to U.of.M Steam Plant—3400ft.

U. of M. Steam Plant to U. of M. Switchgear Via Railroad Right of Way—2400ft.

U. of M. Steam Plant to U. of M. Switchgear Via Existing Ductbank—3500ft.

Note: All Distances Are Scaled Distances.

				DRAWN <u>MSC</u>		HELMICK & LUTZ ENGINEERS		MINNEAPOLIS		MINNESOTA		
				CHECKED _____								
				APPROVED _____								
REVISIONS		DATE	DWN	APP.	DATE	3-30-78						
UNIVERSITY OF MINNESOTA MINNEAPOLIS, MINNESOTA						ELECTRICAL GRID CONNECTION 25 PLOT PLAN				SCALE <u>1" = 100'</u> NO 625 ESK-1		REV. 0

NOTE:

UE - Denotes Underground
Electrical Ductbank

4th Street S.E.

GRID I.C.E.S. STUDY

				DRAWN <u>MSC</u>		HELMICK & LUTZ ENGINEERS MINNEAPOLIS MINNESOTA	
				CHECKED _____			
				APPROVED _____			
REVISIONS		DATE	DWN	APP.	DATE <u>3-30-78</u>		
UNIVERSITY OF MINNESOTA MINNEAPOLIS, MINNESOTA						ELECTRICAL GRID CONNECTION OUTDOOR SWITCHGEAR PLAN	
						SCALE 1" = 20' NO 625 ESK-2	
						REV. 0

NOTES:

- A. Solid lines show switchgear and feeder additions required to use by-product electricity internally.
- B. Dotted lines show existing switchgear and feeders plus equipment for the Basic Plan.

GRID I.C.E.S. STUDY

				DRAWN <u>MSC</u>		HELMICK & LUTZ ENGINEERS MINNEAPOLIS MINNESOTA	
				CHECKED _____			
				APPROVED _____			
REVISIONS	DATE	DWN	APP.	DATE	<u>3-30-78</u>		
UNIVERSITY OF MINNESOTA MINNEAPOLIS, MINNESOTA						ELECTRICAL GRID CONNECTION ALT. 13.8KV. DISTR. L/D - S.E. PLT.	
						SCALE NONE NO <u>625</u> ESK-4	REV. <u>0</u>

DISTANCES

S.E. Steam Plant to N.S.P. Main Street Substation—2000ft.

S.E. Steam Plant to U. of M. Steam Plant—3400ft.

Note: Distances Are Scaled.

GRID I.C.E.S. STUDY

				DRAWN <u>MSC</u>		HELMICK & LUTZ ENGINEERS		MINNEAPOLIS		MINNESOTA					
				CHECKED _____											
				APPROVED _____											
REVISIONS		DATE	OWN	APP.	DATE 4-18-78										
UNIVERSITY OF MINNESOTA						ELECTRICAL GRID CONNECTION						SCALE	+	+	
MINNEAPOLIS, MINNESOTA						29 PLOT PLAN						NO	625 ESK-5	REV.	0

Implementation of the project and selected options requires consideration of the various sub-systems as shown on the following "Project Systems Design Outline".

In accordance with that outline the "Major Equipment List" is included. Specifications for this equipment and tabulation of prices received are included in Volume 3 of this report.

Flow sheets illustrating the preliminary design are included as follows:

- 625 HB1 - Heat Balance
- 625 HB2 - Heat Balance
- 625 FS1 - Flow Sheet - S.E. Plant - Boilers
- 625 FS2 - Flow Sheet - S.E. Plant - Pyrolysis (Vol. 4)
- 625 FS3 - Flow Sheet - S.E. Plant - Feedwater
- 625 FS4 - Flow Sheet - University Plant
- 625 FS5 - Steam Distribution Sheet I
- 625 FS6 - Steam Distribution Sheet II
- 625 FS7 - Hot Water Distribution
- 625 FS8 - Steam Distribution Sheet IV
- 625 M-P - Water Heating Schematic

Instrumentation and control of the various systems has been developed as shown on the "Systems Instrumentation Schedule" and as shown on the following control diagrams:

- 625 C1 - Controls - Steam
- 625 C2 - Controls - No. 1 Boiler
- 625 C3 - Controls - No. 3 Boiler
- 625 C4 - Controls - No. 4 Boiler
- 625 C5 - Controls - Options
- 625 C6 - Controls - Console and Panel

Electric system design has been developed as illustrated on the following:

- 625 E1 - 13.8 KV Distribution Line Diagram
- 625 E3 - Secondary Distribution Line Diagram (Basic Plan)
- 625 E4 - Secondary Distribution - Option II (Volume 4)

Project capital cost budget, outline construction specifications and preliminary design layout and piping drawings are included in Volume 3.

A. Basic Plan

1. Plant Interconnections
 - a. Steam and Condensate
 - b. High Voltage Electric
 - c. Oil Line (No. 2 Oil)
 - d. Coal Handling (to bunker)
2. Southeast Utilities
 - a. Water
 - b. Sewer
 1. Lift Station
 2. Grit Basin
3. Southeast Fuel Handling
 - a. Coal Storage Remodeling and Conveyors to Bunker
 - b. Oil Storage and Pump Set (No. 2 Oil)
4. Southeast Plant Systems
 - a. Boiler Rework
 - b. Condensate System
 - c. Makeup Water Treating
 - d. Feedwater Deaerator and Pumps
 - e. Steam Piping
 - f. Plant Electric System
 1. Drive Changes
 - g. Emergency Systems
 - h. Pollution Control - Baghouse (Breeching changes, etc.)
 - i. Ash Handling
 - j. Compressed Air
5. Southeast Plant Remodeling
 - a. Exterior Work
 1. General
 2. Lighting
 - b. Interior Revisions
 - c. Roof Repair
6. Southeast Plant Generator
 - a. Turbine Generator
 1. Foundation
 2. Erection
 3. Piping
 - b. Switchgear
 1. Wiring
 2. Controls
 - c. Instrumentation
 1. Steam Metering

7. Southeast Plant Instrumentation
 - a. Boiler Controls
 1. Instrument Air Compressor
 2. Air Piping
 3. Electric Wiring
 - b. Steam and Condensate Metering
 - c. Computer Interface
 1. Fuel
 2. Steam and Condensate
 3. KWh
 8. University (Minneapolis) Heating Plant
 - a. Baghouses (under contract)
 - b. Incinerator Remodeling
- B. Option I - Add-Ons
1. Tunnel (University of Minnesota)
 2. Steam and Condensate Piping (to St. Mary's)
 3. Metering
 - a. St. Mary's
 - b. Fairview
 - c. Augsburg
 - d. University of Minnesota (total)
 4. Tunnel Lighting
 5. Steam and Condensate to Augsburg
 6. Augsburg Distribution and PRV's
- C. Option II - Pyrolysis
1. Andco System Delivered and Erected
 2. Waste Heat Boiler
 3. Inducted Draft Fan and Drive
 4. Boiler Instrumentation and Controls
 5. Refuse Crane and Auxiliaries
 6. Equipment Erection (not including Andco)
 7. General Construction Including Slag Tank
 8. Fly Ash System
 9. Baghouse Addition (pollution control)
 10. Mechanical Construction
 11. Electrical Construction

D. Option III - Hot Water

1. Upgrade Low Pressure Header
2. Hot Water Generating System
 - a. Heat Exchangers
 - b. Pumps (variable speed)
 - c. Receiver and Expansion
 - d. Water Treatment
 - e. Electric Wiring
3. Hot Water Loop Piping
4. Hot Water Instrumentation and Metering
5. Building Heating System Changes

4.8

MAJOR EQUIPMENT LIST

4.8.1

MAJOR EQUIPMENT ITEM NO. 1

TURBINE GENERATOR

1. Major Component or System

Turbine Generator

2. Function & Performance

SAENC - Single automatic extraction, non-condensing.
Generate electric power by steam pressure reduction.
Throttle conditions - 350,000 #/hr. max at 450 psig, 750°F TT
Extraction pressure - 180 psig
Exhaust pressure -20 psig

3. Intended Service

Capacity Rating - Turbine - 7500 KW @ pressure rise point.
Generator - 12500 KW @ 0.85 power factor, 13,800 volts.

4. Basis of Selection

Heat balance study indicates steam flow quantities available at peak load conditions at each pressure level.

5. Commercial Availability

Manufactured and fabricated for delivery in 16 to 18 months.
Available Vendors: General Electric Company
Turbodyne Corp. (Steam Turbine Division)

MAJOR EQUIPMENT ITEM NO. 2BAGHOUSE SYSTEM

1. Major Component or System

Baghouse System

2. Function & Performance

To remove particulate from the boiler flue gas so that the resulting emissions will meet State pollution requirements.

3. Intended Service

Capacity: 135,000 acfm @ 300°F

Air to cloth ratio: Approximately 2/1

Bags to be capable of withstanding continuous temperature of 500°F.

4. Basis of Selection

A baghouse will efficiently remove particulate from a flue gas stream down to 0.1 pounds per million BTU boiler input when burning low sulfur coal.

5. Commercial Availability

Manufactured and fabricated item delivered in 8 to 10 months.

Industrial Clean Air

Mikropul Corporation

Zurn Industries

Western Precipitation Division

Wheelabrator-Frye, Inc.

BAGHOUSE I.D. FAN

1. Major Component or System

Baghouse I.D. Fan

2. Function & Performance

To provide the draft loss through the baghouse system.

3. Intended Service

135,000 ACFM @ 300°F
Inlet static: -8.0"H₂O
Outlet static: 0.0"H₂O

4. Basis of Selection

With a multiple boiler installation served by a single dust collector, the most economical method of providing for the pressure drop through the dust collector is to provide an induced draft fan following the collector.

5. Commercial Availability

Manufactured item delivered in 22 to 26 weeks.
Zurn Industries
Buffalo Forge Company
Westinghouse Electric Corporation

BOILER FEED PUMPS

1. Major Component or System

Boiler Feed Pumps

2. Function & Performance

To provide the feedwater to the boilers.

3. Intended Service

Head	- 1300 feet
Capacity	- 300 gpm each
NPSH	- 20 feet
Temperature	- 250°F

4. Basis of Selection

Electric motor driven centrifugal pumps provide the best overall plant efficiency in a plant which has electric generation.

5. Commercial Availability

Manufactured item delivered in 8 months.
Ingersol-Rand Company
Byron Jackson Pump Division
Worthington Pump Corporation

WATER SOFTENING SYSTEM

1. Major Component or System

Water Softening System

2. Function & Performance

To treat city water for make-up to Plant Feedwater System.

3. Intended Service

Capacity: 100 gpm continuous
150 gpm peak

4. Basis of Selection

A hot lime-zeolite system is required to bring the impurities of the make-up water down to acceptable levels for use in a plant which has superheat boilers and a turbine-generator.

5. Commercial Availability

Manufactured and fabricated item delivered in 24 to 26 weeks.
Cochrane Environmental Systems
Environmental Dynamics Corporation

CONDENSATE TREATING SYSTEM

1. Major Component or System

Condensate Treating System

2. Function & Performance

To treat the condensate returned from the Campus heating system before introducing it into the boiler feedwater system.

3. Intended Service

Capacity:	600 gpm continuous
	800 gpm peak
Temperature:	140° - 200°F
Treated water quality:	20 ppm, max.

4. Basis of Selection

A regenerable ion-exchange type condensate treatment system was chosen to remove the suspended and dissolved impurities in the condensate returned from the Campus because of its low initial cost and operating cost.

5. Commercial Availability

Manufactured item delivered in 24 to 26 weeks.
Cochrane Environmental Systems
Environmental Dynamics Corporation

DEAERATING HEATER AND STORAGE TANK

1. Major Component or System

Deaerating Heater and Storage Tank

2. Function & Performance

To heat, remove dissolved gases, and provide storage for feedwater.

3. Intended Service

Deaerating heater capacity:	300,000 #/Hr. nominal
	400,000 #/Hr. peak
Storage tank capacity:	10,000 gals. min.
Guaranteed deaerator outlet:	Oxygen - less than 0.005 cc/liter
	Carbon Dioxide - 0.0

4. Basis of Selection

Feedwater supplied to the boilers must be heated and deaerated to prevent thermal stress and corrosion in the boiler drums and tubes.

5. Commercial Availability

Fabricated item delivered in 24 to 26 weeks
Chicago Heater
Environmental Dynamics Corporation
Cochrane Environmental Systems

CONTINUOUS BLOWOFF SYSTEM

1. Major Component or System

Continuous Blowoff System

2. Function & Performance

To provide for regulation of boiler water dissolved solids concentration at the desired level. Heat is recovered from the flash steam, which is used in the 20 psig system, and the waste water, which is used to heat incoming city water.

3. Intended Service

Quantities: Boiler output - 300,000 #/Hr.
 Blowdown, max.- 15,000 #/Hr.

4. Basis of Selection

Overall plant efficiency will be improved by the recovery of most of the heat in the boiler blowoff water.

5. Commercial Availability

Manufactured item delivered in 24 to 26 weeks.
Cochrane Environmental Systems
Environmental Dynamics Corporation
Madden Corporation

AIR COMPRESSOR WITH INTAKE FILTER, AFTERCOOLER,
AIR RECEIVER AND AIR DRYER

1. Major Component or System

Air Compressor with Intake Filter, Aftercooler, Air Receiver and Air Dryer

2. Function & Performance

To provide oil free compressed air for instruments and controls.

3. Intended Service

Capacity -	160 scfm, nominal
Discharge pressure -	100 psig
Intake temperature -	95°F max.

4. Basis of Selection

A teflon ring non-lubricated air compressor will provide oil-free compressed air and the addition of a refrigerated type air dryer will prevent condensed water in the instruments down to approximately 35°F.

5. Commercial Availability

Manufactured item delivered in 16 weeks.
Worthington Pump Corporation
Ingersoll-Rand Company
Chicago Pneumatic Tool Company
Dollinger Corporation
Air Maze
Air Tek

ASH HANDLING SYSTEM

1. Major Component or System

Ash Handling System

2. Function & Performance

To remove ashes from the boilers and baghouse, convey to a storage silo and transfer ashes from the silo to trucks.

3. Intended Service

Heavy duty, abrasive resistant, designed especially for handling coal ashes and fly ash.

4. Basis of Selection

A negative pressure pneumatic conveyor is the most economical method of handling ash and fly ash in the quantities produced in the plant.

5. Commercial Availability

Manufactured items delivered in 29 to 36 weeks.

United Conveyor Corporation

Allen-Sherman-Hoff

Beaumont Birch

Detroit Stoker Corporation

WASTE HEAT RECOVERY BOILER

1. Major Component or System

Waste Heat Recovery Boiler

2. Function & Performance

To generate steam from the waste gas generated by the pyrolysis system.

3. Intended Service

Produce steam at 450 psig, 725°F

Waste gas flow - 108,000 #/Hr. @ 2300°F

Inlet gas pressure - -18 lwg

Outlet gas temperature - 460°F max.

4. Basis of Selection

Exhaust gas from the pyrolysis unit is comparable to the gas produced by burning fuel in a conventional boiler. This gas is used to produce steam in a boiler similar to that of a conventional boiler.

5. Commercial Availability

Fabricated item delivered in 8 to 9 months.

Deltak Corporation

Erie City Energy Division, Zurn Industries

WASTE HEAT BOILER I.D. FAN

1. Major Component or System

Waste Heat Boiler I.D. Fan

2. Function & Performance

To transfer gas from downstream of the waste heat boiler to the inlet of the gas cleaning system.

3. Intended Service

Capacity: 55,000 ACFM @ 460°F and 28 inwg.

4. Basis of Selection

The pyrolysis system and the waste heat boiler have a draft loss which must be provided by the use of fans. Part of the loss is provided by fans on the air supply side and the remainder by this induced draft fan.

5. Commercial Availability

Fabricated item delivered in 22 to 26 weeks.

Buffalo Forge Company

Zurn Industries

Westinghouse Electric Company

1,000 KVA UNIT SUBSTATION**1. Major Component or System**

1000 KVA Unit Substation

2. Function & Performance

The substation provides a reduction in voltage from 13.8 KV to 480 V. It also provides switching and interrupting capabilities along with associated control, metering, protection and regulation on the primary and secondary sides of the transformer and secondary feeders.

3. Intended Service

Three phase, 60 cycle, 13,800 volt primary and
Three phase, 60 cycle, 480 volt secondary

4. Basis of Selection

The ability to reduce voltage and the ability to switch and control the primary and secondary of the transformer along with the secondary feeders.

5. Commercial Availability

35 week delivery
Allis Chalmers
General Electric
Westinghouse

2,500 KVA UNIT SUBSTATION

1. Major Component or System

2500 KVA Unit Substation

2. Function & Performance

The substation provides a reduction in voltage from 13.8 KV to 2300 V. It also provides switching and interrupting capabilities along with associated control, metering, protection and regulation on the primary side of the transformer and secondary feeders.

3. Intended Service

Three phase, 60 cycle, 13,800 volt primary and
Three phase, 60 cycle, 2300 volt secondary

4. Basis of Selection

The ability to reduce voltage and the ability to switch and control the primary of the transformer and secondary feeders.

5. Commercial Availability

20 week delivery
Allis Chalmers
General Electric
Westinghouse

13.8 KV METAL-CLAD SWITCHGEAR

1. Major Component or System

13.8 KV Metal-Clad Switchgear

2. Function & Performance

The switchgear is to provide switching and interrupting capabilities along with associated control, metering, protection and regulation.

3. Intended Service

Three phase, 60 cycle, 13,800 volts.

4. Basis of Selection

The ability to switch, synchronize and control the 13.8 KV service and feeders.

5. Commercial Availability

Manufactured item delivered in 40 weeks

General Electric

I-T-E

Westinghouse

COAL HANDLING SYSTEM

1. Major Component or System

Coal Handling Systems

2. Function & Performance

- A. Convey coal from the R.R. car unloading hopper to the storage piles at the Minneapolis Campus Heating Plant and the S.E. Steam Plant.
- B. Reclaim coal from storage pile and convey to boiler bunkers.

3. Intended Service

- A. Unloading to storage: 40, 100 T. cars in 10 hours
- B. Reclaim to bunker: 100 T. per hour

4. Basis of Selection

Based on previous experience, components selected will provide the intended service at the least initial cost and lowest maintenance.

5. Commercial Availability

Manufactured and fabricated items deliver in 6 to 10 months.
Nott Company
Jeffery Manufacturing Company
Rexnord Inc.

OVERHEAD TRAVELING CRANE

1. Major Component or System

Overhead Traveling Crane

2. Function & Performance

To convey refuse from the refuse pit to the feeder/hopper on the gasifier.

3. Intended Service

Capacity 10T

CMAA Class D Service

Incinerator Grapple Cap. 3 cu.yds.

4. Basis of Selection

Based on layout of pyrolysis system and building space limitations, an overhead crane with grapple is the only effective means of handling the refuse.

5. Commercial Availability

Manufactured item delivered in 20 weeks

Whiting

Shaw-Box

Shepherd Niles

TRANSMITTERS

A. Electronic

1. Flow - Bailey Type BQ 74221 Transmitters Including Orifice Plates, and Condensate Chambers
 - a. Southeast Plant System
 1. Condensate Flow
 2. Make-Up Water Flow
 3. Steam to Turbine Throttle
 4. Steam Flow from Turbine Extraction
 5. Steam Flow from Turbine Exhaust
 6. Steam Flow to Campus - 180 lb Header
 7. Steam Flow to Campus - 20 lb Header
 - b. No. 1 Boiler
 1. Feedwater Flow
 2. Steam Flow
 - c. No. 3 Boiler
 1. Feedwater Flow
 2. Steam Flow
 - d. No. 4 Boiler
 1. Feedwater Flow
 2. Steam Flow
 - e. Option I - Add-On Customers
 1. Steam Flow to St. Mary's Hospital
 2. Steam Flow to Fairview Hospital
 3. Steam Flow to Augsburg College
 4. Total Steam Flow to Add-On Customers
 - f. Option II - Pyrolysis Waste Heat Boiler
 1. Feedwater Flow
 2. Steam Flow
2. Flow - Bailey Type JR 1243, Style FS, Model VAIX Transmitter
 - a. No. 1 Boiler - Oil Flow
3. Flow - Bailey Type BY 5310 Transmitters
 - a. No. 1 Boiler
 1. Air Flow
 - b. No. 3 Boiler
 1. Air Flow
 - c. No. 4 Boiler
 1. Air Flow
4. Pressure - Bailey Type KS 68221 Transmitters
 - a. Southeast Plant System
 1. Feedwater Header
 2. Steam Header - 450 lb
 3. Steam Header - 180 lb
 4. Steam Header - 20 lb
 5. Steam Header - Softener

- b. No. 1 Boiler
 - 1. Drum
 - 2. Fuel Oil Header
 - 3. No. 1 Burner Fuel Oil
 - 4. No. 2 Burner Fuel Oil
 - 5. No. 3 Burner Fuel Oil
 - c. No. 3 Boiler - Drum
 - d. No. 4 Boiler - Drum
 - e. Option I - Add-On Customers - Steam Header
 - f. Option II - Pyrolysis Waste Heat Boiler - Drum
 - 5. Pressure - Bailey Type BQ 7321 Transmitters
 - a. Baghouse System - Inlet Duct
 - b. No. 1 Boiler - Furnace
 - c. No. 3 Boiler - Furnace
 - d. No. 4 Boiler - Furnace
 - e. Option II - Pyrolysis Waste Heat Boiler - Pyrolysis Pressure
 - 6. Differential Pressure - Bailey Type BY 5310 Transmitters
 - a. Baghouse System - Inlet to Outlet Manifolds
 - 7. Temperature - Bailey Thermocouple Assembly, Model Number as required for the specific temperature and pressure requirements.
 - a. Southeast Plant System
 - 1. Feedwater
 - 2. Steam Header - 750° F
 - 3. Steam Header - 450 lb/180 lbs PRV
 - 4. Steam Header - 180 lb to Campus
 - 5. Steam Header - 180 lb/20 lb PRV
 - b. No. 1 Boiler
 - 1. Superheater Outlet
 - 2. Economizer Water Outlet
 - 3. Fuel Oil Header
 - c. No. 3 Boiler - Superheater Outlet
 - d. No. 4 Boiler
 - 1. Superheater Outlet
 - 2. Economizer Water Outlet
 - e. Option II - Pyrolysis Waste Heat Boiler - Superheater Outlet
 - f. Option III - Campus Hot Water Heating System
 - 1. Water Return from Campus
 - 2. Water Supply to Campus
 - 8. Temperature - Bailey Sealed Resistance Temperature Detector, Model Numbers as required for the specific temperature and pressure requirements.
 - a. No. 1 Boiler
 - 1. Boiler Gas Outlet
 - 2. Economizer Gas Outlet
 - 3. Air Heater Gas Outlet
 - 4. Air Heater Air In
 - 5. Air Heater Air Out

- b. No. 3 Boiler
 - 1. Boiler Gas Outlet
 - 2. Air Heater Gas Outlet
 - 3. No. 1 Pulverizer Air In
 - 4. No. 1 Pulverizer Fuel/Air Out
 - 5. No. 2 Pulverizer Air In
 - 6. No. 2 Pulverizer Fuel/Air Out
 - c. No. 4 Boiler
 - 1. Boiler Gas Outlet
 - 2. Economizer Gas Outlet
 - 3. Air Heater Gas Outlet
 - 4. Air Heater Air In
 - 5. Air Heater Air Out
 - d. Baghouse System - Inlet Gas
 - e. Option II - Pyrolysis Waste Heat Boiler - Boiler Outlet
9. Level - Bailey Type BQ7 Transmitter, Range and Materials are required for the specific service.
- a. Southeast Plant System
 - 1. Deaerator Storage Tank
 - 2. Condensate Storage Tank
 - b. No. 1 Boiler - Drum Level
 - c. No. 3 Boiler - Drum Level
 - d. No. 4 Boiler - Drum Level
10. Oxygen - Bailey Type OJ11111-1 Oxygen Analyzer complete with all components
- a. No. 1 Boiler
 - b. No. 3 Boiler
 - c. No. 4 Boiler
 - d. Option II - Pyrolysis Waste Heat Boiler
11. Particulate Monitor - Bailey Type UJ100 Particulate Monitor with mounting and calibration kit
- a. Baghouse System Outlet
 - b. No. 1 Boiler
 - c. No. 3 Boiler
 - d. No. 4 Boiler
 - e. Option II - Pyrolysis Waste Heat Boiler Outlet

B. Pneumatic

- 1. Flow - Bailey Pneumatic Differential Pressure Transmitter including Orifice Plate
 - a. Option III - Campus Hot Water Heating System - Return Water from Campus
- 2. Level - Bailey Pneumatic Differential Pressure Transmitter
 - a. Southeast Plant System - Continuous Blowoff Tank
 - b. University Plant System - Condensate Tank
 - c. Option III - Campus Hot Water Heating System
 - 1. Condensate - 180 lb Heat Exchanger
 - 2. Condensate - 20 lb Heat Exchanger
 - 3. Condensate Return Tank

RECORDERS

A. Electronic - Bailey Type 772 Wide Roll Strip Chart Recorders with Necessary Signal Converters

1. Southeast Plant System
 - a. 3 Pen: Condensate to Deaerator; Make-Up Water to Deaerator; Storage Tank Level
 - b. 2 Pen: Feedwater Header Pressure; Feedwater Temperature
 - c. 2 Pen: Header Pressure - 450 lb; Header Temperature - 750° F
 - d. 3 Pen: Throttle Steam Flow; Extraction Steam Flow; Exhaust Steam Flow
 - e. 2 Pen: Campus Flow - 180 lb; Campus Pressure - 180 lb
 - f. 2 Pen: Campus Flow - 20 lb; Campus Pressure - 20 lb
2. Baghouse System - 3 Pen: Inlet Gas Temperature; Inlet to Outlet Differential Pressure; Outlet Particulate
3. No. 1 Boiler
 - a. 3 Pen: Steam Flow; Drum Pressure; Superheater Outlet Temperature
 - b. 2 Pen: Feedwater Flow; Drum Level
 - c. 2 Pen: Oxygen; Particulate
 - d. 2 Pen: Oil Flow; Oil Header Pressure
 - e. 3 Pen: Boiler Outlet Gas Temperature; Economizer Outlet Gas Temperature; Air Heater
 - f. 3 Pen: Economizer Outlet Water Temperature; Air Heater Inlet Air Temperature; Air Heater Outlet Air Temperature
4. No. 3 Boiler
 - a. 3 Pen: Steam Flow; Drum Pressure
 - b. 2 Pen: Feedwater Flow; Drum Level
 - c. 2 Pen: Oxygen; Particulate
 - d. 2 Pen: Boiler Outlet Gas Temperature; Air Heater Outlet Gas Temperature
 - e. 2 Pen: Pulverizer No. 1 Air Inlet Temperature; Pulverizer No. 1 Fuel/Air Outlet Temperature
 - f. 2 Pen: Pulverizer No. 2 Air Inlet Temperature; Pulverizer No. 2 Fuel/Air Outlet Temperature
5. No. 4 Boiler
 - a. 3 Pen: Steam Flow; Drum Pressure; Superheater Outlet Temperature
 - b. 2 Pen: Feedwater Flow; Drum Level
 - c. 3 Pen: Boiler Outlet Gas Temperature; Economizer Outlet Gas Temperature; Air Heater Outlet Gas Temperature
 - d. 3 Pen: Economizer Outlet Gas Temperature; Air Heater Inlet Air Temperature; Air Heater Outlet Air Temperature
 - e. 2 Pen: Oxygen; Particulate
6. Option I - Add-On Customers
 - a. 3 Pen: St. Mary's Hospital Steam Flow; Fairview Hospital Steam Flow; Augsburg College Steam Flow
 - b. 2 Pen: Total Steam Flow; Steam Header Pressure
7. Option II - Pyrolysis Waste Heat Boiler
 - a. 3 Pen: Steam Flow; Drum Pressure; Superheater Outlet Temperature
 - b. 3 Pen: Feedwater Flow; Drum Level; Superheater Outlet Temperature
 - c. 2 Pen: Oxygen; Particulate

B. Pneumatic - Bailey Type KM55A 3 Pen Recorder, Round Chart, 24 Hour Rotation, with Integration

1. Option III - Campus Hot Water Heating System: Return Water Flow (Record and Integrate); Return Water Temperature; Supply Water Temperature

4.9.3 COUNTERS - BAILEY TYPE 769 COUNTERS WITH SIGNAL CONVERTERS

A. Southeast Plant System

1. Throttle Steam and Extraction Steam
2. Exhaust Steam
3. Campus 180 lb Steam and Campus 20 lb Steam
4. Condensate to Deaerator and Make-Up Water to Deaerator

B. No. 1 Boiler

1. Steam and Feedwater
2. Fuel Oil

C. No. 3 Boiler

1. Steam and Feedwater

D. No. 4 Boiler

1. Steam and Feedwater

E. Option I - Add-On Customers

1. St. Mary's Steam and Fairview Steam
2. Augsburg Steam and Total Steam

F. Option II - Pyrolysis Waste Heat Boiler

1. Steam and Feedwater

4.9.4 INDICATORS - BAILEY TYPE 775 MULTI-INDICATORS

A. Southeast Plant System

1. Condensate Flow, Make-Up Water Flow, and Deaerator Storage Tank Level
2. Feedwater Pressure and Feedwater Temperature
3. Turbine Throttle: Flow, Pressure and Temperature

4. Campus Header - 180 lb: Flow, Pressure, and Temperature
5. Campus Header - 20 lb: Flow and Pressure
- B. No. 1 Boiler
 1. Air Flow, Oil Flow, Oil Temperature
 2. Oil Burner Pressure: No. 1, No. 2, and No. 3
 3. Drum Pressure and Drum Level
- C. No. 3 Boiler
 1. Steam Flow and Air Flow
 2. Drum Pressure and Drum Level
- D. No. 4 Boiler
 1. Steam Flow and Air Flow
 2. Drum Pressure and Drum Level
- E. Option II - Pyrolysis Waste Heat Boiler
 1. Drum Pressure and Drum Level
- F. Option III - Campus Hot Water Heating System (Include P/I Transducers)
 1. Return Water Flow, Return Water Temperature, and Supply Water Temperature

4.9.5 DRAFT GAUGES - BAILEY TYPE PG, WITH INTERNAL ILLUMINATION

- A. Baghouse System
 1. Inlet Gas
 2. Exit Gas
 3. I.D. Fan Outlet
 4. Reverse Air Header
- B. No. 1 Boiler
 1. F. D. Fan Outlet
 2. Windbox
 3. Furnace
 4. Boiler Outlet
 5. Economizer Outlet

6. Air Heater Outlet
 7. I. D. Fan Outlet
- C. No. 3 Boiler
1. F. D. Fan Outlet
 2. Furnace
 3. Boiler Outlet
 4. Dust Collector Outlet
 5. Air Heater Outlet
 6. I. D. Fan Outlet
 7. No. 1 Pulverizer Suction
 8. No. 1 Pulverizer Discharge
 9. No. 2 Pulverizer Suction
 10. No. 2 Pulverizer Discharge
- D. No. 4 Boiler
1. F. D. Fan Outlet
 2. Stoker Plenum
 3. Overfire Air
 4. Furnace
 5. Boiler Outlet
 6. Dust Collector Outlet
 7. Economizer Outlet
 8. Air Heater Outlet
 9. I. D. Fan Outlet
- E. Option II - Pyrolysis Waste Heat Boiler
1. Inlet Gas
 2. Exit Gas
 3. Economizer Outlet

- A. Electronic - Bailey Controllers, Type 701, 711, 712 and 714 complete with signal converting hardware necessary to control the various items.
1. Southeast Plant System
 - a. Condensate Tank Level
 - b. Deaerator Tank Level
 - c. Plant Master Steam Pressure
 - d. Turbine Extraction Pressure
 - e. 450 lb/180 lb PRV Station
 - f. Desuperheater for 450 lb/180 lb PRV
 - g. Desuperheater for Campus 180 lb Header
 - h. 180 lb/20 lb PRV Station
 - i. Desuperheater for 180 lb/20 lb PRV
 - j. Softener PRV
 2. Baghouse System - Inlet Manifold Pressure
 3. No. 1 Boiler
 - a. Boiler Master Steam Pressure
 - b. Feedwater Flow
 - c. Forced Draft Fan Damper
 - d. Forced Draft Fan Coupling
 - e. Induced Draft Fan Damper
 - f. Induced Draft Fan Coupling
 - g. Fuel Oil Flow
 4. No. 3 Boiler
 - a. Boiler Master Steam Pressure
 - b. Feedwater Flow
 - c. Forced Draft Fan Damper
 - d. Forced Draft Fan Coupling
 - e. Induced Draft Fan Damper
 - f. Induced Draft Fan Coupling
 - g. No. 1 Feeder
 - h. No. 1 Exhauster
 - i. No. 2 Feeder
 - j. No. 2 Exhauster
 5. No. 4 Boiler
 - a. Boiler Master Steam Pressure
 - b. Feedwater Flow
 - c. Forced Draft Fan Damper
 - d. Forced Draft Fan Coupling
 - e. Induced Draft Fan Damper
 - f. Induced Draft Fan Coupling
 - g. Overfire Air Fan Damper
 - h. Stoker Drive
 6. Option II - Pyrolysis Waste Heat Boiler
 - a. Boiler Inlet Pressure
 - b. Boiler Outlet Pressure
 - c. Feedwater Flow

7. Option III - Campus Hot Water Heating System
 - a. Return Water Temperature
 - b. No. 1 Pump Speed Control (H/A)
 - c. No. 2 Pump Speed Control (H/A)
 - d. No. 3 Pump Speed Control (H/A)

B. Pneumatic - Bailey Type AJ62 Indicator-Controllers

1. Option III - Campus Hot Water Heating System
 - a. Supply Water Temperature
 - b. Condensate Level - 180 lb Heat Exchanger
 - c. Condensate Level - 20 lb Heat Exchanger
 - d. Condensate Tank Level

C. Local Pneumatic - Fisher Type 2516 Controller with Type 67FR Regulator

1. Southeast Plant System - CBO Level
2. University Plant - Condensate Tank Level

4.9.7

FINAL ELEMENTS

A. Control Drives - Bailey Type AC with Electronic or Pneumatic Positioner, Sized to Meet the Required Torque

1. Baghouse System - I.D. Fan Damper Control
2. No. 1 Boiler
 - a. Forced Draft Fan Damper
 - b. Induced Draft Fan Damper
3. No. 3 Boiler
 - a. Forced Draft Fan Damper
 - b. Induced Draft Fan Damper
 - c. No. 1 Feeder
 - d. No. 1 Exhauster
 - e. No. 2 Feeder
 - f. No. 2 Exhauster
4. No. 4 Boiler
 - a. Forced Draft Fan Damper
 - b. Induced Draft Fan Damper
 - c. Overfire Air Fan Damper
 - d. Stoker Drive
5. Option II - Pyrolysis Waste Heat Boiler
 - a. Boiler Outlet Damper
 - b. Induced Draft Fan Damper

B. Control Valves - Fisher E Body Valves with Pneumatic Operators and I/P Transducers, Size and Pressure Rating as Required for the Service.

1. Southeast Plant System
 - a. Condensate to Deaerator
 - b. Soft Water to Deaerator
 - c. CBO Tank Drain
 - d. Turbine Extraction

2. University Plant - Condensate to Southeast Plant
3. No. 1 Boiler
 - a. Feedwater
 - b. Fuel Oil
4. No. 3 Boiler - Feedwater
5. No. 4 Boiler - Feedwater
6. Option II - Pyrolysis Waste Heat Boiler - Feedwater
7. Option III - Campus Hot Water Heating System
 - a. Steam to 180 lb Heat Exchanger
 - b. Condensate from 180 lb Heat Exchanger
 - c. Condensate form 20 lb Heat Exchanger
 - d. Condensate Return to Plant

4.9.8 CONDENSATE METERS - CADILLAC, SIZED FOR THE FLOW

A. Option I - Add-On Customers

1. St. Mary's Hospital
2. Fairview Hospital
3. Augsburg College
4. Total Condensate

4.9.9 ANNUNCIATORS - Panalarm Series 80, with Cabinets for Wall Mounting, 2 Windows high x 5 windows wide, Twin Point where Indicated, Sequence TFS, first-out indication, with Flasher and Remote Horn

- A. No. 1 Boiler: F. D. Fan; I. D. Fan; High/Low Drum Level; High Steam Pressure; No. 1 Burner Flame Out and No. 2 Burner Flame Out (Twin-point); Burner Air Flow and Low Air Flow (Twinpoint): Smoke; Low Water Cut-Off; Low Atomizing Steam Pressure and Low Fuel Oil Pressure (Twin-point); No. 3 Burner Flame Out and Fuel Cock Open (Twinpoint)
- B. No. 3 Boiler: F. D. Fan; I. D. Fan; High/Low Drum Level; High Steam Pressure; Low Air Flow; Smoke; Low Water Cut-Off; High O₂
- C. No. 4 Boiler: F. D. Fan; I. D. Fan; High/Low Drum Level; High Steam Pressure; Coal Flow; Low Air Flow; Smoke; Low Water Cut-Off; High O₂; Stoker Shear Pin
- D. Waste Heat Boiler, Baghouse and Plant Air: Waste Heat Boiler I. D. Fan; Waste Heat Boiler High/Low Drum Level; Baghouse I. D. Fan.; Baghouse Pressure Drop; Low Instrument Air Pressure; Waste Heat Boiler Smoke; Waste Heat Boiler High Steam Pressure; Baghouse Smoke; Low Plant Air Pressure
- E. Turbine, Campus and Hot Water System: Turbine Throttle Pressure; Campus 180 lb Header Pressure; Condensate Surge Tank High/Low Level; Regenerate Softener; Hot Water Heat High/Low Supply Temperature; Feedwater Header Pressure; Campus 20 lb Header Pressure; Deaerator Storage Tank High/Low Level; Hot Water Heat Low Water Flow; Hot Water Heat High/Low Return Temperature

- A. Operator's Console
 - 1. Bailey Style QCD Contour No. 3
 - 2. Length - 16'-0"
- B. Recorder Panel
 - 1. Bailey Style QAD
 - 2. Length - 113"
 - 3. Height - 84"
 - 4. Depth - 30"
- C. Option I - Add-On Customers
 - 1. Bailey Panel Style QAD
 - 2. Length - 23"
 - 3. Height - 84"
 - 4. Depth - 30"
- D. Option III - Campus Hot Water Heating System
 - 1. Bailey Panel Style QAD
 - 2. Length - 41"
 - 3. Height - 84"
 - 4. Depth - 30"

SOUTHEAST GENERATING STATION

MPLS. HEATING PLANT

PRELIMINARY DESIGN, PHASE II, STAGE 2

Rev.	Date	By	Remarks	None
1	1-1-75		FOR REPORT	
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PRELIMINARY DESIGN, PHASE II, STAGE 2				
Rev	Date	By	Check	Appr
MUN	11-1-77		FOR REPORT	
	3-3-78		FOR REPORT	
			UNIVERSITY OF MINNESOTA MINNEAPOLIS, MINNESOTA	
			GRID 100'S 0000	
			FLOW SHEET - SE. PLANT - BOILERS & T.G.	
			Helmick & Lutz Engineers Minneapolis, Minnesota	
			625 FS-1

KEY:
W - WINTER PEAK LOAD IN GPM OF 250°F
S - SUMMER " " " " 300°F

PRELIMINARY DESIGN, PHASE II, STAGE 2			
Rev.	Date	By	Check
1	3-5-70		For Review
UNIVERSITY OF MINNESOTA MINNEAPOLIS, MINNESOTA			NONE
GRID I, C.E.S. STUDY			
HOT WATER DISTRIBUTION DIAGRAM			625
Heinrich & Lutz Engineers			FS
Missneapolis, Minnesota

PRELIMINARY DESIGN, PHASE II, STAGE 2

Date	Drawn	Rev.	Remarks	Scale
11-1-12			For report	1"=100'
3-3-28			For Report	
			Grid I.C.E.S. Study	
			STEAM DISTRIBUTION DIAGRAM SHT IV	625
			Helwick & Lutz Engineers Minneapolis, Minnesota	FS-8

PRELIMINARY DESIGN, PHASE II, STAGE 2			
Rev	Date	By	Check
1	3-3-74	PRELIMINARY	None
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PRELIMINARY DESIGN, PHASE II, STAGE 2

Date	By	Rev.	Notes	Project	Sheet
3-2-75			PRELIMINARY FOR REVIEW	UNIVERSITY OF MINNESOTA MINNEAPOLIS, MINNESOTA	65
				GAO LIES STUDY	
				CONTROLS - N2 3 BOILER	625
				Helmich & Lutz Engineers Minneapolis, Minnesota	C-3

PRELIMINARY DESIGN, PHASE II, STAGE 2

Rev	Date	By	Check	Notes	Sub
1	1-1-78			PRELIMINARY FOR REPORT	MORE
				GRADUATES STUDY	
				CONTROL OPTIONS - ADD ON PYROLYSIS & HOT WATER	625 C-5
				Malnick & Lutz Engineers Minneapolis, Minnesota

PANEL LAYOUT
RECORDERS & TRANSMITTERS
NO. 1, 3 & 4 BOILERS
WASTE HEAT BOILER
TURBINE & CAMPUS

PANEL LAYOUT
ALARM & ANNUNCIATOR

PANEL LAYOUT
HOT WATER SYSTEM

PRELIMINARY DESIGN, PHASE II, STAGE 2

Rev	Date	By	Check	Notes
1	3-3-59			PRELIMINARY
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The following materials represent the preliminary design of the inter-connecting deep tunnel between the University's West Bank tunnel system in the vicinity of Middlebrook Hall to the proposed meter chamber at St. Mary's Hospital. Other volumes of the Stage II, Phase 2 report contain capital budget estimates, specifications and Phase III, IV, and V work plans.

UNIVERSITY OF MINNESOTA
TWIN CITIES

Engineering and Construction Division
Physical Planning Office
26 Folwell Hall
9 Pleasant Street S.E.
Minneapolis, Minnesota 55455

February 9, 1978

TO: Jim O'Gara

FROM: O.J. Nelson *O.J. Nelson*

SUBJECT: ICES Option I, Phase II, Stage II

Included in this memo is the information and attachments my office is required to furnish for the 210 day submittal to D.O.E. The information is identified by the task numbers as called for in Exhibit III of the Supplemental Agreement.

Task 3 Reporting and Deliverables

Phase II Final Design

Design analysis

- A. Elevation - The tunnel was located in the St. Peter Sandstone because this material is easily mined and comparatively safe. The Plattville Limestone provides a structurally sound roof above the tunnel. A tunnel in the sandstone is preferred over an open cut shallow tunnel because disruption to surface features is eliminated and construction costs are about the same. The University has successfully designed and constructed several miles of similar tunnel in the St. Peter Sandstone.
- B. Alignment - It was necessary to bend the tunnel to the southwest because of an elevation conflict with in-place City of Minneapolis sewer tunnels.
- C. Terminal point - The terminal shaft was located next to St. Marys Hospital Heating plant because it will be easily accessible; it is located in an area that will not be used for future building expansion; it is located next to the heat tunnel that serves Fairview Hospital; and the steam service can be easily extended to Augsburg College.

UNIVERSITY OF MINNESOTA STANDARD CONCRETE SPECIFICATIONS

May 22, 1970

Contract Item No.	Concrete Classification	Designated Use	Maximum Size Coarse Aggregate Inches	Minimum Cement Content Sacks/Cu. Yd.	Admixture per Manufacturer's Recommendation	Maximum Slump Inches	Air Content %
1	2500-12 P	Mass Concrete	1-1/2	4.4	Pozzololith	4"	3 ± 1
2	2500-12 P	Mass Concrete	1-1/2	5.0	----	4"	----
3	3000-12 P	Footings, Piers, Foundation	1-1/2	4.85	Pozzololith	4"	3 ± 1
4	3000-12	Walls, Heavy Section, etc.	1-1/2	5.5	----	4"	----
5	3000-06 P	Interior Slabs on grade and	3/4	5.35	Pozzololith	4"	3 ± 1
6	3000-06	Walls 4" to 8", Thin Section	3/4	6.00	----	4"	----
7	3750-12 P&D	Paving, Exterior Walls	1-1/2	5.25	Pozzololith & Darex	4"	4 ± 1.5
8	3750-12 D	Heavy Sections, etc.	1-1/2	5.75	Darex	4"	4 ± 1.5
9	3750-06 P&D	Exterior Walks, Curbs	3/4	5.75	Pozzololith & Darex	4"	6 ± 1.5
10	3750-06 D	Walls 4" to 8", Thin Section	3/4	6.25	Darex	4"	6 ± 1.5
11	4000-12 P	Heavy Structural Members &	1-1/2	5.5	Pozzololith	4"	3-1/2 ± 1
12	4000-12	Troweled Slabs over 6" Thick	1-1/2	6.0	----	4"	----
13	4000-06 P	Light Structural Section &	3/4	5.75	Pozzololith	3"	3-1/2 ± 1
14	4000-06	Troweled Slabs 4" to 6" Thick	3/4	6.25	----	4"	----
15	4000-03	Topping (Regular)	3/8	6.5	----	3"	3 ± 1
16	4000-03 D	Topping (Light Weight)	3/8" Acolite or 3/8" Materialite	6.75	Darex	3"	5 1/2 ± 1 1/2
17	5000-12 P	Structural Heavy Columns	1-1/2	6.5	Pozzololith	4"	3-1/2 ± 1
18	5000-06 P	Structural Medium Columns	3/4	7.0	Pozzololith	4"	----
19	5000-06 P&D	Exterior Precast	3/4	6.75	Pozzololith & Darex	4"	3-1/2 ± 1
20	5000-06 D	Exterior Precast	3/4	7.25	Darex	4"	6 ± 1.5
21	3750-12 DX	Pumping Mix	1-1/2" - 700# 3/4" - 1020# Sand - 1480#	5.34	Darex	3"	4 ± 1
22	3750-06 DX	Pumping Mix	3/4" - #4 1750# Sand 1480#	6.25	Darex	3"	4 ± 1
23	4000-04 DX	Pumping Mix	1/2" - 1070#	7.5	Pozzololith & Darex	3"	4 ± 1

Designation of Concrete Classification Column 2.

The first number indicates the minimum 28 day compressive strength in pounds per square inch.

The second number indicates the maximum size of coarse aggregate in eighths of an inch.

The letter "P" indicates the addition of pozzololith to the mix and the letter "D" the addition of Darex as an air entraining agent to the mix.

X indicates pumping mix.

The minimum cement content is for maximum slump shown and should produce strengths 15% to 20% over minimum strengths specified.

This supersedes standards dated March 20, 1970.

LEGEND

SANITARY SEWER
STORM SEWER
WATER MAIN UNDER 8" DIAM.
WATER MAIN OVER 8" DIAM.
GAS MAIN UNDER 8" DIAM.
GAS MAIN OVER 8" DIAM.
TELEPHONE UNDERGROUND
TELEPHONE OVERHEAD
ELECTRIC UNDERGROUND
ELECTRIC OVERHEAD
DRAIN TILE
FENCE
TUNNEL - DEEP
TUNNEL - SURFACE
STEAM (OR HEAT) UNDERGROUND
STREET LIGHTING ELECTRIC
WESTERN UNION
EXISTING GRADE
FINISH GRADE
SURVEY MONUMENT
SURVEY POINT
MANHOLE
MANHOLE WITH VALVE
CATCH BASIN, STREET
CATCH BASIN, FIELD
HYDRANT
VALVE
LAMP POST
UTILITY POLE
UTILITY POLE WITH TRANSFORMER
METER
PROPERTY LINE
TREE, SIZE, SPECIES

STANDARD LEGEND

GRID I.C.E.S. HEAT TUNNEL TO ADD ON CUSTOMERS

LOCATION PLAN

INDEX TO SHEETS

1. TITLE PAGE, KEY PLAN, INDEX
2. PLAN & PROFILE STA. 0+00 TO STA. 4+00
3. PLAN & PROFILE STA. 4+00 TO STA. 9+00
4. PLAN & PROFILE STA. 9+00 TO STA. 12+64
5. DETAIL PLAN AT MIDDLEBROOK HALL
6. DETAIL PLAN AT ST. MARY'S SHAFT & METER CHAMBER
7. TYPICAL DETAILS

REFER TO DRAWING NO. 13008 FOR SHAFT AND TUNNEL DETAILS
SUPERSEDES DRAWING NO. 17281

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

DATE _____ REG. NO. _____

UNIVERSITY
OF
MINNESOTA

ENGINEERING & CONSTRUCTION DIVISION
PHYSICAL PLANNING OFFICE

STAGE 2 - PHASE 2 - PRELIMINARY DESIGN
GRID CONNECTED INTEGRATED COMMUNITY ENERGY SYSTEM
UNIVERSITY OF MINNESOTA TO ADD ON CUSTOMERS - INTERCONNECTING HEAT TUNNEL

84

BY	DATE	SCALE	SHEET
OJN			
ADG		NOTED	1 of 7
CHECKED	DATE	REVISED	DRAWING
	2-14-78		
	1-13-78		17326

PRELIMINARY DESIGN GRID I.C.E.S. HEAT TUNNEL TO ADD-ON CUSTOMERS STA. 0+00 TO STA. 4+00		DATE: 12-78 SCALE: 1"=25' SHEET NUMBER: TWO
UNIVERSITY OF MINNESOTA DEPARTMENT OF PLANT SERVICES MINNEAPOLIS, MINN. 55455		DRAWING NUMBER: 17326

PRELIMINARY DESIGN GRID ICE'S HEAT TUNNEL TO ADD-ON CUSTOMERS STA. 4+00 TO 9+00		DATE 1-12-78 SCALE 1"=20' SHEET NUMBER THREE DRAWING NUMBER 1732.6
UNIVERSITY OF MINNESOTA DEPARTMENT OF PLANT SERVICES MINNEAPOLIS, MINN. 55455

REMOVE ARCH IN EXISTING LIMESTONE BLOCK TUNNEL. REPLACE W/ CONCRETE AS SHOWN.

DETAIL PLAN AT MIDDLEBROOK HALL

ENGINEERING & CONSTRUCTION DIVISION
PHYSICAL PLANNING OFFICE

PRELIMINARY DESIGN STAGE 2 - PHASE 2
GRID CONNECTED INTEGRATED COMMUNITY ENERGY SYSTEM
UNIVERSITY OF MINNESOTA TO ADD-ON CUSTOMERS - INTERCONNECTING HEAT TUNNEL

by	building	scale	sheet
ADG		1/2" = 1'-0"	5087
checked	date	revised	drawing
	1-12-78		17326

DETAIL OF ST. MARY'S SHAFT & METER CHAMBER

ENGINEERING AND CONSTRUCTION DIVISION
PHYSICAL PLANNING OFFICE

by	building	scale	sheet
ADG		1/4"=1'-0"	6 of 7
checked	date	revised	drawing
	1-12-78		17326

EXISTING TUNNEL AT
ST. MARY'S HOSPITAL

BEAM DETAIL AT
METER CHAMBER

EXPANSION CHAMBER SECTION

EXPANSION CHAMBER PLAN

TYPICAL TUNNEL AND EXPANSION
CHAMBER SECTION

TYPICAL SHAFT SECTION

(HALF SECTIONS ARE SYMMETRICAL)
ABOUT CENTERLINE

TYPICAL DETAILS

by	building	scale	sheet
ADG		1/2" = 1'-0"	7 of 7
checked	date	revised	drawing
	1-12-75		17326

PRELIMINARY DESIGN - STAGE 2 - PHASE 2
GRID CONNECTED INTEGRATED COMMUNITY ENERGY SYSTEM
UNIVERSITY OF MINNESOTA TO ADD-ON CUSTOMERS-INTERCONNECTING HEAT TUNNEL

SYMBOLS

- AN INCANDESCENT FIXTURE FOR ONE 60W - 4-21 LAMP
- 2⊗ A DUPLEX RECEPTACLE - 20 AMP (2 DESIGNATES 2 GANG)
- ⊗ A SINGLE RECEPTACLE - 60 AMP 3 POLE - 4 WIRE
- A JUNCTION BOX (NEW)
- (EXISTING)
- A PANELBOARD (SEE SCHEDULE)
- ⊗ SWITCH - 1 POLE - 20 AMP (LETTER DESIGNATES CONTROL)
- 3⊗ SWITCH - 3 WAY (LETTER DESIGNATES LIGHTS CONTROLLED)
- CONDUIT & WIRING (ARROW NOTES HOME RUN) (CROSS HATCH NOTES NUMBER OF WIRES)
- - - - EXISTING CONDUIT & WIRING .

FIXTURE TYPES

ELECTRICAL

by	building	scale	sheet
WM	000	NOTED	1 of 3
checked	date	revised	drawing
			17326E

NOTES:

- ① TEMPORARY SERVICE TO BE REMOVED WHEN PROJECT IS COMPLETED.
- ② CONNECT LTR TO EXIST. TUNNEL LTR. CIRCUIT. & SWITCH AT TUNNEL ENTRANCE & AT GRADE ENTRANCE.
- ③ MAKE CONNECTION TO STEAM METERS.
- ④ PROVIDE A #6 COPPER GROUNDING CONDUCTOR CONNECTED TO A GROUNDING ELECTRODE PER 250-26 OF N.E.C.

by	WM. OCO	scale	NOTED	sheet	3 of 3
checked	date	revised	drawing		
	1-13-78				17326E

PIPE GUIDE ANCHORS NOTE: FOR PIPE GUIDES USE SINGLE ANCHOR PLATE SIMILAR TO TUNNEL ANCHORS ABOVE. SEE PLAN FOR LOCATION.

UNIVERSITY
OF
MINNESOTA

STANDARD DETAILS
DEEP HEAT TUNNEL AND SHAFT

94

STAGE 2 - PHASE 2
GRID CONNECTED INTEGRATED COMMUNITY ENERGY SYSTEM
UNIVERSITY OF MINNESOTA TO ADD ON CUSTOMERS INTERCONNECTING HEAT TUNNEL

BY	DATE	REVISION	SCALE	SHEET
OJN	26	NOTED	1 of 1	
ADG				
CHECKED	DATE	REVISOR	DATE	DRAWING
	1-23-68	2-14-78	1-11-78	13008

Option III of the Grid-ICES is the conversion of an existing steam distribution system on the University's West Bank Campus to a 300° F hot water distribution system originating at the University Heating Plant. The heat exchangers at the plant which provide the 300° hot water utilizes high and low-pressure turbine steam and improves the by-product power rate of electric generation through a process known as regeneration.

The district hot water distribution will replace an existing steam distribution system as a demonstration program to show the utility of combined hot water distribution and by-product power distribution.

The materials contained in this Section provide the building loading, control system, and equipment location within a building. The buildings shown on the loading table are already hot water systems. This design then represents the materials necessary to convert the input steam distribution equipment within the building to hot water distribution.

Other volumes of the Phase II, Stage 2 report contain the capital budgets and specifications.

For background information, the following advantages and disadvantages are listed for hot water as a transport medium in a Grid-ICES.

Advantages

1. Energy source (power plant)
 - a. The lower the quality of the thermal energy needed for heating and cooling buildings, the higher the output of by-product electricity.
 - b. By converting the energy distribution medium from steam to hot water, the power plant has complete control of the steam and condensate system for the boiler turbine generation operation.
2. Transport (distribution system)
 - a. Distance to transport the energy is not a problem with hot water when compared to steam.
 - b. Variable volume pumping, designed to follow the load swings, minimizes pumping costs for optimized pipe sizes.
 - c. The lower temperature of the hot water reduces line loss in the transport system.
 - d. With the absence of steam traps and the closed system effect of hot water, lower maintenance costs result.
3. End User
 - a. Medium (300° F) to low (below 200° F) temperature hot water will be the lowest cost energy source for end users in a Grid-ICES. What the end user has to determine is can the savings in hot water over steam (over a set period of years) balance the capital costs of modifying a facility to utilize the lower quality energy.

4. Interaction with Community Planning
 - a. The long-range plan for the Twin Cities, as to their energy needs, is being studied by both Northern States Power and the Minnesota Energy Agency with both projects looking at hot water district heating as a viable solution. The primary energy source would be N.S.P. electric generating plants with plants such as the University of Minnesota being used for topping.
 - b. Hot water systems would be compatible as backup energy for solar heating and cooling.

Disadvantages:

1. Energy Source
 - a. Heat exchangers would be an add-on cost--offset somewhat by condensate filters and treatment needed when plant steam is distributed into the transport system.
2. Transport
 - a. Piping costs for short distances under .8 of a mile would be less for a steam system.
 - b. The existing University of Minnesota steam transport system is adequate for the planned Grid-ICES.
3. End User
 - a. There would be little or no changes in existing buildings to degrade from 200 psig to 180 psig.
 - b. Metering is more costly for the hot water systems. Certainly there were other values to review such as socio-environmental effects, OSHA, state-of-the-art, etc., but the impacts are minor because of the similarity of steam and hot water distribution systems as they relate to these concerns.

DISTRICT HEATING - HOT WATER - ENERGY AND OPERATION EFFECTIVENESS

A 300° F district hot water distribution system will replace an existing 200 psig steam distribution system on West Bank Campus.

The system can be segregated into major categories as follows:

1. Hot Water Generation at Southeast Steam Plant
2. Hot Water Distribution to Buildings
3. Building System Conversions
4. Thermal Storage Systems

The primary advantage of hot water heating is the storage capacity of water (lbs heat per cubic foot) compared to steam at equivalent saturation pressures. Because of the inherent storage capacity, design of hot water systems permit controlled circulation (variable speed pump drive) and system degeneration that requires less boiler capacity for an equivalent sized district steam system. This fact saves investment costs in capacity, in piping, in energy for pumping, in maintenance and operation, and in fuel costs.

Extraction of more heat per cubic foot from water versus equivalent steam allows system flow rates in distribution to be less. As a result, piping sizes and pump horsepower is reduced. Pump speed can be controlled with heat load thus reducing pumping energy costs.

Since the hot water system does not require pressure reduction stations, condensate return pumps, and steam traps, additional savings accrue in investment and maintenance costs.

System pressure loss along the distribution hot water mains are much less than a steam distribution system, and as a result the hot water system can be more effectively controlled and serve an area farther out on a distribution system than steam.

Makeup water requirements are practically non-existent thus reducing investment and operating costs for feedwater treatment equipment and makeup water costs.

The hot water distribution system insulated piping will be installed in existing deep tunnel systems on West Bank. The hot water distribution system will replace an existing 200 psig steam distribution system on West Bank. Hot water discharge from Southeast Steam Plant into the distribution system will vary from 300° F maximum to 200° F minimum. Return condensate will be maintained at 160° F. Since the hot water piping will be installed in existing tunnel systems containing steam mains there will not be any added environmental effects.

Hot water distribution and return piping will be run from the primary steam to hot water converters at the University Heating Plant to East Bank Campus and across the bi-level Washington Avenue bridge. An alternate route across the railroad bridge could also be used.

The following pages provide diagrams about the distribution system and calculations for pumping requirements and pipe sizes.

TABLE 6

AFFECT OF ΔT UPON PUMPING CAPACITY AND PIPE SIZE

Temp. Diff., ΔT	$^{\circ}\text{F}$	<u>20</u>	<u>50</u>	<u>100</u>	<u>150</u>
Plant Discharge Temp.	$^{\circ}\text{F}$	270	300	350	400
Return Temperature	$^{\circ}\text{F}$	250	250	250	250
20 MBTU Service Demand, 1000	lb/hr	1,000	400	200	133
Return Water Density	lb/Gal	7.86	7.86	7.86	7.86
Pump Capacity	GPM	2,125	850	425	283
*Assumed Pump Head	FT	100	100		
Pump Efficiency	%	60	60	60	60
Distribution Pipe Size	IN	8	6	4	3.5
*Assumed Pump Head to Prevent Flashing	FT	100	100	150+	200+

TABLE 7
RELATIVE COMPARISONS OF STEAM VERSUS
HOT WATER DISTRIBUTION SYSTEMS

	<u>Steam</u>	<u>Hot Water</u>
Thermal Transmission Effects (Insulation)	-	3 to 5% greater - Smaller pipe
Feedwater System	Condensate Flashing, Trap Leakage	No flashing, no traps
Blowdown	Losses of up to 1% unless returned to process	All water is recirculated
Boiler Firing and Control	Elevated Stack Temp. Uneven firing because of peaking and pressure drops	Peaking minimized by heat storage. Better System Control because of reduced pressure losses.
Pumping Costs	Larger, constant volume	Variable and less
Piping	Larger, pipe and water treatment	Smaller pipes, no scale, closed system
Operation	-	Savings in operation costs by degeneration during off peaks
Maintenance	Leaking traps, etc.	Less required no traps, etc.
Investment	-	Less

TABLE 8

**COMPARISON OF MAXIMUM PIPING SIZE REQUIREMENTS AND HEAT DEGRADATION -
STEAM VERSUS HIGH TEMPERATURE WATER DISTRIBUTION**

East Bank Requirements - 34,000,000 BTU/hr - Maximum Winter Rate
West Bank Requirements - 41,132,000 BTU/hr - Maximum Winter Rate

Discharge Requirement	BTU/Hr	EAST BANK			WEST BANK		
		Steam 34,000,000	Hot Water 34,000,000		Steam 41,132,000	Hot Water 41,132,000	
			T ₁	T ₂		T ₁	T ₂
Operating Pressure	PSIA	174	25	67	174	25	67
Discharge Temperature	°F	370	240(Low)	300(HIGH)	370	240(Low)	300
							(HIGH)
Return Temperature	°F	180	160	160	180	160	160
Enthalpy @ Discharge, h	BTU/lb	1,196	208	270	1,196	208	270
Enthalpy @ Condensate, h	BTU/lb	148	128	128	148	128	128
Difference, Δh	BTU/lb	853	80	142	853	80	142
Flow Rate	lb/hr	39,859	425,000	239,436.62	48,220	514,150	289,662
Density of Fluid	lb/ft ³	0.38	59.10	57.31	0.38	59.10	57.31
Volume	ft ³ /Sec	29.14	2.00	1.16	35.25	2.42	1.40
Design Velocity	ft/Sec	25.00	6.00	6.00	35.00	8.00	8.00
Required Cross Section	Sq. Ft.	1.17	0.33	0.19	1.01	.30	.18
Pipe Size (Sch. 80)	Inches	18	10	8	*24	*12	8
	(Dia.)	(16.126 ID)	(9.564 ID)	(7.625 ID)	(21.56 ID)	(10.75 ID)	(7.625 ID)
Pipe Volume/5000 ft ³	ft ³	7,091.00	2,495.00	1,585.50	11,950.00	3,151.00	1,585.50
Available Heat	BTU/ft ³	324.14	4,728	8,138.02	324.14	4,728.00	8,138.02
Heat Storage/5000 ft ³	BTU(10 ⁶)	2.30	11.80	12.90	3.87	14.90	12.90
Time Required to Absorb Stored Heat	Minutes	5.05	20.76	22.78	5.65	21.73	18.82

*12", 24" allows for pressure drop

Equations:

$$\text{Volume} = \frac{\text{Flow Rate}}{3,600 \times \text{Density}}$$

$$\text{Required Section} = \frac{\text{Volume}}{\text{Design Velocity}}$$

$$\text{Pipe Volume} = \text{Length} \times \pi \cdot r^2$$

$$\text{Available Heat} = \text{Density} \times \Delta h$$

$$\text{Heat Storage} = \text{Available Heat} \times \text{Pipe Volume}$$

$$\text{Time Required} = \frac{\text{Heat Storage} \times 60}{\text{Flow Rate} \times \Delta h}$$

The University of Minnesota's steam distribution system (steam and condensate lines) is in concrete-lined tunnels that are built in the St. Peter Sandstone. This relatively dry sand strata helps minimize the line losses in the system. The heat loss from the insulated steam and condensate pipes in the tunnels to the 50° F strata temperature is slow because of the insulating value of the dry sand. Though the line losses are low, they could be further reduced by a lower thermal distribution temperature. Our basic distribution system is saturated steam at 200 psig with a corresponding temperature of 388° F. The present ΔT is 388° F - 50° F or 338° F. For hot water on maximum load and a temperature of 300° F, the ΔT is 300° F - 50° F or 250° F. The theoretical savings in line losses for equal insulation is $85 \div 335$ or 25 percent. During light loads when the hot water loop is degraded to 240° F, the ΔT for hot water drops to 190° F, with a corresponding savings in line loss of $145 \div 335$ or 43 percent.

The normal concern on hot water distribution is a misguided quote stating that pumping costs are too high. In our modest-sized hot water loop, we anticipate an energy loss (pumping energy) of less than one percent. This will more than be offset by an improvement in our line loss that presently is between 10 and 15 percent. An average improvement of 30 to 40 percent could mean a drop in line losses of 3 to 6 percent.

Hot water greatly benefits cogeneration by obtaining a lower quality thermal base for the turbine-generator unit and thereby provides more energy outputs per unit of heat delivered to the process.

The hot water loop proposed in the ICES involves picking up all of the University of Minnesota West Bank buildings and selected buildings on the East Bank presently on the steam distribution system having internal hot water distribution. The University of Minnesota has a long-range plan of converting all steam heated buildings to hot water. The steam heated buildings will be added at a later date.

The thermal load for the proposed loop will come from existing buildings, or buildings under construction, that are heated by hot water and air conditioned by low pressure steam adsorption units. The existing steam to hot water converters in the buildings will be modified to water convertors. The low pressure steam adsorption chillers will be converted to hot water adsorption chillers-- buildings will be retrofitted and will create a maximum heating demand of $84,000 \times 10^6$ BTU/hr--chillers with a maximum capacity of 4,465 tons of refrigeration will be retrofitted with a corresponding maximum thermal load of 84,835 lb/hr steam.

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minneapolis

GRID ICES - OPTION III
PHASE II - STAGE 2
DISTRICT HOT WATER HEATING SECTOR

The horsepower loadings are presented for variable speed drive and maximum and minimum thermal loads. At 300° F the minimum allowable system pressure is 80 psig to prevent flashing. Calculations will be shown for horsepower required to overcome piping loss.

PEAK HOT WATER SERVICE DEMAND (NO DEGENERATION)

$$Q = 41,132 \times 10^6 \text{ Btu/hr}$$

$$\Delta T = 300^\circ \text{ F} - 160^\circ \text{ F} = 140^\circ \text{ F}$$

$$Q = W \Delta T$$

$$W = 293,800 \text{ pph water rate}$$

$$\text{GPM} = \frac{293,800}{60 \times 8.135} = 602$$

6,000 ft - 10 inch pipe - Pressure loss:

$$\Delta P_{100} = .085$$

$$\Delta P_{T_1} = 60 \times .085 = 5.1 \text{ PSIG}$$

$$\Delta P_{\text{TOTAL}} = 5.1 \times 2 = 10.2 \text{ ft} \times 2.3 = 23.5$$

$$\text{Pipe Loss Hp} = \frac{4,897 \times 23.5}{33,000} = 4.2 \text{ Horsepower}$$

PEAK HOT WATER SERVICE DEMAND (WITH DEGENERATION)

$$Q = 41.132 \times 10^6 \text{ btu/hr}$$

$$\Delta T = 240^\circ \text{ F} - 160^\circ \text{ F} = 80^\circ \text{ F}$$

$$Q = W \Delta T$$

$$W = 514,150 \text{ lbs/hr}$$

$$\text{GPM} = \frac{514,150}{60 \times 8.135} = 1,053 \text{ GPM}$$

6000 ft pipe - 10" pipe @ 2,151 GPM

$$\Delta P_{100} = .260$$

$$\Delta P_{T_1} = 60 \times .260 = 15.6 \text{ PSIG}$$

$$\Delta P_{\text{TOTAL}} = 15.6 \times 2 = 31.2 \times 2.3 = 71.8 \text{ ft.}$$

$$\text{Pipe Loss Hp} = \frac{8,569 \times 71.8}{33,000} = 18.6 \text{ Horsepower}$$

OPTION III - BUILDING RETROFIT
EQUIVALENT PEAK 300° F HOT WATER LOADING

Building Name	Steam Loads, Pounds			300° F Water		
	Peak Load		Minimum Off Season	Max GPM		Off Season
	Winter	Summer		Winter	Summer	
002 - Pattee Hall*	875,000 - Jan	393,000 - May	102,000 - Aug	20	9	3
006 - Wulling Hall*	788,000 - Jan	306,000 - July	92,000 - Aug	18	7	2
008 - Burton Hall*	1,617,000 - Jan	627,000 - July	189,000 - Aug	36	14	4
019 - Child Dev.*	1,819,000 - Jan	788,000 - July	146,000 - Sept	45	18	3
020 - Elliott Hall	4,255,000 - Jan	5,366,000 - July	923,000 - Apr	95	112	21
021 - Shevlin Hall*	500,000 - Jan	194,000 - July	59,000 - Aug	12	4	1
✓028 - Sanford Hall	3,610,000 - Jan	178,000 - June	93,000 - July	81	4	2
036 - Norris Gym*	1,615,000 - Jan	90,000 - Aug	73,000 - July	36	2	1
040 - Scott Hall*	655,000 - Jan	488,000 - July	22,000 - Sept	15	11	1
042 - Walter Libr.*	3,554,000 - Jan	75,000 - July	67,000 - Aug	80	1	1
116 - Science Clsm.*	914,000 - Jan	44,000 - July	0 - June	20	1	1
✓122 - Kolthoff*	4,200,000 - Jan	6,353,000 - July	825,000 - Oct	95	143	19
✓201 - Bus. Admn.	1,597,000 - Jan	15,000 - Sept	7,000 - Aug	35	1	1
✓202 - Soc. Science	2,031,000 - Jan	523,000 - June	407,000 - May	46	13	10
✓203 - Blegen Hall	1,948,000 - Jan	290,000 - July	236,000 - Aug	44	6	3
✓204 - Wilson Library	5,427,000 - Dec	27,623,000 - July	991,000 - Oct	130	620	22
✓205 - Anderson Hall	1,446,000 - Dec	284,000 - June	90,000 - July	34	6	2
✓207 - Wiley Hall	1,454,000 - Dec	1,513,000 - May	237,000 - Apr	34	35	3
✓208 - Middlebrook	5,143,000 - Jan	2,968,000 - July	81,000 - Sept	115	67	1
✓209 - Rarig Center	2,176,000 - Jan	5,272,000 - July	810,000 - Mar	48	116	1
✓211 - Law Bldg.	1,500,000 - Dec	1,500,000 - June	200,000 - May	35	35	2

*Indicates future building conversions. The preliminary piping distribution design is sized for these future loads.

✓Ind. Btu meter installation for ICES program.

TYPICAL HEAT EXCHANGER CONTROL DIAGRAM

BY	GDM	BUILDING	SCALE	SHEET
CHECKED	DATE	REVISED	DATE	DRAWING
	2-13-78

BLDG NO. 028 - SANFORD HALL

OPTION III - BUILDING RETROFIT
 PRELIMINARY DESIGN - PHASE II - STAGE 2
 GRID-CONNECTED INTEGRATED COMMUNITY SYSTEM

BASEMENT

**BLDG NO. 240 - ART BUILDING
BASEMENT**

**OPTION III - BUILDING RETROFIT
PRELIMINARY DESIGN - PHASE II - STAGE 2
GRID-CONNECTED INTEGRATED COMMUNITY SYSTEM**

114

BLDG NO. 205 - ANDERSON HALL
 206 - WEST BANK BOOK STORE
 WEST BANK BURSAR'S OFFICE

OPTION III - BUILDING RETROFIT
 PRELIMINARY DESIGN - PHASE II - STAGE 2
 GRID-CONNECTED INTEGRATED COMMUNITY SYSTEM

BLDG NO. 201 - BUSINESS ADMINISTRATION
13th FLOOR

OPTION III - BUILDING RETROFIT
PRELIMINARY DESIGN — PHASE II — STAGE 2
GRID-CONNECTED INTEGRATED COMMUNITY SYSTEM

BUILDING NO. 202 - SOCIAL SCIENCE 15th FLOOR

OPTION III - BUILDING RETROFIT
PRELIMINARY DESIGN — PHASE II — STAGE 2
GRID-CONNECTED INTEGRATED COMMUNITY SYSTEM

OPTION III - BUILDING RETROFIT
 PRELIMINARY DESIGN -- PHASE II -- STAGE 2
 GRID-CONNECTED INTEGRATED COMMUNITY SYSTEM

SUB BASEMENT
 BLDG NO. 204 - O. MEREDITH WILSON LIBRARY

HWH DEEP TUNNEL

OPTION III - BUILDING RETROFIT
 PRELIMINARY DESIGN — PHASE II — STAGE 2
 GRID-CONNECTED INTEGRATED COMMUNITY SYSTEM

FIFTH FLOOR

BLDG NO. 204 - O. MEREDITH WILSON LIBRARY

DEEP TUNNEL SHAFT

3 1/2" SUPPLY

UP TO 4TH FLOOR

HWH

OPEN TO
ROOM
BELOW

MEZZANINE LEVEL

OPTION III - BUILDING RETROFIT
PRELIMINARY DESIGN -- PHASE II -- STAGE 2
GRID-CONNECTED INTEGRATED COMMUNITY SYSTEM

EDGE OF OVERHEAD STRUCTURE

AREAWAY

140

BACKSTAGE

TRAPS

130 C

130 D

130 B

ORCH PIT

190

PROSCENIUM
THEATRE

DEEP TUNNEL

TO BLDG 208

EDGE OF OVERHEAD STRUCTURE

OPEN TO BELOW

EDGE OF OVERHEAD STRUCTURE

110

1 ABSORBER

GROUND FLOOR

BLDG NO. 209 - RARIG CENTER

121

BLDG NO. 208 - MIDDLEBROOK HALL
SUB-BASEMENT

OPTION III - BUILDING RETROFIT
PRELIMINARY DESIGN -- PHASE II -- STAGE 2
GRID-CONNECTED INTEGRATED COMMUNITY SYSTEM