275 3-11-80 LIVERGY

DR 363

COO-4977/1(Vol.3)



DISTRICT HEATING AND COOLING SYSTEMS FOR COMMUNITIES THROUGH POWER PLANT RETROFIT DISTRIBUTION NETWORK

Volume 3, Final Report for September 1, 1978-May 31, 1979

October 1979 Report Date

Work Performed Under Contract No. EM-78-C-02-4977

Public Service Electric and Gas Company Newark, New Jersey

7.



U. S. DEPARTMENT OF ENERGY

Division of Buildings and Community Systems

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

DISCLAIMER

"This book was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof."

This report has been printed directly from copy supplied by the originating organization. Although the copy supplied may not in part or whole meet the standards for acceptable reproducible copy, it has been used for reproduction to expedite distribution and availability of the information being reported.

Available from the National Technical Information Service, U. S. Department of Commerce, Springfield, Virginia 22161.

Price: Paper Copy \$14.00 Microfiche \$3.50

DISTRICT HEATING AND COOLING SYSTEMS FOR COMMUNITIES THROUGH POWER PLANT RETROFIT DISTRIBUTION NETWORK

Volume III

This book was prepared as an account of work sponsored by an agency of the United States Government Neither the United States Government nor any agency thereof, nor any of their employees, makes an experience of a sponsored programment of the property of their employees, makes any experience of a sponsored programment, or apparatus, product, or process disclosed, completeness, or usefulness of any information, apparatus, product, or process disclosed, comprehensity that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trode name, trademark, manufacturer, or otherwise, do not necessarily constitute or imply, its endorsement, recommendation, or favoring by the Unite States Government or any agency thereof. The views and opinions of authors sepressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

Final Report - September 1, 1978 - May 31, 1979

Prime Contractor:

Public Service Electric and Gas Company 80 Park Place Newark, NJ 07101

Subcontractors:

Stone and Webster Engineering Corporation Stone and Webster Management Consultants Transflux International, Ltd.

Report Date: October 1979

Prepared for the

U.S. Department of Energy
Assistant Secretary for Conservation
and Solar Applications
Office of Buildings and Community Systems

Work Performed under Contract No. EM-78-C-02-4977

FOREWORD

This is the Final Report of Phase 1 of "District Heating for Communities Through Power Plant Retrofit Distribution Network." It is separated into four volumes:

Volume I: Executive Summary

Volume II: Task 1: Demonstration Team

Task 2: Identify Thermal Energy Sources and Potential Service Areas

Task 3: Energy Market Analysis

Volume III: Task 4: Technical Review and Assessment

Volume IV: Task 5: Institutional Assessment

Task 6: Preliminary Economic Analysis

Task 7: Proposal for Further Work

ACKNOWLEDGEMENTS

The following key personnel contributed to the completion of this report:

- C. R. Guerra, PSRC Research & Development Department
- M. L. Zwillenberg, PSRC Research & Development Department
- P. D. Chase, PSRC Research & Development Department
- V. Saleta, Stone & Webster Engineering Corporation
- R. Ulfstam, Stone & Webster Engineering Corporation
- G. S. Levitt, Stone & Webster Management Consultants
- M. G. Kurz, Transflux International, Ltd.

Numerous contributions by other subcontractor personnel and members of other PSE&G departments are gratefully acknowledged.

DISTRICT HEATING AND COOLING SYSTEMS FOR COMMUNITIES THROUGH POWER PLANT RETROFIT DISTRIBUTION NETWORK

TASK 4 - TECHNICAL REVIEW AND ASSESSMENT

PUBLIC SERVICE ELECTRIC & GAS COMPANY

TASK-4

TABLE OF CONTENTS

	•	Page
Summary		4-1
A. Plant Retrofit		4-3
B. Thermal Distrib	ution Schemes	4-27
C. Consumer Conver	sion Scheme	4-46
D. Consumer Meteri	ng System	4-52
Appendix A	Use of Back Pressure Turbines Versus Pressur Valves to Supply Steam for District Water Ho	
Appendix B	System Descriptions & Heat Balance Diagrams	
Appendix C	Electrical Load Capability Curves	
Appendix D	Heat Carrying Media Criteria	
Appendix E	Heat Loads and Distribution Piping Costs	
Appendix F	Consideration of Different Types of Cooling	Plants
Appendix G	Consideration of Different Options for Trans Heat from Steam to a Distribution Medium	sfering
Appendix H	Consideration and Selection of Storage Poss	ibilities
Appendix I	Developments of District Heating Systems	
Appendix J	Customer Conversion Schemes	
Appendix K	Capital Costs of Heating/Cooling Supply Met	ers
Appendix L	Capital Costs of Conversion Schemes	
Appendix M	Maintenance Required for the Customer System	m
Appendix N	Water Treatment Considerations	
Appendix O	Common Heating and Cooling Distribution Sys	tems
Appendix P	Cost Estimate of District Heating Systems	

LIST OF FIGURES

Figure No.		Title (1)	Page
4-1	District Hea	ting Water Temperature vs. Ambient	4-9
4-2	Distribution	Piping in Concrete Culvert	4-41
4-3	Distribution Mineral Po	Piping in Loose Filled Insulation wder	4-41
. 4-4	Types of Ins	tallations	4-42
4-5	Hot Water He	ating System Module	4-49
4-6	Warm Air Hea	ting System Module	4-50
4-7 .	Typical Mete	ring Station	4-55
			• .
		LIST OF TABLES	
Table No.	_	Title	Page
4-1	Generating S	tations Evaluated	4-3
4-2		nt District Heating & Electrical Capacities	4-26
4-3	Prefabricate	d Pipe and Loose Fill Insulation Products	4-40
4-4	Installed Pi	pe Costs	4-44
4-5	Unit Piping	Costs	4-44
		I TOM OF DRAUTNOS	•
		LIST OF DRAWINGS	
Drawing No.	Station	Title	Page
13222-FSK-B-1	Bergen	Extraction Steam From Cross-Overs	4-12
13222-FSK-B-2	Bergen	District Heating Water and Heater Drains	4-13
13222-FSK-E-1	Essex	Extraction Steam & Back-up Boilers	4-14
13222-FSK-E-2	Essex	District Heating Water & Heater Drains	4-15
13222-FSK-H-1	Hudson	Extraction Steam From Cross-Overs	4-16
13222-FSK-H-2	Hudson	District Heating Water and Heater Drains	4-17
13222-FSK-K-1	Kearny	Extraction Steam From Cross-overs	4-18
13222-FSK-K-2	Kearny	District Heating Water and Heater Drains	4-19
13222-FSK-DH-4		District Heating Water Pumps	4-20
13222-ESK-B1 &	2 Bergen	One Line Diagram	4-21
13222-ESK-E1	Essex	One Line Diagram	4-22
13222-ESK-H1 &	2 Hudson	One Line Diagram	4-23
12222 FCV V7 S.	Q Voorny	One Line Diagram	4-24

LIST OF DRAWINGS

Drawing No.	Scheme No.	<u>Title</u>	Page
13222-FSK-DH-1	1	Flow Diagram, District Heating Piping Distribution System	4-31
13222-DH-1	1	District Heating Piping Distribution System	4-32
13222-FSK-DH-2	2	Flow Diagram, District Heating Piping Distribution System	4-33
13222-DH-2	2	District Heating Piping Distribution System	4-34
13222-FSK-DH-3	3	Flow Diagram, District Heating Piping Distribution System	4-35
13222-DH-3	3	District Heating Piping Distribution System	4-36

SUMMARY

The most promising district heating concept identified in the Phase I study for the PSE&G's service area is a hot water system in which steam is extracted from an existing turbine and used to drive a new, small backpressure turbine-generator. The backpressure turbine provides heat for district heating and simultaneously provides additional electric generating capacity to partially offset the capacity lost due to the steam extraction. This approach is the most economical way to retrofit the stations studied for district heating while minimizing electric capacity loss.

The generating stations selected to supply the district-heating steam are Essex, Hudson, and Bergen. All of these generating stations are located close to the potential heating and cooling load areas.

To obtain the maximum amount of heating steam from these plants with minimal reduction of electrical generation, it is proposed that steam be extracted from the cross-overs to the low-pressure turbines. The district heating water will be heated in shell and tube heat exchangers fed by low pressure steam and pumped through transmission and distribution piping to supply the heating requirements of the potential customers. Auxiliary boilers will be provided to serve as back-up and to supply peaking requirements. For base load heating, steam taken from the cross-overs is expanded through back-pressure turbines, or throttled through pressure reducing valves, before being admitted to the district heating water heaters. The particular scheme adopted depends on the level of steam pressure available at the cross-overs. For peak-load heating, a set of peaking heaters will be provided. Steam to the peaking heaters is taken either from the cross-overs if it is available, or from the auxiliary boilers. Temperature-controled valves are used to regulate the steam flow to the heaters. In the event that the main turbines are shut down, the auxiliary boilers will supply the total amount of heating steam required for both base-load and peak-load heating.

Three alternative thermal distribution schemes have been developed. Scheme I utilizes Hudson Units 1 & 2 to supply 1.6 x 10^9 BTU/hr to Jersey City, Hoboken, and the future development in the Meadowlands area. Scheme II utilizes Essex Unit 1 to supply 0.772 x 10^9 BTU/hr to the City of Newark. Scheme III utilizes Hudson Units 1 & 2 and Bergen Units 1 & 2 to supply 2.8 x 10^9 BTU/hr to Jersey City, Hoboken, and the future development of the Meadowlands area, and Essex Unit 1 to supply 0.772 x 10^9 BTU/hr to the City of Newark.

For the Phase I study, only the heating requirements of a potential load area were used to size the distribution systems. The distribution systems and the district heating water heating plants were sized for constant district heating water flow and variable water temperature operation. The maximum district heating water supply temperature was selected to be $290^{\circ}F$ at an outside ambient temperature of $0^{\circ}F$. The corresponding district heating water return temperature is $170^{\circ}F$. Both the supply and return water temperatures vary inversely with the outside ambient temperature.

From a preliminary assessment of the communities cooling requirements, it appears that producing chilled water at the substations has better economic merits compared to producing the chilled water at the generating stations. At the substations, either electric centrifugal machines or absorption machines supplied with district heating water could be used to provide the required chilled water.

Cost estimates have been developed for the plant retrofit for each of the generating stations, the alternate piping distribution schemes, and the conversion schemes at the consumer's end. All the costs are based on present day dollar. A summary of all the costs is given in Appendix P.

A. PLANT RETROFIT

Nine fossil fuel fired power generating stations within the Public Service Electric and Gas system were evaluated for the possibility of supplying heat for district heating and cooling in co-generating operations. Studies were made to analyze the heat supply capability of the generating units within these stations under various retrofit options. At the same time, potential heating and cooling loads around each station were estimated in order to match the heat supply capability of the station. A list of the generating units evaluated is given in Table 4-1. This table shows the type of unit, the megawatt capacity, and the commercial operation date.

Table 4-1 Generating Stations Evaluated

	Type	Capacity	Commercial Operation Date
Burlington 5	non-reheat	118	1940
Burlington 6	non-reheat	120	1943
Burlington 7	reheat	180	1955
Mercer 1	reheat .	300	1960
Mercer 2	reheat	300	1961
Mercer 2	2		
Marion 10	non-reheat	116	1941
Linden l	non-reheat	230	1957
Linden 2	reheat	225	` 1957
Linden 4	back-pressure	80	1972
Linden 4	back-pressure	• •	
Sewaren l	non-reheat	109	1948
Sewaren 2	non-reheat	111	1948
Sewaren 3	non-reheat	109	1949
Sewaren 4	reheat	127	1951
Sewaren 5	reheat	335	1962
bewaren 5	,		
Essex 1	non-reheat	100	1947
A ,		142	1953
Kearny 7	reheat	142	1953
Kearny 8	reheat	142	1733
1141	reheat	383	1964
Hudson 1	reheat	630	1968
Hudson 2	i enea c		
Paran 1	reheat	280	1959
Bergen 1	reheat	280	1960
Bergen 2	Lenear		

During the early stages of the study, the Burlington, Mercer, and Sewaren units were removed from consideration due to insufficient district heating loads within the geographical areas they serve. The Sewaren units had also been considered to supply heat to the Newark area, but the distance of over 12 miles made this choice difficult to justify economically. The Marion unit was eliminated because its generating equipment had been retired. The Linden Station was originally designed as a co-generation station which supplies both 750 psig steam and 150 psig steam to the Exxon's Bayway Refinery. Presently this station has excess capacity of 150 psig steam which can be used to drive back-pressure turbines and to produce low pressure heating steam. When a market survey of the surrounding area showed poor district heating potential, this station was eliminated.

Kearny Units 7 & 8 are both reheat units and have triple-flow turbines. The generating station is located between Jersey City and Newark, in an area which has potential district heating loads. This station was eliminated, however, because of mechanical problems associated with the extraction of a suitable amount of heating steam from the cross-unders.

The remaining stations, namely Hudson, Bergen, and Essex, are all located within areas which have potential district heating loads. Hudson Units 1 & 2 are the newest fossil generating units in the PSE&G system. Presently Unit 1 burns oil while Unit 2 burns coal. Both units have double reheat boilers and tandem compound turbines. Bergen Units 1 & 2 were built in 1959-60, and are identical units. These units have single reheat boilers and cross-compound turbines. Essex Unit 1 was built back in 1947 and is a non-reheat unit. This unit has been retired but has possibility of being retrofitted for district heating operation, if PSE&G will bring it back into operation to meet electrical generation needs. Both the Bergen and the Essex units burn oil.

To determine the locations where maximum amounts of steam can be extracted from the existing turbines in these units, turbine manufacturers were consulted. Results of preliminary investigation showed that the most probable locations are the cross-overs to the low-pressure turbines. From these locations, large amounts of steam can be extracted with minimal reduction in electrical generations. The amount of heat which can be supplied by the preliminary steam flows determined is of sufficient magnitude to meet the anticipated district heating load. During Phase II of the study, turbine manufacturers will be asked to perform detailed evaluations of the proposed retrofit schemes and to confirm the extraction flows to a high degree of accuracy.

The plant retrofit scheme developed consists of extracting steam from the cross-over to the low-pressure turbine, upstream of a butterfly type pressure control valve which will be installed at the cross-over. A motor-operated shut-off valve and an air-operated non-return valve are provided on an extraction line from the cross-over. When the turbine operates in the electric generation mode, the butterfly valve is fully open and both the motor-operated shut-off valve and the air-operated non-return valve are fully closed. Steam from the intermediatepressure turbine exhaust flows to the low-pressure turbine through the cross-over piping. When the turbine operates in the co-generation mode, the butterfly valve is partly closed to allow certain amounts of steam flow down the low-pressure turbine for cooling the low pressure stages. The motor-operated shut-off valve and the air-operated non-return valve are opened to pass the extracted steam for district heating. There is no loss of capacity when the turbine operates in the electric generation mode. When the turbine operates in the co-generation mode, the generation from the low-pressure turbine will be reduced depending on the amount of steam extracted from the cross-over. When a large amount of steam is

extracted from the cross-over for district heating, the existing feedwater heater extracting steam upstream of the cross-over will experience excess extraction steam flow conditions. The need for design modifications of this heater and its associated piping will be determined in Phase II of the study.

In selecting a heat-carrying medium, both steam and hot water had been considered (see Appendix D for a detailed discussion). Steam has been and is still being used as a heat-carrying medium in district heating systems in many parts of the U.S. For long distance heat transport, nowever, steam must be extracted from the turbine at fairly high pressures in order to satisfy the pressure drop requirements. The pipe size needed for transmission and distribution is larger compared with that required for hot water. Furthermore, when steam is used the condensate must be either discarded or returned. Both alternatives are expensive. If the condensate is returned, the entire district heating system must meet the water quality requirements of the boilers in the generating plants. When water is used as the heat carrying medium, the district heating water is completely separate from the water in the turbine cycle. Water has been used for many years in Europe for long-distance heat transmission. The percentage heat loss in a hot water transport system is very small compared to the thermal energy storage in the system. Furthermore, if hot water is used for district heating, the pressure of the heating steam required need not be as high as that required for a steam district heating system. The extraction of steam at lower pressures in the turbine cycle permit more electrical generation for the hot water system. Based on the above considerations, water was chosen as the most desirable medium for the transport of heat in the present study.

Subsequent to the selection of water as a heat-carrying medium, a study was made to determine the optimum district heating water supply and return temperature

compatible with the extraction steam pressure. Five temperature ranges were considered as follows (see Appendix G for a detailed discussion):

Supply Temp. F	Return Temp. F	Temp. Diff. F
390	270	120
390	190	200
290	230	60
290	170	120
230	190	40

From the above temperatures, 290 F was selected as the supply temperature of the district heating water. This temperature is adequate to meet district heating demands while simultaneously striking a reasonable balance between initial costs and equipment performance. For the power plant units selected to supply heat for district heating, the steam pressure at the cross-overs is compatible with the 290 F water temperature.

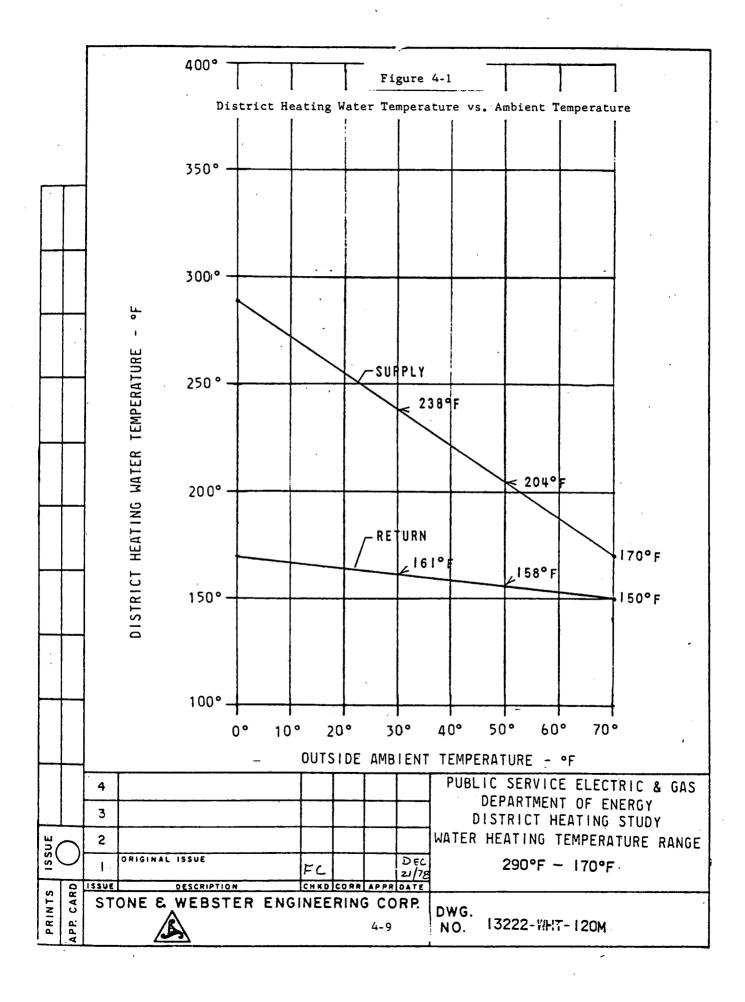
The 390 F temperature level was eliminated because steam for water heating would have to be extracted from either the main steam, the cold reheat, or the hot reheat. Extracting steam from any of these locations would result in significant loss of electrical generation. In addition higher equipment design pressure and the use of more expensive insulation materials for the distribution system would be required.

The 230 F temperature was also found to be undesirable because the lower water temperature would require higher flow rates and consequently larger pipes and higher piping and equipment costs. Although the turbine cycles would produce more generation with lower extraction steam pressure corresponding to lower supply water temperature, the increased benefit was not considered substantial to justify the increased cost.

The district heating water return temperature was chosen to be 170 F instead of 230 F. The volume flow rate of district heating water needed for the 290 F - 170 F system is lower compared with that needed for the 290 F - 230 F system. The reduction in water volume flow rate directly effects the reduction in the size of piping and pumps, and the pumping costs.

For the Phase I study, the district heating system developed is a constant district heating water flow and variable temperature system. This scheme allows for operation flexibility of the main turbine generators, and better equipment operation efficiency. The system was sized to deliver sufficient hot water to the consumer and to provide for an indoor ambient temperature of 70 F when the outdoor temperature is 0 F. At this outdoor temperature, the district heating water supply temperature is 290 F. The corresponding district heating water return temperature is 170 F. At an outdoor ambient temperature of 50 F, the supply and return water temperatures are 204 F and 158 F respectively. The variations of the district heating water supply and return temperatures are shown in Fig. 4-1. During the summer months when space heating is not needed, the district heating water flow rate can be reduced by reducing the number of circulation pumps in service.

In the retrofit scheme developed, district heating water is heated in the generating stations through multi-stage heating in shell and tube heat exchangers, or heaters. Base load heating is done in one or two heaters in series. Peak load heating is done in an additional heater down-stream. Steam for water heating is taken from the main-turbine cross-overs through extraction piping to a supply header. For base load heating, steam from the supply header is expanded through back-pressure turbines to the appropriate pressures before being admitted into the heaters. For Essex Unit 1, no back-pressure turbine is used because the cross-over steam pressure is too low. Instead steam from the supply header is



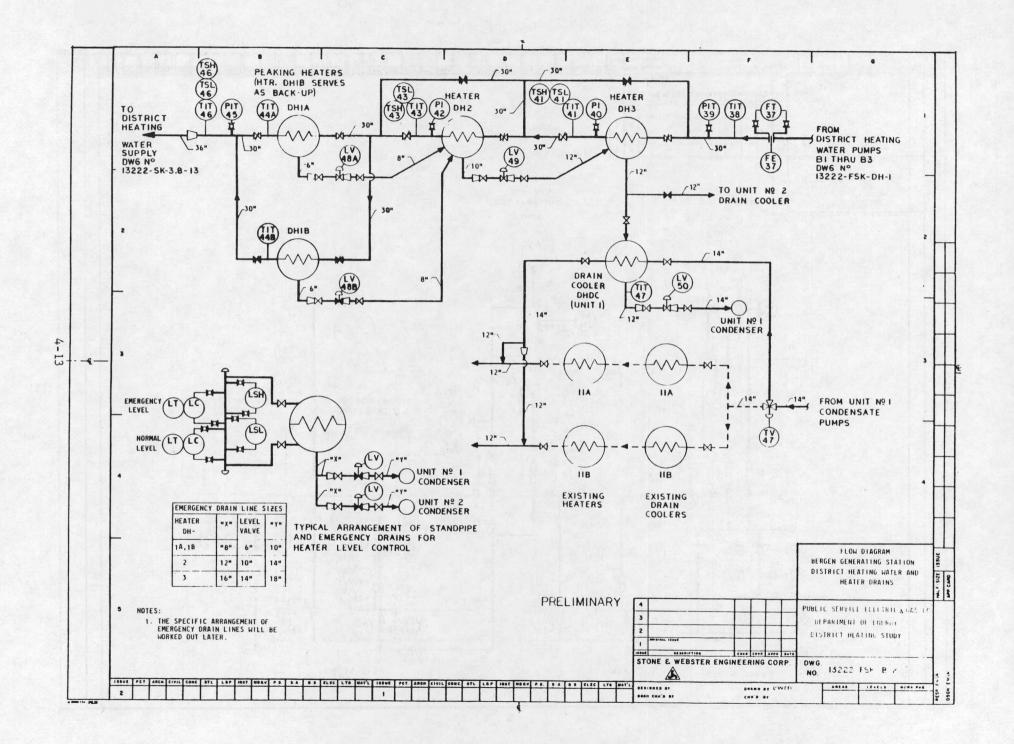
heating, steam from the supply header is fed to the peaking heaters through pressure reducing valves. For Essex Unit 1, steam for peak load heating is taken from one of two auxiliary boilers through pressure reducing valves before being admitted into the peak load heater. During the periods when the ambient temperature is above 30 F, no peak load heating is needed and less steam is extracted from the main units. This minimizes the capability charge for the generating stations during periods of high electrical load.

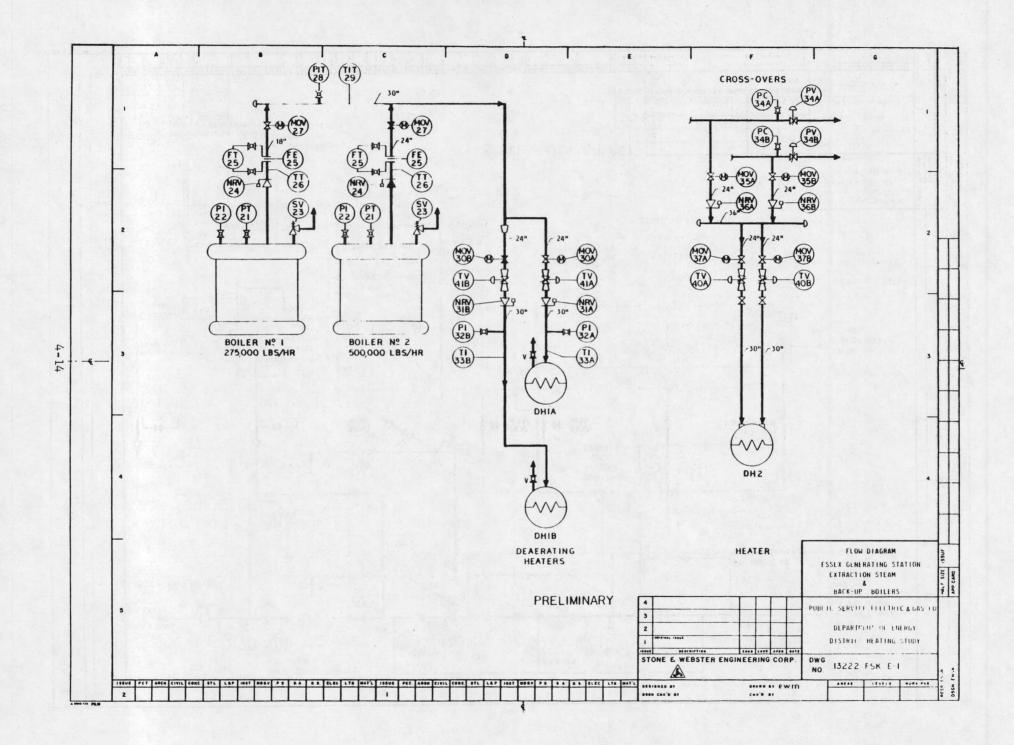
For base load heating, the maximum district heating water supply temperature needed is 238 F. To provide this temperature water, the corresponding pressure of the extraction steam needed is only 29 psia, assuming a heater terminal temperature difference of ten degree F. For the Bergen and the Hudson units, the cross-over pressures are 74 psia and 81 psia respectively. Thus if the extraction steam from the cross-overs can be expanded through a back pressure turbine before being admitted into a base load heater, additional generation can be realized. To determine the economic justification of back-pressure turbine, a study was made which shows that for the pressure ratio of 74/29 a back-pressure turbine is a better choice compared to pressure reducing valve (see Appendix A for a detailed discussion).

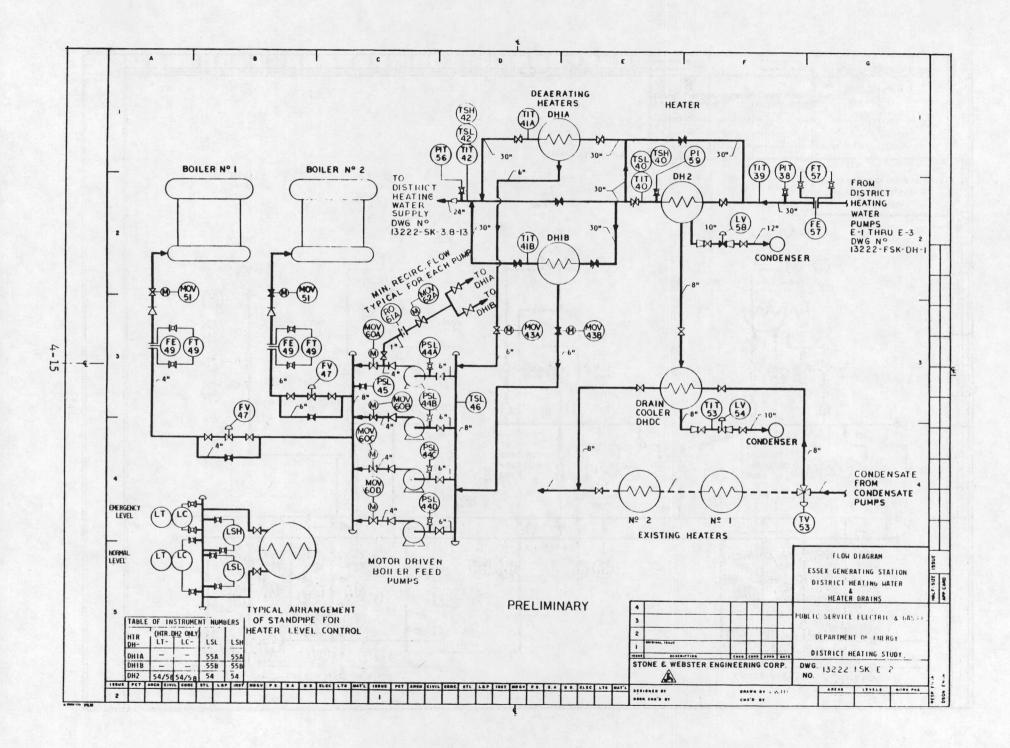
Steam condensed in a heater is drained to the next lower pressure heater. Drains collected in the lowest pressure heater is further cooled in an external drain cooler before being returned to the condenser of the main units. The external drain cooler uses condensate from the main unit as cooling medium. The temperature of the drains to the condenser is about 127 F. In Phase I Study, no evaluation has been made to determine if pumping the drains forward into the condensate stream would give better economic benefit. This work is

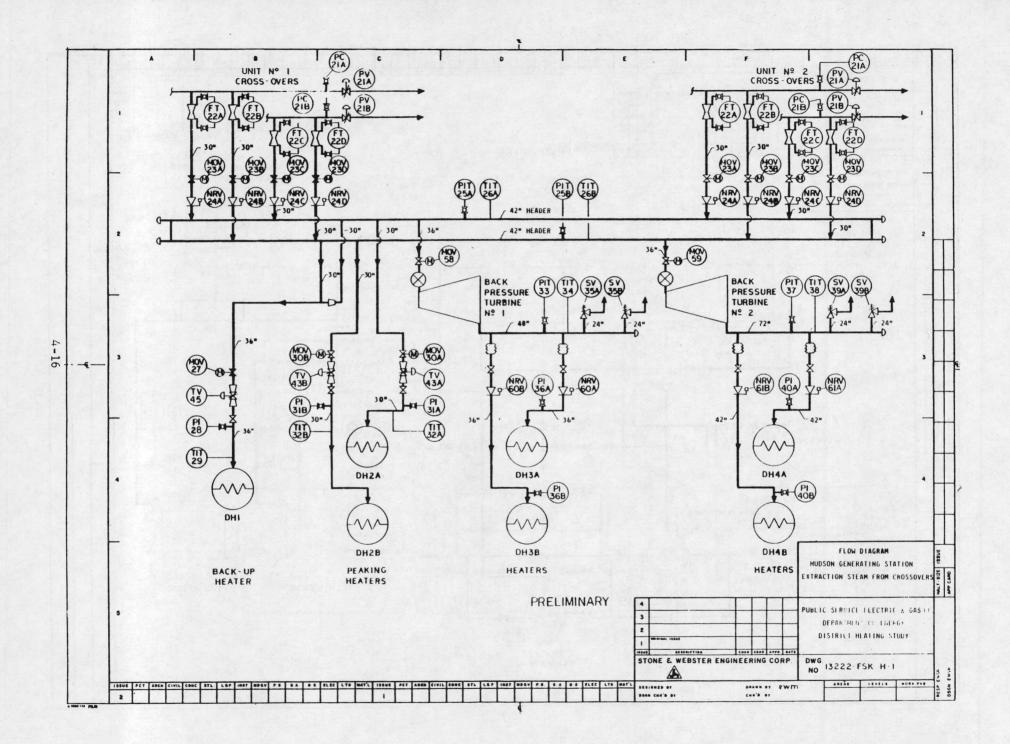
being proposed for Phase II. For Essex Unit 1, drains from the peaking heaters are pumped back into the auxiliary boilers. A detailed description of the plant retrofit for each of the generating stations, together with the heat balances, is given in Appendix B. The electrical load capability curves which show the maximum possible and minimum required electrical loads on the units are given in Appendix C. The engineering flow diagrams and the electrical one-line diagrams developed for the selected stations are given in the following pages.

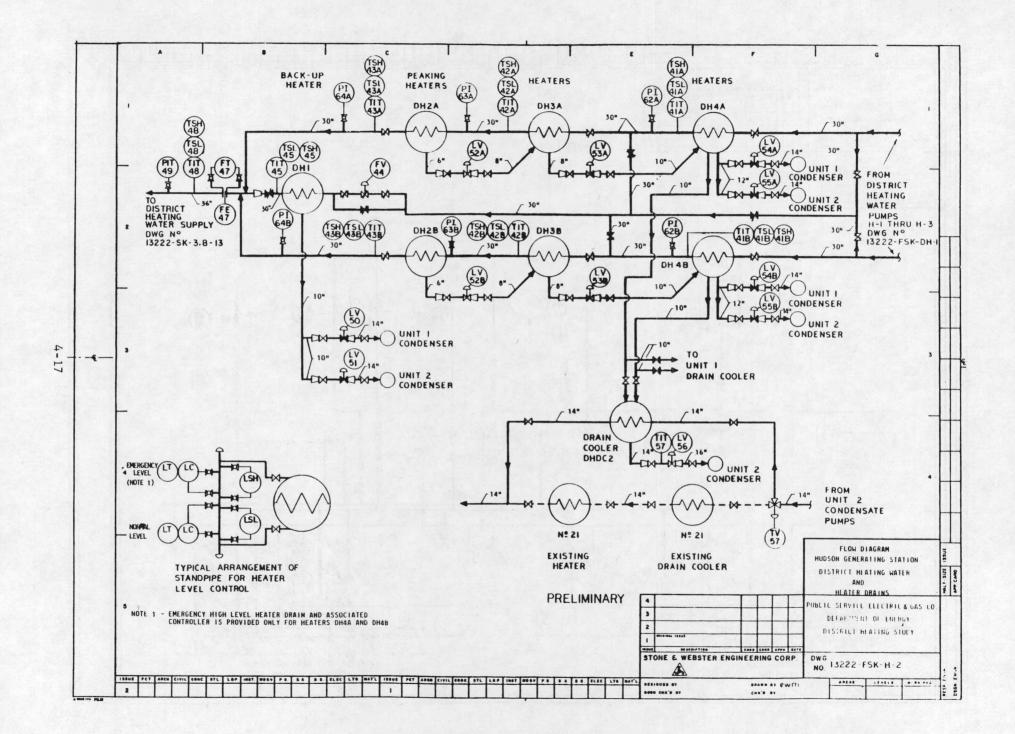
The extent of the district heating system and the degree of redundancy required will depend on the reliability criteria which must be specified. During Phase I study, the question of retrofit plant reliability has been explored. For both the Hudson and Bergen generating stations, the district heating water heating plants were sized for the amount of steam which can be extracted from only one generating unit. Both generating units at each station will be retrofitted so that each unit can operate in the co-generation mode, with the other unit serving as a back-up. For Bergen Generating Station, either Unit 1 or Unit 2 can be selected to supply steam for district heating during normal operation. For Hudson Generating Station, Unit 2 will normally be used to supply the heating steam since this unit burns coal and operates at lower fuel cost. A low pressure auxiliary boiler of 825,000 lbs/hr capacity is provided in the retrofit scheme for the Hudson Generating Station. This boiler will serve as a full back-up, including peak load heating, in the event that both generating units are taken out of service. At the Essex Station, the two auxiliary boilers provided in the design will be able to supply the full heating capacity, including peak load heating, in the event that Unit 1 is taken out of service. A detailed study of the system reliability will be undertaken during Phase II of this study. Based on the design retrofit concept as described above, the retrofit plant district heating and electrical generation capacities determined for the generating stations selected are given in Table 4-2.

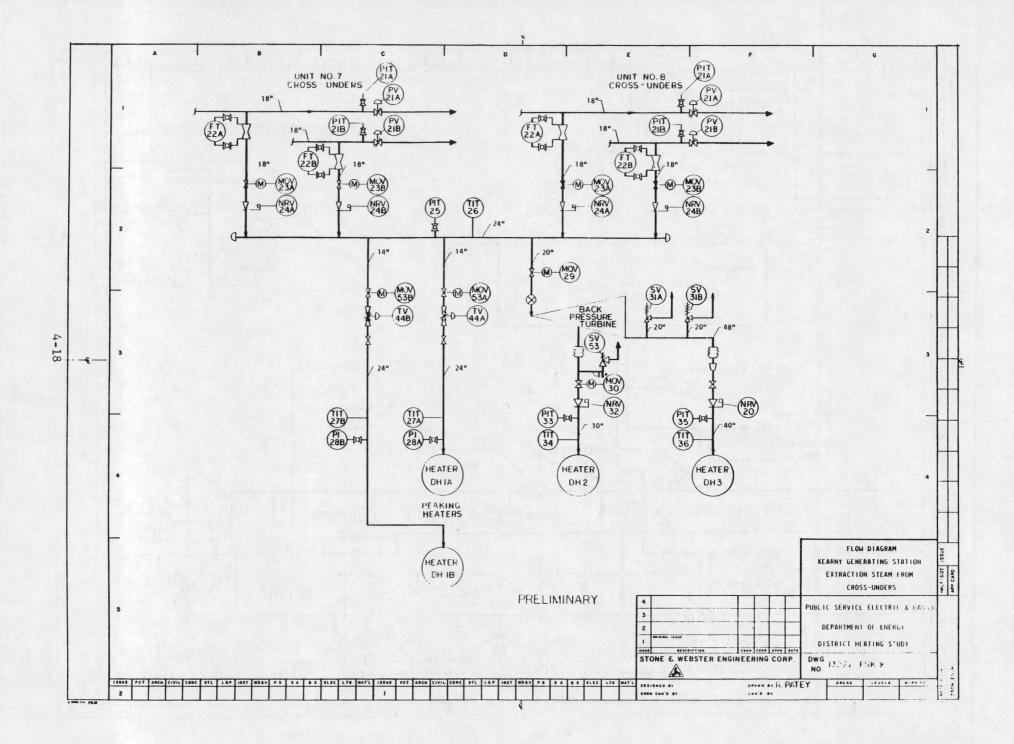


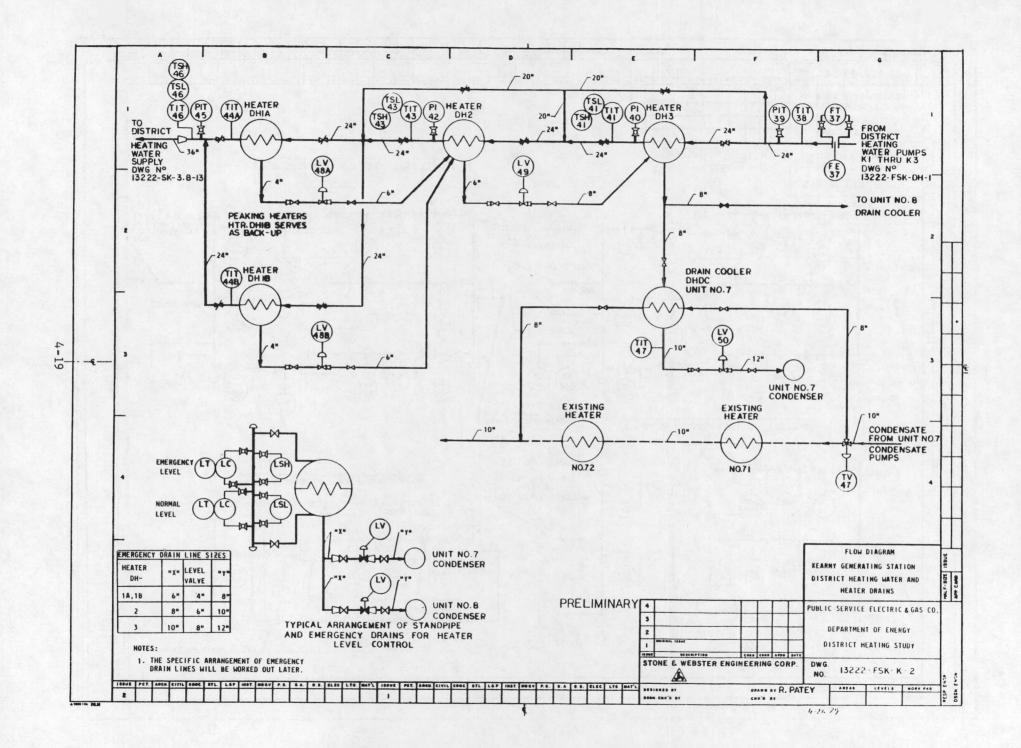


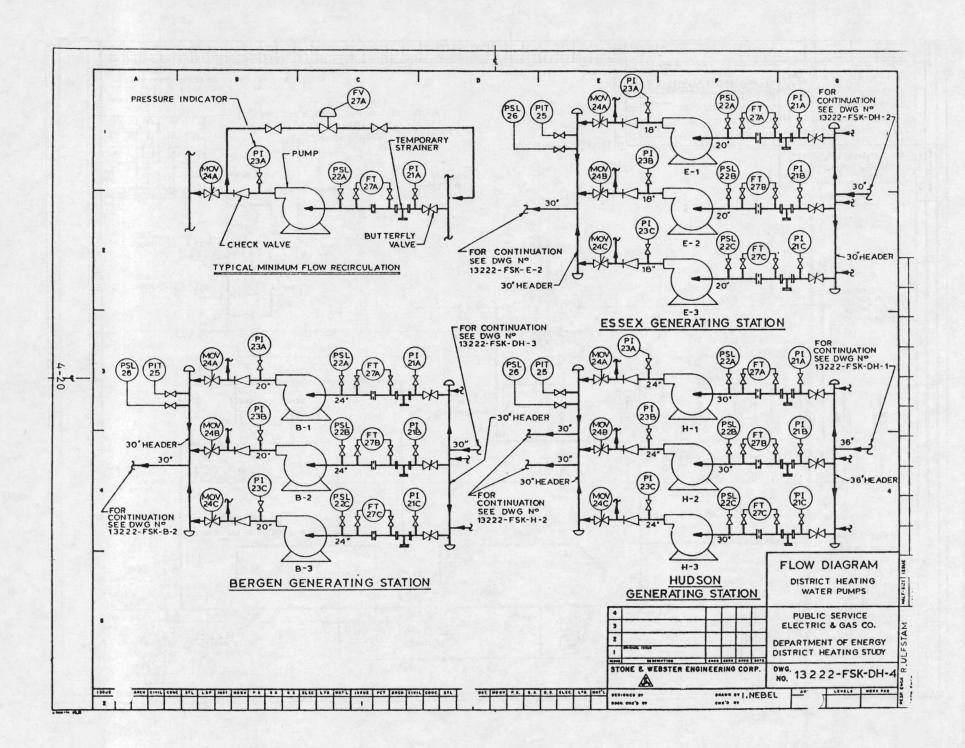


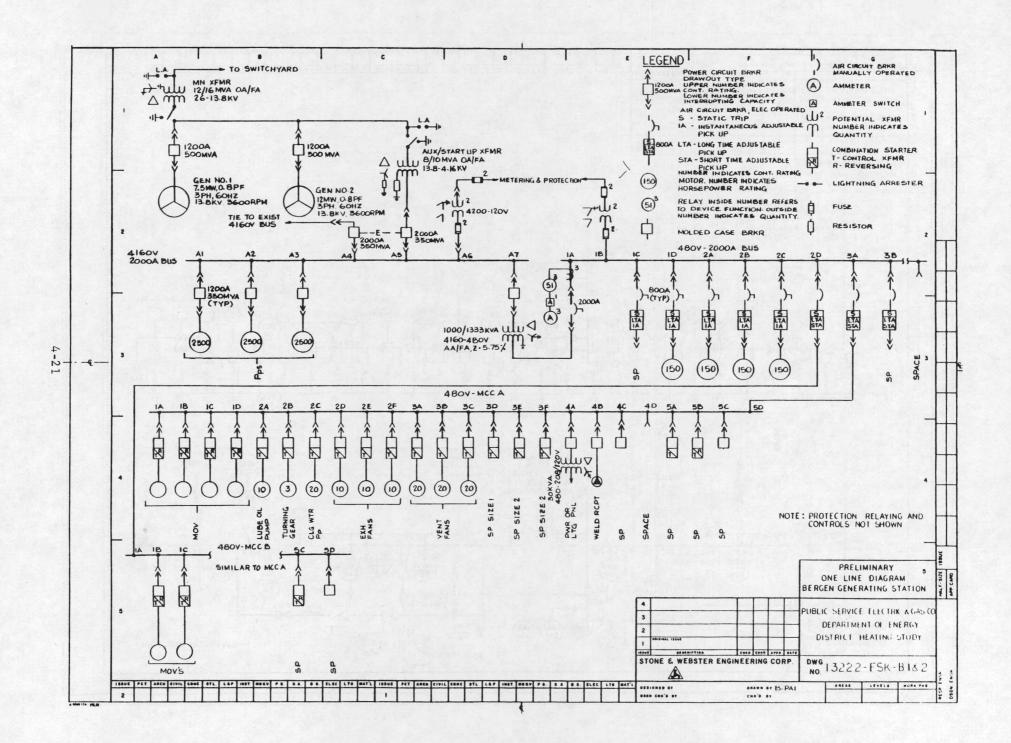


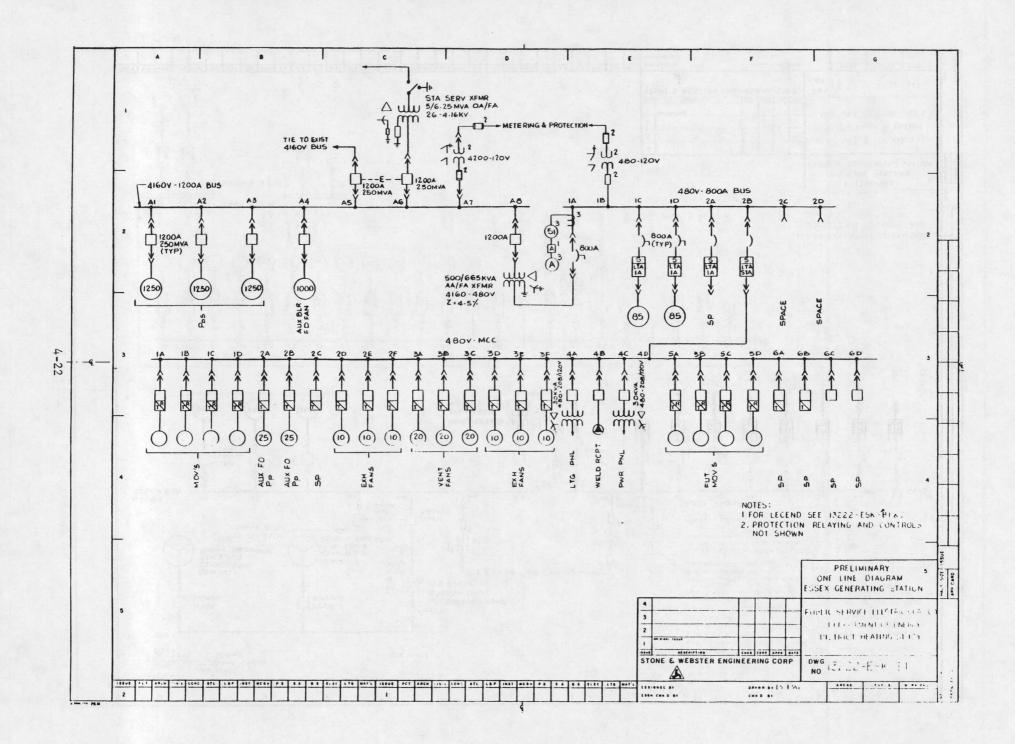


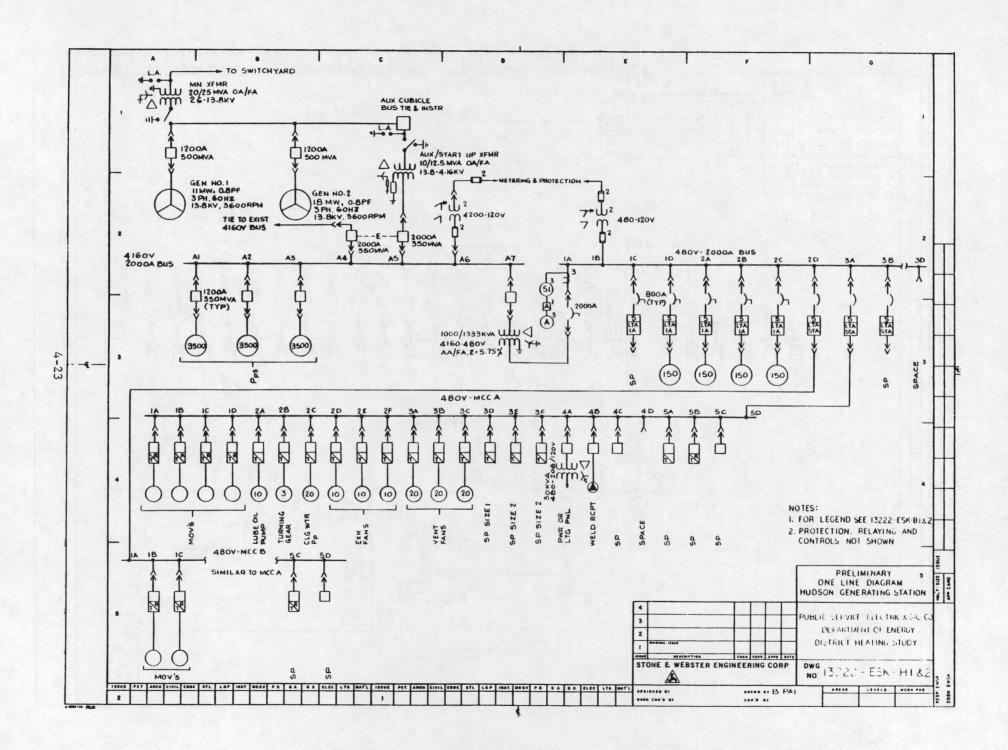


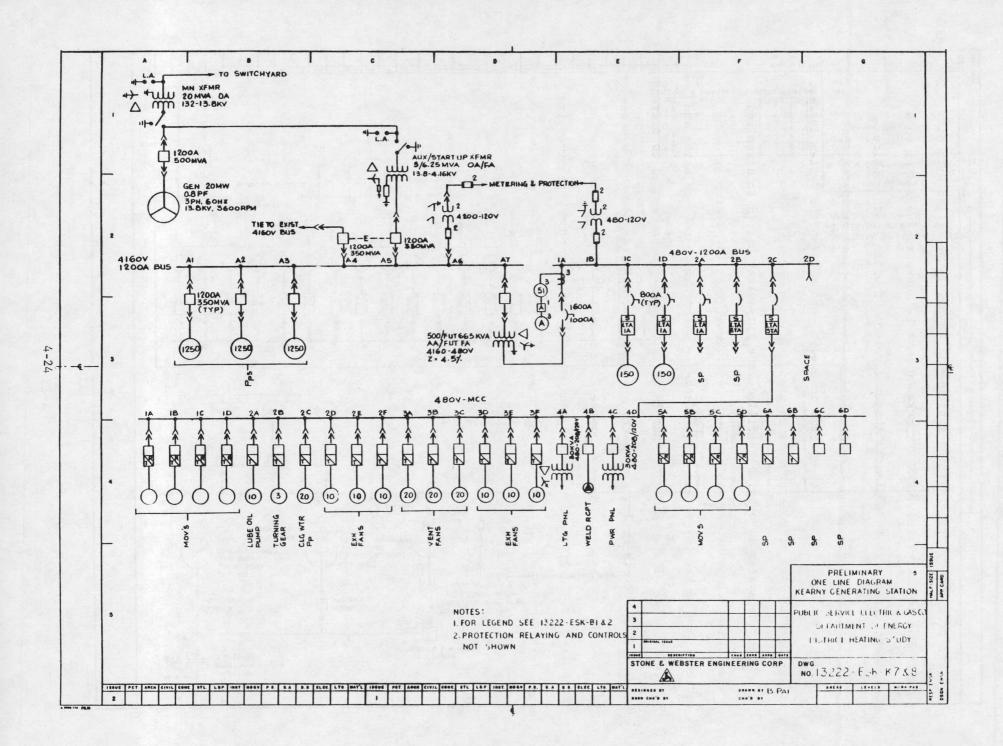












The proposed district heating system will initially be filled with city water. Due to losses and leakages, make-up must be added to the system on a continuous basis. It is estimated that the volume of water in the entire system will be replaced once a year. This estimate is based on operational experience of district heating systems in Sweden. To make-up the system losses, it is proposed that city water will be used.

When the system is originally filled, the city water has in it dissolved oxygen and other non-condensable gases. As the water in the system is being heated, some of the oxygen and non-condensable gases come out of solution and must be vented. The remaining oxygen in solution needs to be removed to prevent corrosion of the piping and equipment. Hardness of the water due to the presence of calcium and magnesium (in bicarbonate form) needs to be removed to prevent scale deposit. Details of the water conditioning considerations are given in Appendix N.

TABLE 4-2

Retrofit Plant District Heating & Electrical Generation Capacities

Generating Unit_	Essex Unit 1#	Bergen Unit 1 or 2	Hudson Unit 1	Hudson Unit 2
Gross Electrical Generation, Mw (No District Heating)	100	297	410	652
Gross Electrical Generation, Mw* (With District Heating)				
0°F Ambient 30°F Ambient 50°F Ambient	69.9 69.6 82.4	209 246 267	288 340 369	529 585 612
Reduction in Generation, Mw				
0°F Ambient 30°F Ambient 50°F.Ambient	30.1 30.4 17.6	88 51 30	122 70 41	123 67 40
Electrical generation by back pressure turbine, Mw				
OF Ambient 30°F Ambient 50°F Ambient		16.8 19.7 12.0	26 29 17	26 29 17
District Heating Capacity, 10 ⁶ (BTU/hr)/Mw thermal				
0°F Ambient 30°F Ambient 50°F Ambient	772/226 495/145 292/86	1200/352 770/226 454/133	1596/468 1024/300 604/177	1596/468 1024/300 604/177
Ratio of Mw Thermal Mw Electrical				
0°F Ambient 30°F Ambient 50°F Ambient	7.4 4.7 4.7	4.0 4.4 4.4	3.8 4.3 4.3	3.8 4.5 4.5

[#] Includes auxiliary steam boilers at Essex

^{*} Includes new electrical generation by back pressure turbines

B. THERMAL DISTRIBUTION SCHEMES

The type of thermal distribution system used affects the ability to service the end users, whether they be residential, commercial or industrial customers. The transmission and distribution system of hot water or chilled water depends largely on the particular thermal load requirements of an area or the geographical layout of the distribution system.

Several distribution system schemes were developed for piping district heating/chilled water to the various communities in New Jersey. These communities, or load areas, consist of residential areas, apartment complexes, commercial establishments, recreational facilities, hospitals, and industrial complexes. Some load areas contain a heavy concentration of residential house while others contain predominantly industrial and/or commercial establishments. Some areas have a combination of the above loads.

There are several alternatives of matching a given power plant with a particular load area. For this reason a study was made to determine the most efficient and economical distribution network. Since such a system will be a first in New Jersey, the study considered the feasibility and practicality of the various alternatives to assure installation of a system most likely to serve as a model for future networks.

In defining the alternative distribution systems, the maximum amount of steam that could be extracted from the power stations selected was first determined.

Based on the quantity of steam available for heating district heating water, some of the plants can be grouped to serve one or more areas or used as backups for the primary plant. An evaluation was then conducted to assess the most likely and practical main piping routes at minimum cost. Pressure drops in the system were also estimated in order to identify the areas which might require booster pump substations.

The load potential investigations demonstrated that considerable load concentrations exist in the vicinity of the power plants selected. These load concentrations can be grouped into three potential load centers as follows:

- a) Downtown Newark
- b) Northern part of Jersey City and Hoboken
- c) Future Meadowlands Development Area

The power stations considered as supply centers for the loads defined above are:

- a) Essex Unit No. 1
- b) Hudson Units No. 1 and No. 2
- c) Bergen Units No. 1 and No. 2

The reasons for selecting these power stations were:

- a) Close proximity to the potential load centers considered,
- b) High concentration of present loads around the stations,
- c) High concentration of developing loads around the stations.

The distribution system layout and subsequent piping costs was developed from heating and air conditioning requirements based upon the field survey as well as statistical data supplied by PSE&G and other commercially available sources, such as the Hackensack Meadowlands Comprehensive Land Use Plan (dated October 1970).

For the purpose of this study only the heating requirements of a potential load area were used to size the distribution system. The air conditioning and chilled water requirements for an area will be evaluated on a case by case basis, depending upon whether a building has its own existing chilled water plant or if chilled water can be economically supplied from an external source.

The distribution systems for connecting the power plants with load potential areas were investigated and alternate schemes were developed as shown below.

Scheme No. 1

Either one of the two units at Hudson Station can supply downtown Jersey City, Hoboken and the southern portion of the Hackensack Meadowlands area with $1,600 \times 10^6$ BTU's per hour. The piping costs for these areas were based upon installing the piping from the Hudson plant to Jersey City and Hoboken via existing urban streets which are heavily congested and the piping for the Hackensack Meadowlands area via existing and new suburban streets which are not as congested as the streets of Jersey City. Also the piping for the Meadowlands area was assumed to be installed along with other services and therefore the installed cost per mile was not as expensive as the urban installation.

The distribution network for this scheme is shown on flow diagram 13222-FSK-DH-1 and distribution piping layout drawing number 13222-DH-1.

Scheme No. 2

The Essex Station would supply downtown Newark with a total of 772 \times 10⁶ BTU's per hour. Two boilers are used for 100% backup capacity to the system. The piping cost was based upon installing the piping from the Essex Plant to Newark via existing heavily congested urban streets.

The distribution network for this scheme is shown on flow diagram No. 13222-FSK-DH-2 and distribution piping layout drawing No. 13222-DH-2.

Scheme No. 3

Scheme No. 3 is essentially a combination of Scheme No. 1 and Scheme No. 2 with the addition of the Bergen Station supplying the Northern portion of the Hackensack Meadowlands area with an additional 1200 x 10^6 BTU's per hour from either one of the two Bergen units for a total heat load of approximately 3,600 x 10^6 BTU/hr.

The distribution network for this scheme is shown on flow diagram No. 13222-FSK-DH-3 and distribution piping layout drawing No. 13222-DH-3.

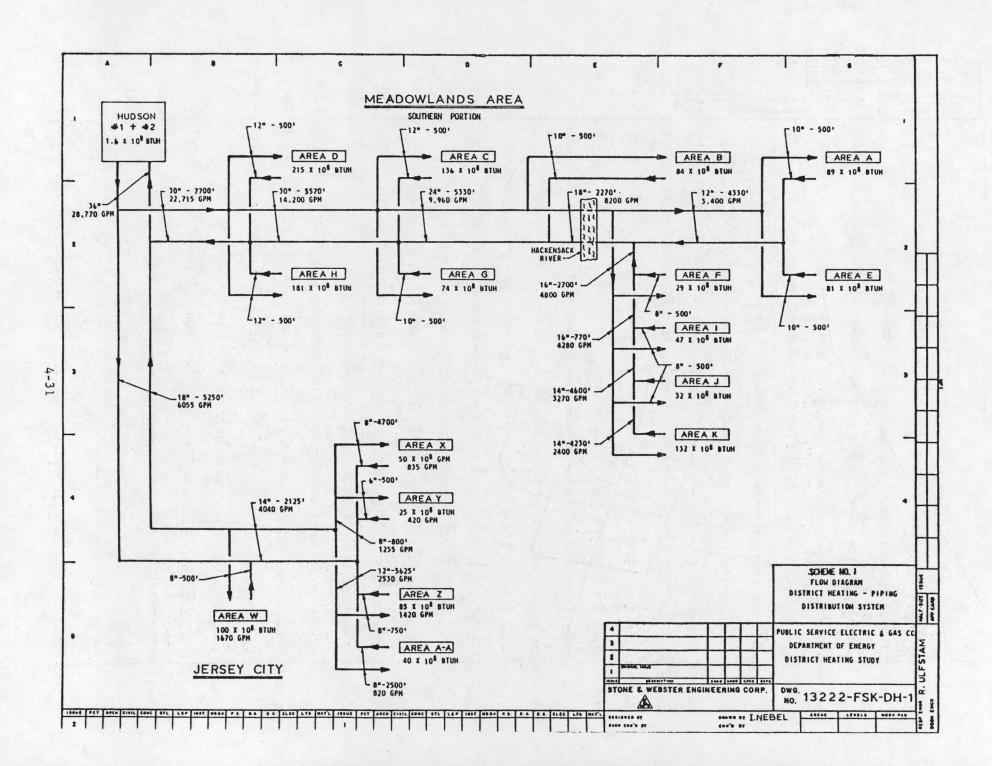
In developing the above system schemes, potential load areas of approximately one square mile each were used as the basic load density area. A summary of the heat loads by area for each of the schemes is given in Appendix E.

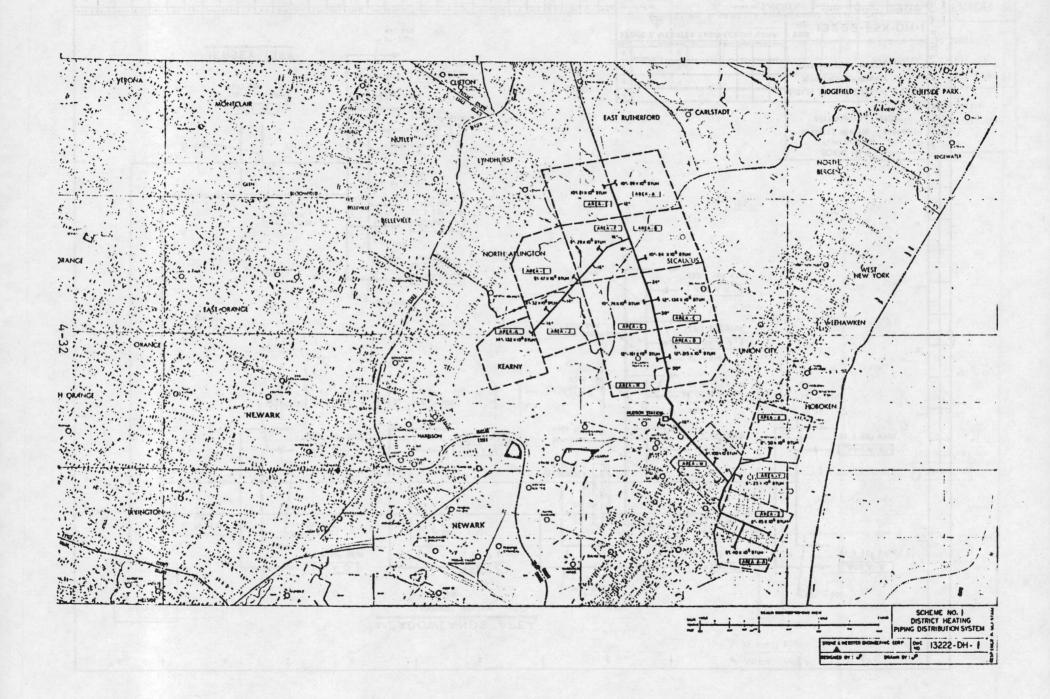
In all the above schemes chilled water can be produced at the power station and piped alongside the district heating water piping in the same trench. However a more economical solution would be to produce the chilled water at a substation at or near the load center. Absorption machines could be supplied with the district heating water to provide chilled water either at a substation or in the building of the consumer.

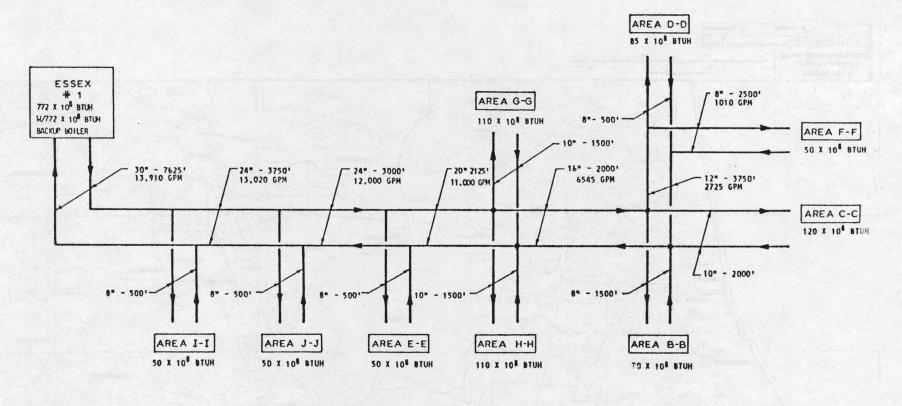
Electric centrifugal machines can also be used to produce chilled water.

The machines can be located at a substation or in each building served. For areas which require a new electric centrifugal machine, the appropriate switching station and transmission lines must also be provided (see Appendix F).

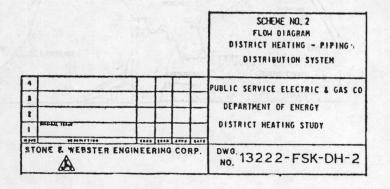
The piping for the thermal distribution system was designed to be a twopipe system installed underground at a minimum depth of 3'-6' below the surface
wherever possible. This will insure that the piping is below the normal frost
line depth. However, in industrial and commercial areas the piping may be run
above ground on new or existing structural supports (the piping may have to be
heat traced above ground). A two pipe system was selected because it has the
advantage over a one pipe system due to its ability to maintain a fairly constant
water temperature in the main from the station to the last end user. The
individual consumers will also have a greater control in using the supplied
heat by metering devices, since return water temperature from each user does
not affect the supply main temperature to other users. Although the material

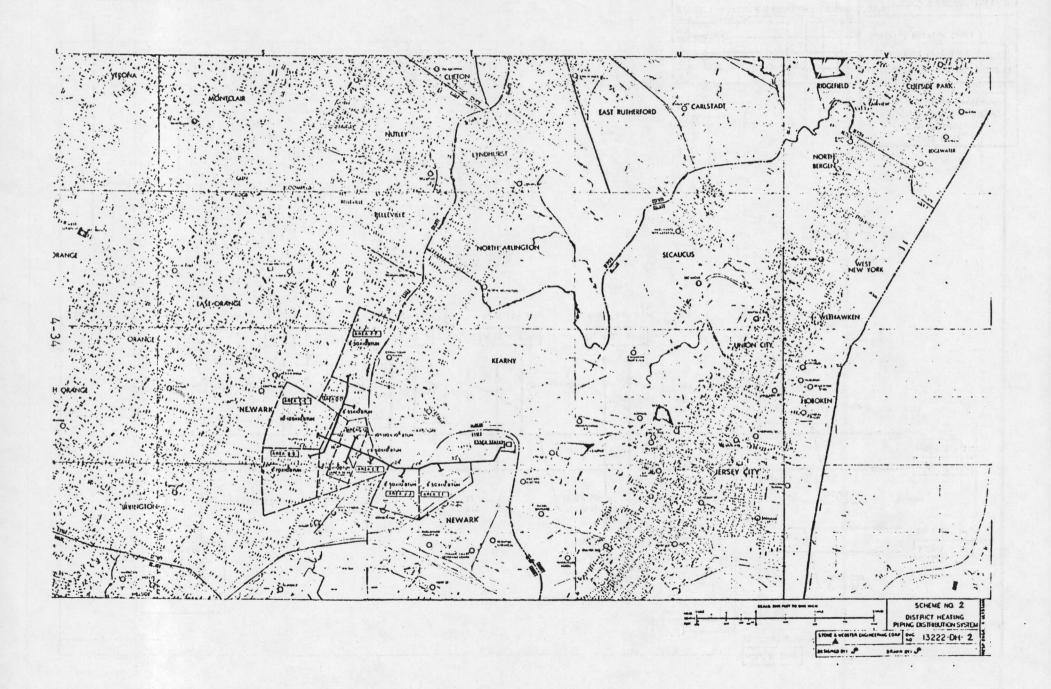


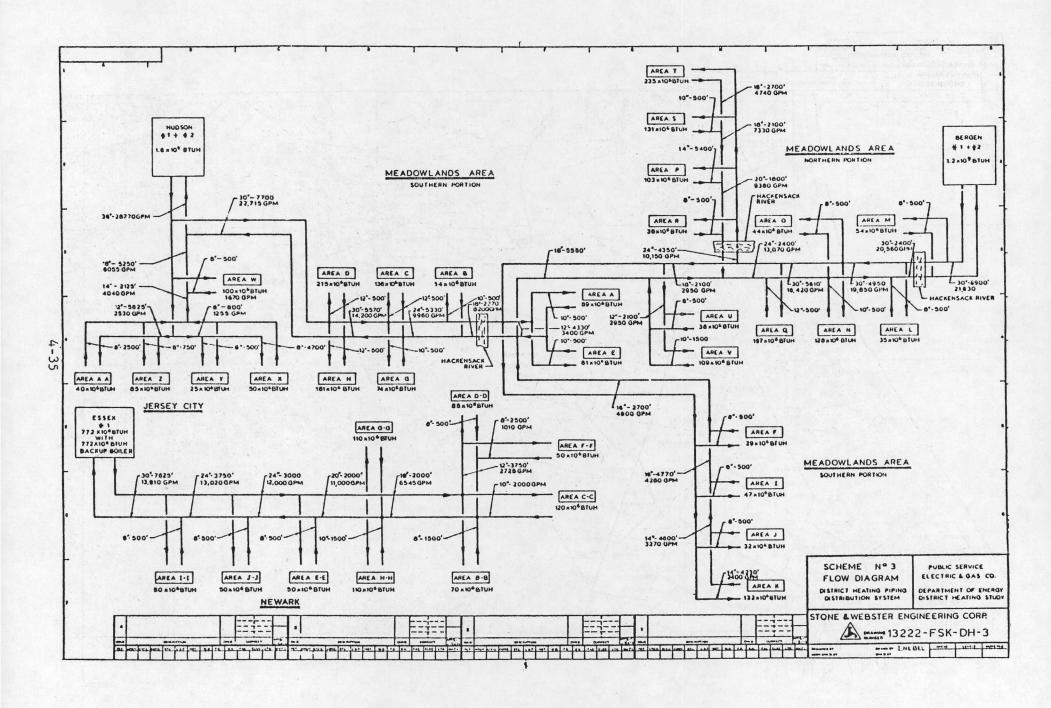


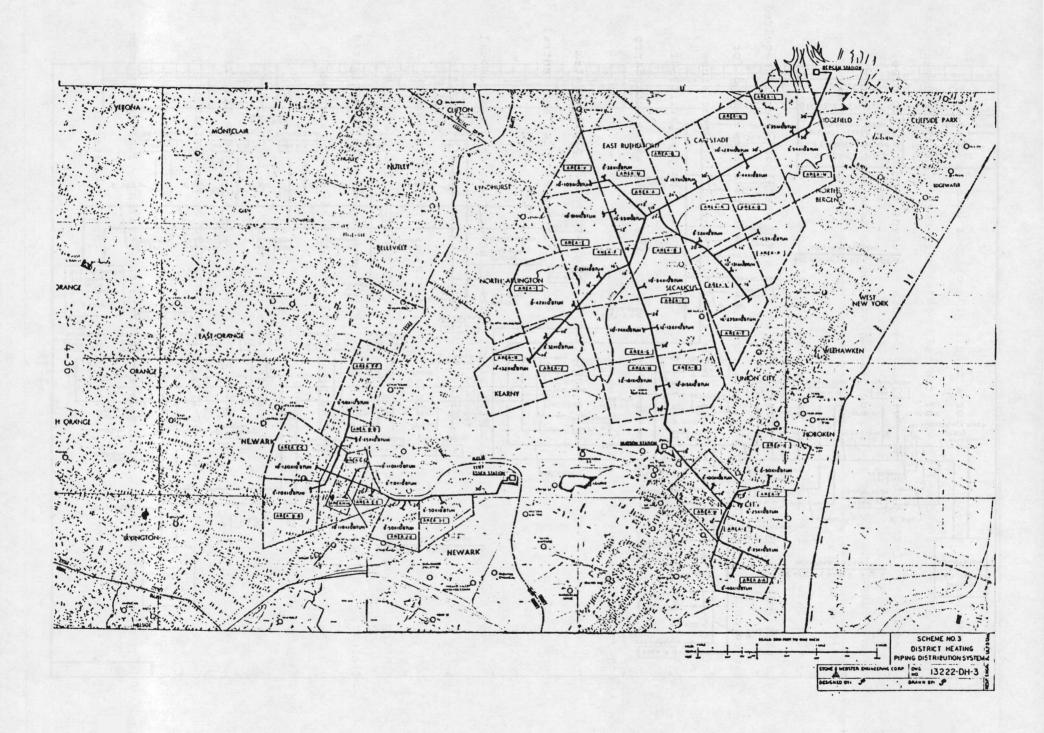


NEWARK









costs may be more expensive than for a single pipe circuit because of two separate pipes, the reduced sizes of the main piping will narrow the differences substantially. Installation cost will not be much different from a single pipe system because the two pipes will run side by side on the same supports, piers, tunnels or trenches.

The same distribution piping can be used for hot water in the heating season and chilled water in the summer except in industrial areas where hot water is required year-round for processing purposes, or where there may be simultaneous demand for heating and cooling. In these areas, separate hot water and chilled water lines shall run in the same trench, tunnel or in the same conduit. The possibility of running the pipes in an existing tunnel or trench shall be evaluated in accordance with regulations of the agencies having jurisdiction.

A leak detection system will be installed in the distribution piping system whereby external or internal leaks can be detected and alarmed at local and central stations.

The installation of distribution piping under existing roads involves removal of the existing pavement and excavation to a sufficient depth and width to allow room for prefabricated pipe. The installation of distribution piping under existing railroads involves tunneling under the railroad tracks and placing a reinforced concrete section over the piping. River crossings will be investigated on a case-by-case basis. Either the piping will be installed on the river bed or hung from existing or new bridges.

Various types of distribution systems were considered. One of these is the placing of underground piping mains with valve stations in concrete culverts (see Figure 4-2). The culverts or troughs are constructed of prefabricated reinforced concrete with the top removable slabs also of reinforced concrete. The troughs rest on gravel to provide for drainage and leveling. Plastic drainage pipe is placed in the gravel for collecting and diverting ground water to a

storm sewer. The cost for this piping system was evaluated and found to be higher in first cost than other systems investigated.

Another type of piping distribution system considered was the use of tunnels. This system was found to be extremely costly and generally could only be justified where ordinary street construction is not possible.

Still another system considered was the use of solid pour concrete conduits where pipes are field welded and installed in trenches and then covered with concrete. This sytem was also found to be too costly as compared with other systems that are not field fabricated.

A piping system which included the enclosing of the underground piping with a field installed loose fill insulation material was also investigated. The loose fill mineral powder is chemically treated to render it permanently water proof and non-flammable. (See Figure 4-3.) The costs of the insulation materials and therefore the overall cost was found to be higher than other systems that are field fabricated. However due to the amount of installation flexibility with a system such as this, it will be analyzed on a case by case basis.

The last system investigated involved factory prefabricated piping which included an outer jacket, insulation and pipe. The piping assembly is shipped to the field generally in 40 ft. sections and field assembled. The prefabricated pipe is available with steel or plastic outer jacket, calcium silicate, fiber-glass or foamed in place urethane insulation, and steel, copper or plastic internal carrier pipes. The initial cost of the factory prefabricated pipe was found to be generally higher than all of the other systems investigated. However since the field labor is kept to a minimum the overall installed cost of the prefabricated piping system is less than the other systems. It is for this reason as well as the ease of installation which made this system the most desirable one for the district heating/cooling study.

The type of pipe construction used to determine the installed cost of piping for this study is as follows:

Carbon steel pipe-standard weight with welded joints

Polyurethane foam insulation suitable for 290°F

Outer jacket of polyvinyl chloride

A listing of the different prefabricated pipe and loose fill insulation products reviewed for use in the distribution system is shown in Table 4-3.

Three types of installation were considered; rural, urban, and suburban (see Figure 4-4).

1) Rural

The pipe cost estimate was prepared first on the basis of rural application with the following considerations:

- a) Pipe field fabricated and installed in approximately 80 foot modules, fabricated on bank side and lowered to trench after bank welding (Shop fabricated length is 20' long, ergo 80' module = 4 x 20' pieces).
- b) Differential Rate established for "Bank" welding vs "Trench" welding.
- c) Open cut excavation considered with sloping sides and minimal impact by such things as traffic, lighting access, or restrictions of any kind.

2) Urban

Having completed the "Base" case i.e., rural application, the extreme case of urban application was considered in the following manner:

- a) Quantify and estimate measurable restrictions
 - . Shoring
 - . Straight cutting of excavation
 - . Cutting and replacing roads
 - Limited access for work particularly effecting pipe laying (no modularization considered - instead piece by piece installation)
 - . Hand excavation deemed necessary because of existing services.
 - . Urban vs rural wage rate differential
 - Barricades and lighting

Air Space Insulation Steel Pipe

TRADE NAME

1	Poly-Therm	Peı
2	Ric-Wil	MiX
3	Super Temptite	Jol
4	Insul-8	Ro
5	Mid Temp	In
6	X-50	Tr
7	Gilsulate 500	AmX
8	Protexulate	Pr
9	All Weather Crete U.P. 20	Si.
10	Thermacor D	Th
11	Aquawarm	Те
12	R=7+	In
13	EBKO	E. X
14	Wohoterm	M _•

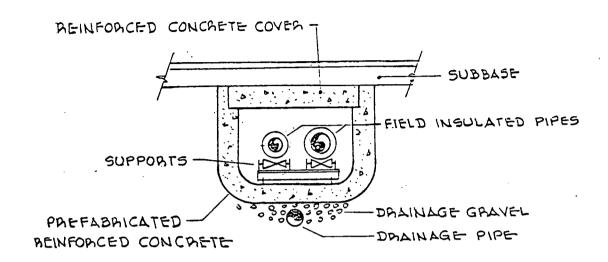


Figure 4-2 Distribution Piping in Concrete Culvert

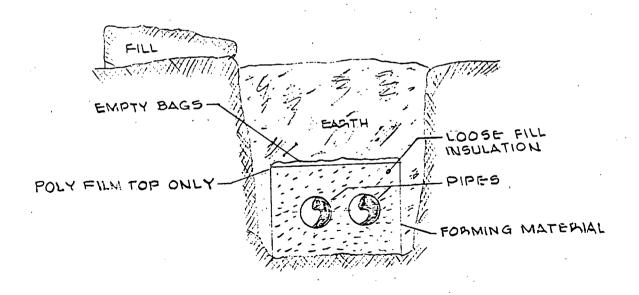
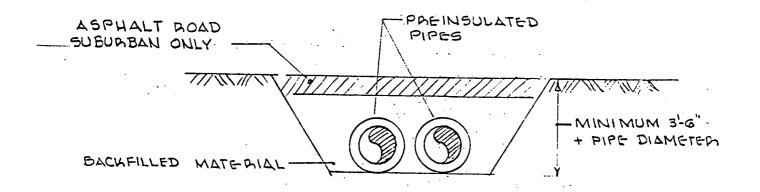
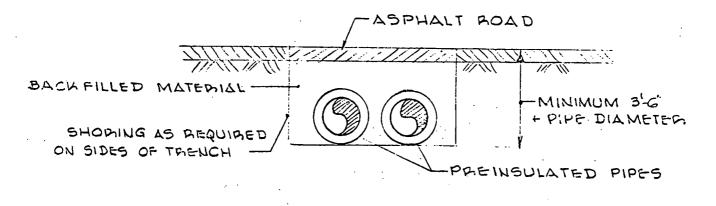


Figure 4-3 Distribution Piping in Loose Filled Insulation Mineral powder



RUBAL & SUBURBAN



UNBAN

Figure 4-4 Types of Installations

b) Allowances for non quantifiable restrictions

- . Guards and watchman (if required)
- Decking (for access)
- . Traffic control
- . Sanitary amenities
- . Staging areas
- . Lay down and equipment areas
- . Permits, licenses and fees
- . Impositions by local authorities, utilities, etc.

3) Suburban

Having considered now both of the extremes i.e., Rural and Urban, it was recognized that Suburban costs would fall somewhere between Urban and Rural. It was visualized that in certain Suburban areas it is possible to experience both Urban and Rural conditions for installation of pipe.

In quantifying the price difference between Rural and Suburban it was on a judgemental basis, considered to be 50% or more than Rural but 50% less than Urban.

The cost estimates for transmission and distribution piping are based on straight runs of pipe with no considerations allowed for bends, fitting, valves, access holes, thrust blocks, etc. A 25% factor was added to the total straight runs piping cost to account for these factors. Also the wage rate established for this effort is considered to be totally contracted (i.e., all contractor's equipment, insurances, site offices, small tools, etc., have been considered). Allowances for hydrostatic testing has been included. A summary of the installed piping costs for each of the three schemes is given in Table 4-4 below.

TABLE 4-4
Installed Pipe Costs

Scheme No.	Area Served	Installed Cost
1	Hudson Station to Meadowlands, (Southern Part) and Jersey City	\$ 45,975,400
2	Essex Station to Downtown Newark	\$ 27,064,500
3	Hudson and Bergen Stations to Meadowlands & Jersey City, Essex Station to Newark	\$109,441,800

The above costs were developed using unit piping material costs and unit piping installed costs in Table 4-5. A breakdown of the distribution piping costs by areas for each of the schemes is given in Appendix E.

TABLE 4-5
Unit Piping Costs

Material and Installed Costs for Distribution Piping shown represent 100 linear feet of trench with (2) pipes of the same diameter per trench.

Pipe Diameter (0.D.) <u>Inches</u>	Ins Rura l	Suburban	Urban	Pipe Material Cost \$/100 L.F. (2 pipes)
1	\$ 3,100	\$ 4,000	\$ 5,000	\$ 770
_ 1½	3,100	4,000	5,000	800
. 2	3,300	4,400	5,400	980
3	4,900	6,400	8,000	1,240
4	5,300	6,900	8,500	1,500
6	6,800	8,800	11,000	2,480
8	8,700	11,400	14,100	3,500
10	11,200	14,600	18,200	5,040
12	13,200	17,200	21,306	5,960
14	15,400	20,100	24,900	7,520

TABLE 4-5 (Cont'd)

Pipe Diameter (0.D.)	meter (O.D.) Ins			Pipe Material Cost
Inches	Rura 1	Suburban	Urban	\$/100 L.F. (2 pipes)
1 6	\$17,200	\$22,500	\$27,900	8,700
18	19,200	25,000	31,000	10,080
20	20,900	27,300	33,800	11,180
24	23,900	31,200	38,700	13,220
30	33,600	43,800	54,300	20,500
36	39,600	51,600	64,100	24,400

C. CONSUMER CONVERSION SCHEMES

The customer system begins where the district heating/cooling pipes enter the premises from the distribution system. It includes any heat exchangers, forced air plenum heating or cooling coils, domestic hot water storage, controls, and heating/cooling supply metering. The customer system does not include components of the existing heating/cooling system, except as it may be necessary to interface with them.

The type of customer system varies with each type of building and affects the method of connection from the district heating/cooling system. The typical connection from the distribution system will have to be adapted for each system on an individual basis. Some of the more common types of customer systems are described in Appendix J.

The conversion schemes considered for this study are applicable to the following types of buildings:

- a) Small commercial buildings
- b) Large commercial buildings
- c) Small industrial buildings
- d) Large industrial buildings
- e) Apartment Buildings

Conversion schemes for the small single family and multi-family dwellings were investigated and found to be too costly to be economically justified at this time.

To determine the economic viability of the conversion schemes which are applicable to the various heating and domestic water systems encountered in the District Heating Study, the following criteria was established:

- 1. The district heating water temperature range for the heating system will be 290° F supply and 170° F return. The supply and return temperatures will vary with the outside ambient air temperature as shown on Fig. 4-1.
- 2. The domestic water supply temperature will be $140^{\circ}F$ with a $40^{\circ}F$ entering water temperature to the storage heater.

The capacity of the hot water system will depend upon the type of building.

Apartment buildings will have the hot water system sized for a 3 hour peak and

2½ persons per apartment. Office buildings or commercial structures and industrial buildings will have their domestic hot water systems sized for the peak demand load of each type of building.

The heating load for the various buildings will be as follows:

- a) small commercial building 40 BTUH/FT².
- b) large commercial building 25 BTUH/FT²
- c) small industrial building 35 BTUH/FT
- d) large industrial building 35 BTUH/FT²
- e) apartment building 20,000 BTUH/Apartment

The various customer heating systems investigated for this activity are as follows:

- a) Hot water heating system with 200°F maximum temperature to finned tube or convector radiation. This system applies to apartment houses and commercial buildings.
- b) Warm air heating system with 290°F maximum water temperature to air heating coil. This system applies to small commercial and industrial buildings.
- c) Steam heating systems were not considered for this activity.

The components of each system are based upon supplying a factory fabricated module for the hot water heating system and domestic water systems. The warm air heating systems will be provided with a factory fabricated module for the domestic water system with field assembled components for the warm air heating system. The total physical size of the factory fabricated module will not be larger than a comparable oil or gas fired furnace.

Hot Water Heating System Module for Multi-Unit Apartment and Commercial Buildings (Figure 4-5)

The heating module will provide space and domestic hot water energy requirements for a multi-unit apartment and commercial office buildings. This module will monitor and maintain all the space heating and domestic hot water requirements while having the capacity of relieving excessive pressure and shutting down the supply and return valves if a leak is detected within the system. It will provide double wall protection for domestic water. The components of the module consist of three shell and tube type heat exchangers HE-1, HE-2, HE-3, Plus:

- Pressure Switch (1)
- Pump (2)
- Air Separator (2)
- Storage Tank (1)
- Valves
- Miscellaneous Piping Between Components

Warm Air Heating System for Small Commercial and Industrial Buildings (Figure 4-6)

The heating module will provide space and domestic hot water energy requirements for the small commercial and industrial buildings. This module will monitor and maintain all the space heating and domestic hot water requirements while having the capacity of relieving excessive pressure and shutting down the supply and return valves if a leak is detected within the system. It will provide double wall protection for domestic water. The components of this module consist of (2) Counterflow, tube in tube heat exchangers HE-1, HE-2, plus:

- Pumps (3)
- Pressure Switches (2 sets)
- Solenoid Valve, Isolation Valves and all valves in Module
- Air Separator & Expansion Tank (2)

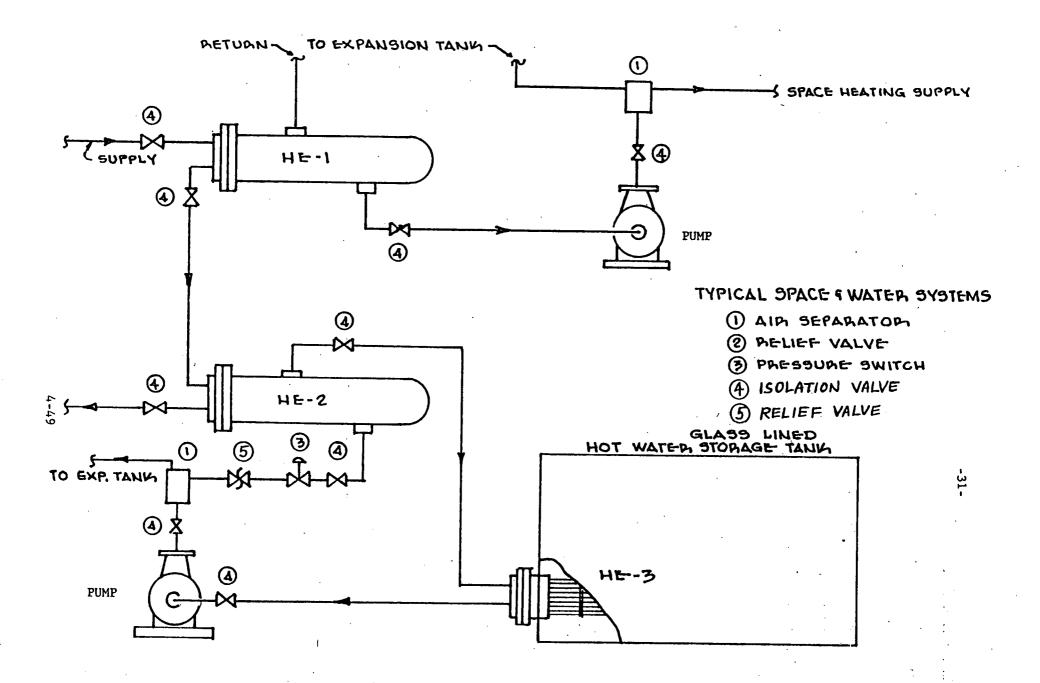


Figure 4-5 Hot Water Heating System Module

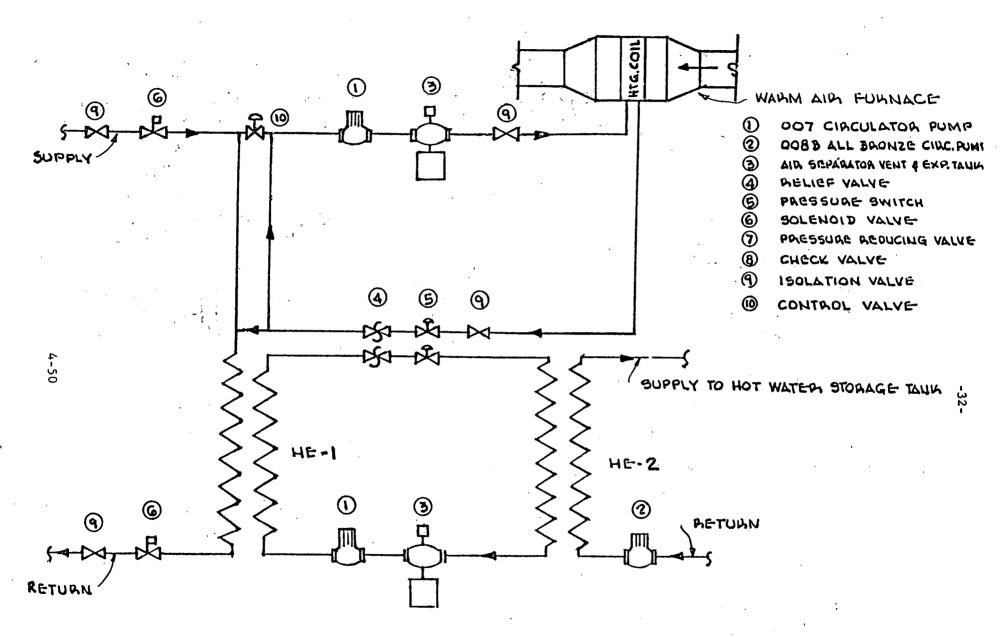


Figure 4-6 Warm Air Heating System Module

- Hot Water Heating Coil (1)
- Additional Duct Work Required to Install Coil
- Miscellaneous Piping Between Components

The capital costs developed for the conversion schemes for various types of customer heating systems are given in Appendix L. Maintenance requirements for the customer systems are given in Appendix M.

D. CONSUMER METERING SYSTEM

The profit of a district heating/cooling system for the utility company lies in the efficient and accurate metering of the amount of energy used by the customer. In order to account for all the energy consumed by the customer, the domestic water heating as well as the building heating/cooling requirements must be determined and metered. In addition the initial costs to potential subscribers connecting to a district heating/cooling system should not exceed those costs that a subscriber would pay had he privately purchased his own system. The capital costs and the operating costs of the system must provide sufficient economic incentive for an owner or landlord to connect his building to a district heating/cooling system.

The following methods of determining accurate usage of the energy by the consumer reflect the current state of the art in the United States and Europe. The types of BTU meters that are considered for the purpose of billing are:

Type A ~ Energy Meter Counter

This type of meter is a wall mounted integration unit with a pair of platinum type resistance thermometers that strap mount to the outside surface of the supply and return lines and a pair of thermowells for insertion into the flowing liquid. This unit and a volume meter are used to measure the present level of energy delivered by both the heating and the chilled water systems.

These meters can be used in the metering of residential, commercial, and industrial buildings.

Type B - Energy Meter Counter and Flow Counter

This type of meter is a wall mounted integration unit with a pair of platinum type resistance thermometers that strap mount to the outside surface of the supply and return lines and a pair of threaded thermowells for insertion into the flowing liquid. This unit and a volume meter integrates differential temperature and the gallons of flow circulated to calculate the heat or cooling value delivered.

When installation where remote readings of many BTU meters are desired, this type of unit has pulse outputs that can be transmitted to a central remote reading unit, it collects data in a convenient location for easier meter reading. These units can be used in the metering of residential, commercial and industrial buildings.

Type C - Central Energy Meter (Degree Day Type)

This type of meter is an electronic temperature central heat meter with an integral function and is equipped with a panel containing a measuring point indicator and an electronic digital counter which shows the actual difference in temperature at each particular reading. This meter centrally registers the number of degree days per apartment on separate counters. The values obtained provide a good basis for allocating fuel costs. The indoor temperature is measured with one or more resistance thermometers which are placed inside each apartment at representative locations. The outdoor temperature is measured by resistance thermometers mounted on the shaded side of the building. These meters can be used in the office and apartment buildings. No volume meter is required for this system.

Type D - Central Energy Meter (Simultaneous Distribution Type)

This type of meter is an electronic central BTU meter measuring simultaneously up to 64 heat distribution circuits. Individual heat quantities consumed are displayed on separate digit counters, one for each measuring point. This meter is particularly suited for high density office or apartment buildings where heating/cooling is supplied from a central source. For a two pipe system supplying heating/cooling each tenant is equipped with two temperature probes and a volume meter is required for this system.

The volume meter must be installed so that the flow is favorable at the entry.

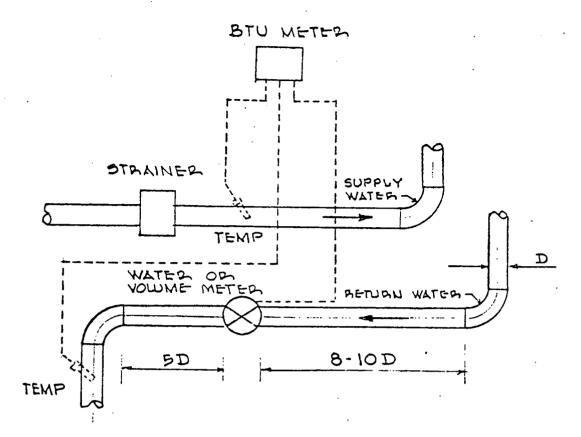
The temperature sensors must also be placed in a way that their outputs will not be affected by other factors than the water temperature.

In an effort to decrease energy consumption, individual distribution metering between different units, i.e., between each apartment in an apartment building, is becoming more and more common. When apartments have received individual energy meters, decreases reaching 25% in space heating energy consumption have been reached in some cases. Energy usage for domestic hot water heating has decreased 30 to 50%.

Distribution metering can also be made centrally. For this purpose the electronic meters consist of resistance temperature sensors and a centrally installed cabinet with counters and an integrating function. The temperature in each apartment is measured and converted to degree days. These are in turn compared to the outdoor temperature. The final results for each apartment are registered on a counter. The values obtained provide a basis for dividing the energy cost charges to the individual users.

One aspect of energy measurement that is often neglected is the design of the location where the meter is installed. The volume meter must be installed so that the flow is favorable at the entry. The temperature sensors must also be placed in a way that their outputs will not be affected by other factors than the water temperature. A typical metering station is shown on Figure 4-7.

The results of a preliminary survey of the hardware costs for the different types of heating/cooling supply meters are given in Appendix K.



TYPICAL METERING STATION

FIGURE 4-7

APPENDIX A

USE OF BACK PRESSURE TURBINE VERSUS PRESSURE REDUCING VALVES TO SUPPLY STEAM FOR DISTRICT WATER HEATING

The scheme for heating district water at the Bergen Generating Station provides for two back pressure turbine-generators. Back Pressure Turbine No. 1, the one which operates with the smaller pressure ratio, provides low pressure exhaust steam for the second stage district water heating.

To heat district water to the desired temperature at the outlet of the second stage heater, steam from the cross-overs of the main unit at 74 psia must be brought to a pressure level of about 29 to 35 psia. If pressure reduction is to be achieved through reducing valves, the low pressure steam to the second stage heater will have a higher enthalpy than the enthalpy of the exhaust steam from the back pressure turbine. The corresponding steam flow rate to be extracted from the cross-overs will be less when reducing valves are used. The maximum difference in net generation of the generating unit, between the case of using a back pressure turbine and the case of using pressure reducing valves, has been estimated to be about 5100 Kw in favor of using the turbine (heat balance data).

It is estimated that, during a typical year, Back Pressure Turbine No. 1 will operate at full load for about 700 hours and at an average generation of 2,550 Kw for an additional 3,000 hours. The capacity factor of this turbine, based on 8,760 hours of the year, is 25.1 percent. The average generation gain during the year is 1,280 Kw in favor of using the back-pressure turbine. This gain is in a sense a free benefit, since no additional fuel needs to be burned to produce it. It is equivalent to a justifiable investment of \$3,992,067 (See calculations on next page). In arriving at the above figure, the following assumptions have been made:

- 1. Fuel price escalation per year: 6 percent
- Interest rate: 10 percent
- 3. Carrying charge: 13.5 percent (from PSE&G data)
- 4. Plant life: 30 years
- 5. No value is assigned to capitalized replacement capacity.

In our present district heating study, the back-pressure turbine and generator (rated at about 6,000 Kw) was priced at approximately \$932,000. The total installed cost, including turbine pedestal, control, and related electrical equipment, was estimated to be about \$1,700,000. Cost of the portion of the building attributable to the turbine-generator has not been included. This cost should not be more than \$800,000 based on our

current pricing of the building to house the district heating facilities. Also not included is interest during construction. We have been informed by PSE&G that operation of the back-pressure turbine-generator will be assumed by their present operating staff.

The above cost benefit comparison demonstrates that the scheme with the back-pressure turbine is a better choice over that using pressure reducing valve. We recommend that a more detailed study be made by our Heat Balance Group during Phase II of this study.

The capacity factor of Back Pressure Turbine No. 1 is calculated as follows:

$$\frac{5,100\text{Kw} \times 700 \text{ hrs} + 2,550 \text{ Kw} \times 3,000 \text{ hrs}}{8,760 \text{ hrs} \times 5,100 \text{ Kw}} = 0.251, \text{ (or 25.1\%)}$$

The annual average generation gain resulted through using the back pressure turbine is:

Annual average generation gain = 0.251 x 5,100 Kw = 1,280 Kw

Fuel cost saving for the year 1979, based on the annual average energy cost for PSE&G system of \$0.027 per KW-hr (obtained from PSE&G's Operating Department):

 $$0.027/\text{Kw-hr} \times 1,280 \text{ Kw} \times 8,760 \text{ hrs/yr} = $302,769./\text{yr}$

Levelized fuel cost saving per year, based on 6% fuel price escalation per year for the next 30 years, is:

 $1.78 \times $302,769./yr = $538,929./yr.$

Justifiable investment based on a carrying charge of 13.5 percent per year is:

\$538,929. / 0.135 = \$3,992,067. Present Worth Value

APPENDIX B - SYSTEM DESCRIPTIONS & HEAT BALANCE DIAGRAMS Includes the following documents for Essex, Kearny, Hudson and Bergen

- 1) System Descriptions
- 2) Heat Balances Diagrams for the following Conditions:
 - a) valve wide open no district heat
 - b) valve wide open 0°F ambient temperature
 - c) valve wide open 30°F ambient temperature

SYSTEM DESCRIPTION DISTRICT HEATING RETROFIT BERGEN GENERATING STATION

System Design

The district heating water heating system at the Bergen Generating Station provides for two non-extracting back pressure turbines, (No. 1 and No. 2). Steam to the turbines is taken from the cross-overs of the main units at the condition of 74 psia and 613 degrees F. The exhaust pressures of the two turbines are 35 psia and 17 psia respectively. Steam from the turbine exhausts is condensed in shell and tube heat exchangers in the first two stages of district water heating. During the periods when the ambient temperature is 30 degrees F or above a maximum district heating water temperature of 238 degrees F can be maintained at the outlet of the second stage heater by operating both back-pressure turbines. During the periods when the ambient temperature is below 30 degrees F, the district heating water is further heated in one of the two peaking heaters to a temperature up to 290 degrees F. Steam to the peaking heater is taken from the main turbine cross-overs through a pressure reducing valve which maintains the final district heating water temperature at the desired level.

It is estimated, subject to further study and approval by the turbine manufacturer, that approximately 1.07×10^6 pounds of steam per hour can be extracted from the Unit 1 main turbine cross-overs during full load operation, with provision of extracting the same amount of steam from the Unit 2 cross-overs as a back-up. During normal operation steam can be taken from either unit since both of the units are identical and both burn the same type of fuel oil. With the above steam flow, approximately 10.0×10^6 pounds of district heating water per hour (or 21,600 gpm) can be heated from a return temperature of 170 degrees F to the maximum required temperature of 290 degrees F.

The district heating water heating system at the Bergen Station has been designed to provide complete back-up in the event that any one of the heaters or both back-pressure turbines are taken out of service. Each piece of equipment can be by-passed and isolated by valves, for maintenance without reducing the heating capacity of the district heating water heating system.

The system provides for two base loaded heaters in series with two full size peaking heaters arranged in parallel. Individual by-pass is provided for each of the two base loaded heaters. During normal operation, only one peaking heater is needed, with the other peaking heater serving as a back-up. In the event that one of the two turbines is down for maintenance, the base loaded heater associated with that turbine can be by-passed. In the event that both back-pressure turbines are shut down or both base loaded heaters are taken out of service, the two peaking heaters operating together can meet the district heating water temperature requirements for any ambient temperature condition considered in the system design.

Drains from heaters are cascaded successively to the next lower pressure heater. The drain from the lowest pressure heater is normally cooled in one of two external drain coolers, by condensate, before being returned to the condenser hot well of the unit which supplies the heating steam. (i.e., The drain cooler of Unit 1 is cooled by the condensate of Unit 1 and drains to Unit 1 condenser. The drain cooler of Unit 2 is cooled by the condensate of Unit 2 and drains to the Unit 2 condenser. Only one drain cooler will be operating at a given time.) Emergency drain lines to both condensers are provided for each heater. In the event of extremely high heater water level, one of the lines will open to discharge the heater drain flow to the condenser of the unit which supplies the heating steam.

The low pressure steam extracted from the main unit cross-overs has a very large volume flow rate. Presently inlet control valves of the size needed to pass the required volume flow rate through the back-pressure turbines are not readily available from turbine manufacturers. However, it is possible to use a control valve and a start-up by-pass valve external to the back-pressure turbine inlet.

Synchronization can be accomplished while the turbine is operating at noload flow. Once the generator is synchronized and locked-in with the outside system frequency, load on the turbine can be increased. The back-pressure turbines will be specified to include overspeed protection with overspeed trip at 110 percent of the rated speed.

The final temperature of the district heating water leaving the plant will vary inversely with the outside ambient temperature. During the periods when the outside temperature is below 30 degrees F, both the back-pressure turbines, their associated base loaded heaters, and one peaking heater will be in operation. During the periods when the outside temperature is above 30 degrees F, the peaking heater will not extract steam from the cross-overs, and no heating will be done through the peaking heater. During the periods when the outside temperature is above 50 degrees F, Back Pressure Turbine No. 1, which supplies steam to the second stage heater, can be shut down, leaving only Back Pressure Turbine No. 2 running.

During the periods of full district heating load, a very small portion (ie, 15%) of the normal low-pressure turbine steam flow is condensed in the condenser. The condenser will be operating at low load and very low absolute pressure, (i.e., 0.5 inch Hg). In order to adequately remove the oxygen leaking into the condenser,

the capacity of the existing condenser air removing equipment must be increased.

Building

The building housing the district heating water equipment measures approximately 190 feet long by 80 feet wide. It consists of two levels. The back-pressure turbine generators are located on the upper level, or operating level. In the lower level are located the district heating water heat exchangers, and district heating water circulating pumps. The building is equipped with an overhead crane and a monorail system of sufficient capacity to service the turbine generator and heaters. The roof of the upper level is at elevation 75 ft above grade. The building is constructed of structural steel frame with insulated corrugated metalic sidings and long span joist with built-up roof. It is located tentatively in the parking lot area directly east of the plant. To make-up the loss in parking spaces the northeast corner of the plant site will be land filled and paved into a parking lot. The foundation of the new building will be placed on piles.

Operation

The district heating water heating system is designed primarily for automatic operation with minimum operator interface. The extraction steam, back-pressure turbine generators, and electric power distribution are monitored and controlled from the plant main control room. The district heating water heat exchangers, water distribution system, heater drains, and other auxiliary systems are controlled from a control room in the building housing the district water heating equipment. Only trouble alarms and critical parameter indications are brought to the plant main control room.

The district heating water flow through the system is essentially constant. District heating load demand is satisfied by varying the district heating water supply temperature, based on the outside ambient temperature. The steam flow to each heater is controlled based on a demand index computed from the following parameters:

- a. Water temperature at the inlet to the heater this varies depending upon the outside ambient temperature and the number of heaters in service.
- Point) set point for the desired water temperature at the outlet of a heater is a sliding number based on the outside ambient temperature and the number of heaters in service.
- c. Water flow through the heaters.

The extraction steam pressure is controlled by the use of the backpressure valves PV21A and PV21B. The demand for extraction steam to the district heating system must be satisfied first, and the balance of steam flow is
sent to the low pressure turbine. The computed steam flow demand indices for the
first stage heater (DH3) and second stage heater (DH2) control the flow rates
(and electrical output) of Back Pressure Turbines No. 2 and No. 1 respectively.
The computed steam flow demand indices for the peaking heaters control their
associated steam flow (temperature) control valves.

The normal drain from each heater is sent to the next lower pressure heater at a rate controlled by a normal level controller. If the level in a heater shell rises beyond the range of the normal level controller, emergency drain to

the condenser of the unit supplying the steam is initiated by an emergency level controller. High and low level in each heater is alarmed. In the event that a heater cannot drain properly because of heater tube leak, valve malfunction, or high level of water in the downstream heater shell, the motor operated valve in the steam extraction line will be closed and, if a back-pressure turbine is connected to the extraction line, it will be tripped. Heaters are taken out of service manually.

The heater drain flowing through the drain cooler is cooled to a set temperature by regulating a three way flow control valve to be provided in the main condensate line to the existing feedwater heaters.

The pressure of the district heating water in the tube side of the heater is higher than the pressure in the shell side. In the event of a tube leakage, the district heating water will flow into the shell side of the heater and thereby contaminate the condensate. A water sampling system is provided to monitor continuously the drain flowing out of each heater. If abnormal level of impurities is detected in the drain from any heater, an alarm is sounded in the control room, the steam flow to the heater is automatically isolated by the use of motor operated valves and the heater is manually by-passed.

System Monitoring and Control

The following monitoring and control shall be provided as a minimum:

- 1. Flow rates of the steam extracted from cross-overs.
- Pressures and temperatures of the steam to the back-pressure turbines and heaters.
- 3. Back-pressure turbine generators No. 1 and No. 2 monitoring and control.

- 4. Pressure and temperature of the exhaust steam from each backpressure turbine.
- 5. Inlet and outlet temperatures of the district heating water across each heater.
- 6. Flow of the district heating water through the system.
- 7. Pressures and temperatures of the supply and return district heating water.
- 8. High and low temperature (sliding) alarms for the district heating water at the outlet of each heater.
- 9. Control, monitoring and protection of the district heating water circulating pumps.
- 10. Monitoring of the drain water quality out of each heater.
- 11. Level monitoring of the water in the shell of each heater and low level/high level alarm.
- 12. Monitoring and control of the electrical equipment in the district heating water building and ties to the switchyard.
- 13. Monitoring and control of the auxiliary systems.

In addition to the above, sufficient instrumentation can be provided to perform diagnostic and efficiency calculations for the back-pressure turbine generators and the heaters, but has not been included in the scope of supply for Phase I of the study.

ELECTRICAL - BERGEN

(See Dwg. No. 13222-ESK-B1 & 2)

Power Distribution

Two new turbine-generators, back-pressure type, will be installed. The generators will be air or water cooled, 7.5 & 12 MW, 0.8 PF, 13.8KV, 3600 RPM, 3-Phase 60 Hertz. Each generator will be grounded through its own neutral grounding transformer and resistor.

Each generator output will be connected through its own generator air circuit breaker and one common main transformer to 26KV station switchyard (not shown on drawing).

Generator air circuit breakers will be metal enclosed, switchgear type and will be rated 1200 amperes, 13.8KV, 500MVA. Additional switchgear cubicles will be provided to house potential & current transformers, metering and tie to the auxiliary/start-up transformer.

Main transformer will be outdoor, OA/FA type, 13/16MVA, 26KV Wye-13.8KV Delta, 3-Phase, 60 Hertz, 200KV BlL. Transformer neutral will be solidly grounded on the high side. Bushing current transformers and lightning arresters will be provided. 15KV, 1200A disconnect switch, grounding type, will be provided for main transformer isolation.

The district heating loads and required auxiliary loads will be supplied from auxiliary/start-up transformer, rated 8/10 MVA OA/FA, 13.8KV Delta-4.16KV Wye, 3-phase, 60 Hertz, 110KV BlL. Bushing current transformers, lightning arresters will be provided for transformer protection, and grounding resistor to limit 4160V ground fault current to 1000 amperes.

Start-up power will be supplied from 26KV switchyard through main transformer to auxiliary/start-up transformer.

During normal operation, new generators will supply power to this transformer, and excess generator power will be delivered to electrical grid at 26KV switchyard.

One section of 4160V metal clad switchgear, one 480V load center and two 480V motor control centers will be provided and installed to distribute power to auxiliary and district heating loads. 4160V switchgear will consist of 1200A, 350 or 250MVA (as will be required) air circuit breakers, namely, main circuit breaker, feeder breakers as required, and tie breaker

to existing station service bus, to provide back-up power to auxiliary load in case the auxiliary/start-up transformer is out of service.

Each switchgear cubicle will contain current transformers and protective relays as required. Separate switchgear cubicle will be provided to house potential transformers, auxiliary relays and metering.

Power from 4160V switchgear will be supplied to large motors (300Hp and above) and the load center.

480V load center will supply large 480V loads, including motors 60 Hp and larger. Motor control center will supply motors 50Hp and smaller, motor operated valves, lighting and power transformers, welding receptacles.

Load center will consist of adequately sized transformer, dry type, 4160-480V, and air circuit breakers with static trip, with long time and short time or instantaneous adjustable trips, as applicable, in order to obtain trip coordination.

125V DC System

For control of the 13.8KV generator breaker, 4.16KV swtichgear, 480V load center air circuit breakers and emergency lighting and two 120V D.C. motors for the emergency bearing oil pumps, a 125V D.C. battery, battery charger and D.C. distribution switchboard will be provided. The battery will be of the lead-acid type, adequately sized for 2 hours duty cycle in case of power failure. Sattery charger will be of the static type. The 125V D.C. distribution switchboard will contain relay and meters for protection and monitoring of the system.

120/208V Regulated Power Supply

For control and instrumentation circuits requiring regulated safe power, regulated power system will be provided. It will consist of 2-20KVA, 480-298/120V dry type transformers, 2-15KVA voltage regulators, automatic transfer switch mechanical or static type, as required, and 120/208V A.C. distribution power panel. One transformer and voltage regulator will be supplied from new motor control center, the back-up power to the other transformer and regulator will be brought from existing 480V motor control center.

Grounding

Grounding will be provided for the new building and equipment. A ground loop consisting of 4/0 bare copper cable and grounding rods will be

installed around the perimeter of new building and interconnected with the existing station ground loop. All electrical equipment, building steel etc. will be grounded in accordance with PSE&G grounding standards and practice.

Raceways and Underground Ducts

All main power cable, 15KV and 5KV will be run in galvanized steel conduits. Separate galvanized steel trays will be used for 480V power, control and instrument cable, except conduit will be used for local runs from tray to equipment.

Underground ducts consisting of plastic conduit encased in concrete will be used for long runs outdoors as required.

Wire and Cable

All cable will be fire retardant, EPR insulation with neoprene jacket stranded copper. Insulation levels as follows:

15KV - 1/c Cable, shielded for all 13.8KV CKTS

5KV - 1/c Cable, shielded for all 4160V CKTS

All other power cable will be 600V insulation single or multiconductor.

All control cable will be copper, stranded, 600V EPR insulation, neoprene jacket, multiconductor cable. Instrument cable will be shielded, 300V EPR insulation, neoprene jacket, #16 AWG single pair, or #18 AWG multipair.

Thermocouple cable will be chromel-constantan shielded, 300V insulation.

Lighting

All new indoor areas will be illuminated in accordance with the latest requirements of IES Levels of Illuminations.

High intensity discharge (HID) lamps of suitable type, will be used for all high bay and low bay areas. Incandescent fixtures will be used for other areas and for all emergency lamps.

Illumination will be provided in accordance with current OSHA requirements for all exit facilities and means of egress.

Normal a-c lighting system will be supplied from motor control center through 480-120/208 volt 30KVA transformer, dry type, and lighting distribution panels.

Emergency lights will be supplied from the 125V D.C. battery through separate a-c panel board, which will be automatically energized on a-c power failure.

Egress lighting and exit signs will consist of internally illuminated exit signs which will be normally powered from a-c circuit but on a-c power failure will be automatically transferred to 125V D.C. battery power. Convenience receptacles will be provided as required. Branch circuits supplying receptacles in wet and conductive areas will be provided with ground-fault circuit interrupter (GFCI) protection.

Outdoor areas will be illuminated with high intensity discharge (HID) lamps or incandescent lamps.

Lighting and receptacle wire will be solid copper for No. 12 and No. 10 AWG and stranded for No. 8 AWG and larger and will have XHHW, cross-linked polyethylene, 90° C insulation, moisture and heat resistant, 600V rating.

All lighting conduit will be minimum 3/4 inch and will be galvanized steel EMT for indoor areas, and rigid galvanized steel for outdoor areas.

Public Address System

Public address system will be installed and connected to the existing system. The paging system will match the existing system as to paging and party-line channels.

Raceways and space for public telephones will be provided, as per requirements to be established.

SYSTEM DESCRIPTION DISTRICT HEATING RETROFIT ESSEX GENERATING STATION

System Design

The district heating water heating system at the Essex Generating Station utilizes the low pressure steam from the main turbine cross-overs of Unit No. 1, and steam from two 100 psig auxiliary boilers, rated at 285,000 lbs/hr and 500,000 lbs/hr respectively. The maximum steam pressure at the cross-overs is 50 psia, not high enough for the peaking heaters. It is estimated that, subject to further study and approval by the turbine manufacturer, a maximum of 475,000 pounds per hour of low pressure steam can be extracted from the main turbine cross-overs. The extracted steam is fed, through pressure reducing valves, to the low pressure first stage heater (DH2). This heater operates at pressures between 29 psia and 34 psia. Approximately 6,430,000 pounds of district heating water per hour (or 13,900 gpm) can be heated in this heater from 170 degree F to 247 degree F. The latter temperature is adequate for the ambient condition at or above 30 degree F. Drain from this heater is normally cooled in an external drain cooler before being returned to the condenser. An emergency drain to the condenser is provided in the event of extreme high heater water level.

During the periods when the ambient temperature drops below 30 degree F one of the two peaking heaters (DHIA, DHIB), taking steam from the 285,000 lbs/hr boiler, is able to heat the district heating water to a temperature up to 290 degrees F. The second peaking heater, which operates in parallel with the first peaking heater, serves as a back-up in the event that the first peaking heater is taken out of service. Steam to the peaking heaters can be supplied from both auxiliary boilers. In the event that the low pressure extraction steam is not available from the main turbine cross-overs or that the first stage heater is down for maintenance, the two peaking heaters will have sufficient capacity, when operating in parallel with steam supplied from both boilers, to heat the district heating water to the required temperature for any ambient condition considered in the system design.

Makeup to the auxiliary boilers enters the peaking heaters. These heaters are equipped to remove oxygen and any non-condensable gases. Drain from the peaking heaters is pumped back to the boilers through a set of four feed pumps arranged in parallel. For normal peaking service, only the 285,000 lbs/hr boiler is needed and one pump will be running. For back-up service, both peaking heaters and both boilers will be operating, and three pumps will be running. The fourth pump serves as a spare.

The auxiliary boiler system presently has no means for draw-off to maintain heater water level. Between the high load and low load conditions, the water levels in the peaking heaters will vary. However, the peaking heater is very large in size, and can serve as a surge tank. It is estimated that a one-foot change in heater water level is possible between the high and low load conditions.

The air operated non-return valves NRV31A, and NRV31B in the steam lines to the heaters DH1A and DH1B prevent water from backing up into the steam lines in the event that motor operated valve MOV30 fails to close. They also serve as isolation valves to allow maintenace of the temperature valves TV41A and TV41B. The valves NRV24 at the auxiliary boilers are automatic nonreturn valves equipped with air cylinders to facilitate opening and closing.

An alternative scheme to provide peaking and back-up capacities for the district heating water heating system is to replace the auxiliary boilers with hot water heaters. In this scheme, high temperature water at 400 degrees F is piped from the hot water heaters to the peaking heaters DH1A and DH1B. Another scheme is to replace heaters DH1A and DH1B with direct fired hot water heaters. It is recommended that a cost benefit analysis be made during Phase II of this study to determine the most economic solution.

Building

The space required to house the district heating water equipment measures approximately 112 feet long by 105 feet wide and by 40 feet high. The district heating water heaters, the district heating water circulating pumps, and the auxiliary boiler feed pumps are all located on one level. Presently the location for this space has not been determined. For the purpose of the cost estimate, a new building constructed of structural steel frame with insulated corrugated metalic sidings has

been assumed. The building will be equipped with suitable material handling equipment to service the heaters and the pumps. It is recommended that, during Phase II of this study, an investigation be made to determine if it is advisable to utilize the existing building by removing the obsolete equipment which can no longer be used.

Operation

The district heating water heating system is designed primarily for automatic operation with minimum operator interface. The extraction steam from the cross-overs is monitored and controlled from the plant main control room. The auxiliary boilers, the district heating water heat exchangers, water distribution system, heater drains, and other auxiliary systems are controlled from the control room in the building housing the district water heating equipment. Only trouble alarms and critical parameter indications are brought to the plant main control room.

The extraction steam pressure is controlled by the use of back-pressure valves PV34A and PV34B. The demand for heating steam to district heating water heater DH2 must be satisfied first, and the balance of the steam flow is sent to the low pressure turbine.

The steam to the deaerating heaters DHIA and DHIB is supplied from the auxiliary boilers No. 1 and No. 2. Each boiler master is set to deliver steam to the heaters at a constant pressure.

The district heating water flow through the system is essentially constant. District heating load demand is satisfied by varying the district heating water supply temperature, based on outside ambient temperature. The steam flow to each heater is controlled based on a demand index computed from the following parameters:

- a. Water temperature at the inlet to the heater this varies depending upon the outside ambient temperature and the number of heaters in service.
- b. Desired water temperature at the outlet of the heater (Set Point) - set point for the desired water temperature at the outlet of a heater is a sliding number based on the outside ambient temperature and the number of heaters in service.
- c. Water flow through the heater.

The computed steam flow demand index for the heater DH2 controls the two steam flow (temperature) control valves TV40A and TV40B. The computed steam flow demand indices for the deaerating heaters DH1A and DH1B control their associated steam flow (temperature) control valves, using the signals of the heater water levels as a trim.

District heating water heater DH2 has its normal drain to the drain cooler and emergency drain to the condenser. The heater drain flowing through the drain cooler is cooled to a set temperature by regulating a three way flow control valve to be provided in the main condensate line to the existing feedwater heaters. Deaerating heaters DH1A and DH1B drain directly to the suction header of the four motor driven auxiliary boiler feed pumps. In the event of heater tube leak, and/or equipment malfunction, the level of water in the heater shell may reach abnormal level. In this event the motor operated valve in the steam side will close and the auxiliary boilers are tripped. Heaters are taken out of service manually.

The pressure of the district heating water in the tube side of the heaters is higher than the pressure in the shell side. In the event of a tube leakage, the district heating water will flow into the shell side of the heater and thereby contaminate the condensate. If abnormal level of impurities is detected in the drain from any heater, an alarm is sounded in the control room, the steam flow to heater DH2 is isolated automatically if the drain from this heater shows abnormal level of contamination. Steam to heaters DH1A and DH1B is isolated (remote) manually by the operator, if the drains from these heaters are contaminated.

Auxiliary Boiler Control

Each auxiliary boiler is controlled by a boiler master controller which maintains the firing rate desired to supply the required steam flow to the district heating water heaters at a constant pressure. Burner management system is provided to operate the boiler safely in accordance with NFPA standards. Feedwater to the boilers is regulated by the use of three

element (steam flow, feedwater flow, and drum level) control. Normally one of the three feedwater pumps will be in service and the standby pump starts automatically on low feedwater header pressure or electrical trip of an operating pump. Each feedwater pump is provided with continuous minimum flow recirculation and is protected against low suction.

System Monitoring and Control

The following monitoring and control shall be provided as a minimum:

- 1. Flow rate of the steam extracted from the cross-overs.
- Pressures and temperatures of the steam supply to the district water heaters.
- 3. Monitoring and control of the auxiliary boiler fuel system, air system, feedwater system, and other auxiliaries.
- 4. Inlet and outlet temperatures of the district heating water across each heater.
- 5. Flow of the district heating water through the system.
- 6. Pressures and temperatures of the supply and return of the district heating water.
- 7. High and low temperature (sliding) alarms for water at the outlet of each heater.
- 8. Control, monitoring and protection of the district heating water circulating pumps.
- 9. Monitoring of the drain water quality out of each heater.
- 10. Level monitoring of water in the shell of each heater and low level/high level alarm.
- 11. Monitoring and control of the electrical equipment in district water heating building.
- 12. Monitoring and control of the auxiliary systems.

ELECTRICAL-ESSEX

(See Dwg. No. 13222-ESK-E1)

The district heating loads and required auxiliary loads will be supplied from new station service transformer, outdoor type, rated 5/6.25MVA,OA/FA,26KV Delta-4.16KV Wye, 3-phase, 60 Hertz, 200KV BIL. Bushing current transformers, lightning arresters will be provided for transformer protection, and grounding resistor to limit 4160V ground fault current to 1000 amperes.

All power will be supplied from 26KV switchyard through this transformer, to auxiliary/start-up transformer.

One section of 4160V metal clad switchgear, one 480V load center and one 480V motor control center will be provided and installed to distribute power to auxiliary and district heating loads. 4160V switchgear will consist of 1200A, 350 or 250MVA (as will be required) air circuit breakers, namely, main circuit breaker, feeder breakers as required, and tie breaker to existing station service bus, to provide back-up power to auxiliary load in case new station service transformer is out of service.

Each switchgear cubicle will contain current transformers and protective relays and metering.

Power from 4160V switchgear will be supplied to large motors (300Hp and above) and to the load center.

480V load center will supply large 480V loads, including motors 60 Hp and larger. Motor control center will supply motors 50 Hp and smaller, motor operated valves, lighting and power transformers, welding receptacles.

Load center will consist of adequately sized transformer, dry type, 4160-480V and air circuit breakers with static trip, with long time and short time or instantaneous adjustable trips, as applicable, in order to obtain trip coordination.

125V DC System

For control of the 4.16KV switchgear, 480V load center air circuit breakers and emergency lighting, a 125V D.C. battery, battery charger and D.C. distribution switchboard will be provided. The battery will be of the lead-acid type, adequately sized for 2 hours duty cycle in case of power failure. Battery charger will be of the static type. The 125V D.C. distribution switchboard will contain relay and meters for protection and monitoring of the system.

120/208V Regulated Power Supply

For control and instrumentation circuits requiring regulated safe power, regulated power system will be provided. It will consist of 2-20KVA, 480-208/120V dry type transformers, 2-15KVA voltage regulators, automatic transfer switch mechanical or static type as required, and 120/208V A.C. distribution power panel. One transformer and voltage regulator will be supplied from new motor control center, the back-up power to the other transformer and regulator will be brought from existing 480V motor control center.

Grounding

Grounding will be provided for the new building and equipment. A ground loop consisting of 4/0 bare copper cable and grounding rods will be installed around the perimeter of new building and interconnected with the existing station ground loop. All electrical equipment, building steel etc. will be grounded in accordance with PSE&G grounding standards and practice.

Raceways and Underground Ducts

All medium voltage power cable will be run in galvanized steel conduits. Separate galvanized steel trays will be used for 480V power, control and instrument cable, except conduit will be used for local runs from tray to equipment.

Underground ducts consisting of plastic conduit encased in concrete will be used for long runs outdoors as required.

Wire and Cable

All cable will be fire retardent, EPR insulation with neoprene jacket, stranded copper. Insulation levels as follows:

5KV-1/c cable shielded for all 4160V CKTS
All other power cable will be 600V insulation, single or multiconductor.

All control cable will be copper, stranded, 600V EPR insulation, neoprene jacket, multiconductor cable. Instrument cable will be shielded, 300V EPR insulation, neoprene jacket, #16 AWG single pair, or #18 AWG multipair.

Thermocouple cable will be chromel-constantan shielded, 300V insulation.

Lighting

'All new indoor areas will be illuminated in accordance with the latest requirements of IES Levels of Illuminations.

High intensity discharge (HID) lamps of suitable type, will be used for all high bay and low bay areas. Incandescent fixtures will be used for other areas and for all emergency lamps.

Illumination will be provided in accordance with current OSHA requirements for all exit facilities and means of egress.

Normal a-c lighting system will be supplied from motor control center through 480-120/208 volt 30KVA transformer, dry type, and lighting distribution panels.

Emergency lights will be supplied from the 125V D.C. battery through separate a-c panel board, which will be automatically energized on a-c power failure.

Egress lighting and exit signs will consist of internally illuminated exit signs which will be normally powered from a-c circuit but on a-c power failure will be automatically transferred to 125V D.C. battery power. Conveneince receptacles will be provided as required. Branch circuits supplying receptacles in wet and conductive areas will be provided with ground-fault circuit interrupter (GFCI) protection.

Outdoor areas will be illuminated with high intensity discharge (HID) lamps or incandescent lamps.

Lighting and receptacle wire will be solid copper for No. 12 and No. 10 AWG and stranded for No. 8 AWG and larger and will have XHHW, crosslinked polyethylene, 90° C insulation, moisture and heat resistant, 600V rating.

All lighting conduit will be minimum 3/4 inch and will be galvanized steel, EMT for indoor areas, and rigid galvanized steel for outdoor areas.

Public Address System

Public address system will be installed and connected to the existing system. The paging system will match the existing system as to paging and party-line channels.

Raceways and space for public telephones will be provided, as per requirements to be established.

SYSTEM DESCRIPTION DISTRICT HEATING RETROFIT HUDSON GENERATING STATION

System Design

The district heating water heating system at the Hudson Generating Station provides for two non-extracting back pressure turbines, (No. 1 and No. 2). Steam to the turbines is taken from the cross-overs of the main units at the condition of 81 psia and 695 degrees F. The exhaust pressures of the two turbines are 35 psia and 17 psia respectively. Steam from the turbine exhausts is condensed in shell and tube heat exchangers, in the first two stages of district water heating. During the periods when the ambient temperature is 30 degrees F or above, a maximum district heating water temperature of 238 degrees F can be maintained at the outlet of the second stage heater by operating both back-pressure turbines. During the periods when the ambient temperature is below 30 degrees F, the district heating water is further heated in the two peaking heaters to a temperature up to 290 degrees F. Steam to the peaking heaters is taken from the main turbine cross-overs through pressure reducing valves which maintain final district heating water temperature at the desired level.

It is estimated, subject to further study and approval by the turbine manufacturer, that approximately 1.38×10^6 pounds of steam per hour can be extracted from Unit 2 main turbine cross-overs during full load operation, with provision of extracting the same amount of steam from Unit 1 cross-overs as a back-up. During normal operation, steam is taken from Unit 2 cross-overs since that unit burns coal and operates at a lower energy cost compared to Unit 1 which burns low sulfur oil. With the above steam flow, approximately 13.3×10^6 pounds of district heating water per hour (or 28,800 gpm) can be heated from a return temperature of 170 degrees F to the maximum required temperature of 290 degrees F.

The physical arrangement of the district heating water heating system at the Hudson Station provides for two parallel strings of heaters with a by-pass. Presently, single string heaters of the size capable of handling the water flow rate and the heating capacity required are not commercially available. Each string has two base loaded heaters and a

peaking heater of about 65 percent capacity each. A back-up heater of sufficient capacity is provided in the by-pass line. In the event that one string of heaters is shut down, a portion of the district heating water can be heated in the back-up heater and blended with heated water from the operating string to meet the district heating water temperature requirements for any ambient temperature condition considered in the system design.

Drains from heaters in a string are cascaded successively to the next lower pressure heater in the same string. Drains from the lowest pressure heaters are normally cooled in one of two external drain coolers, by condensate, before being returned to the condenser hot well of the unit which supplies the heating steam. (i.e. The drain cooler of Unit 1 is cooled by the condensate of Unit 1 and drains to Unit 1 condenser. The drain cooler of Unit 2 is cooled by the condensate of Unit 2 and drains to the Unit 2 condenser.) Only one drain cooler will be operating at a given time . Emergency drain capabilities are provided only for the lowest pressure heaters. to minimize piping congestion at the condenser. The emergency drain lines of these two heaters are connected via control valves to both condensers. The use of parallel heater strings obviates the need of providing emergency drains for every heater. Drain lines from the back-up heater are connected to both condensers. Only one of the two drain lines will be operating at a given time. The operating drain line discharges the drain flow to the condenser hot well of the unit which supplies the heating system.

The district heating water heating system at the Hudson Station has been designed to provide complete back-up in the event that any one of the heaters or both back-pressure turbines are taken out of service. Most of the equipment can be by-passed and isolated by valves for maintenance without reducing the heating capacity of the district heating water heating system.

The low pressure steam extracted from the main unit cross-overs has a very large volume flow rate. Presently, inlet control valves of the size needed to pass the required volume flow rate through the back-pressure turbines are not readily available from turbine manufacturers. However, it is possible to use a control valve and a start-up by-pass

valve external to the back-pressure turbine inlet.

Synchronization can be accomplished while the turbine is operating at no-load flow. Once the generator is synchronized and locked-in with the outside system frequency, load on the turbine can be increased. The back-pressure turbine will be specified to include overspeed protection with overspeed trip at 110 percent of the rated speed.

The final temperature of the district heating water leaving the plant will vary inversely with the outside ambient temperature. During the periods when the outside temperature is below 30 degrees F, both the backpressure turbines and all the heaters in both strings will be in operation. During the periods when the outside temperature is above 30 degrees F, the peaking heater will not extract steam from the crossovers, and no heating will be done through the peaking heaters. During the preiods when the outside temperature is above 50 degrees F, Back Pressure Turbine No.1, which supplies steam to the second stage heaters, can be shut down, leaving only Back Pressure Turbine No. 2 running. The back-up heater is not used during normal operation.

During the periods of full district heating load, a very small portion (i.e. 15 percent) of the normal low-pressure turbine steam flow is condensed in the condenser. The condenser will be operating at low load and very low absolute pressure, (i.e. 0.5 inch Hg). In order to adequately remove the oxygen leaking into the condenser, the capacity of the existing condenser air removing equipment must be increased.

Building

The building housing the district heating water heating equipment measures approximately 180 feet long by 120 feet wide. It consists of two levels. The back-pressure turbine-generators are located on the upper level, or operating level. In the lower level are located the district heating water heat exchangers, and district heating water circulating pumps. The building is equipped with an overhead crane and a monorail system of adequate capacities to service the turbine generators and the heaters. The roof of the upper level is at elevation 78 ft. above grade. The roof of the lower level is at elevation 40 ft. above grade. The building is

constructed of structural steel frame with insulated corrugated metalic sidings and long span joist with built-up roof. It is located tentatively between No.1. Fuel Oil Tank and No.2 Fuel Oil Tank, across the driveway east of the Unit No 2. Turbine Generator. The foundation of the building will be placed on piles.

Operation

The district heating water heating system is designed primarily for automatic operation with minimum operator interface. The extraction steam, back-pressure turbine-generators and electric power distribution are monitored and controlled from the plant main control room. The district heating water heat exchangers, water distribution system, heater drains, and other auxiliary systems are controlled from a control room in the building housing the district heating water heating equipment. Only trouble alarms and critical parameter indications are brought to the plant main control room.

The district heating water flow through the system is essentially constant. District heating load demand is satisfied by varying the district heating water supply temperature, based on the outside ambient temperature. The steam flow to each heater is controlled based on a demand index computed from the following parameters:

- a. Water temperature at the inlet to the heater This varies depending upon the outside ambient temperature and the number of heaters in service.
- b. Desired water temperature at the outlet of the heater (Set Point) - Setpoint for the desired water temperature at the outlet of a heater is a sliding number based on the outside ambient temperature and the number of heaters in service.
- c. Water flow through the heaters.

The extraction steam pressure is controlled by the use of back-pressure valves PV21A and PV21B. The demand for extraction steam to the district heating system must be satisfied first, and the balance

steam flow is sent to the low pressure turbine. The computed steam flow demand indices for the first stage heaters (DH 4A, 4B) and the second stage heaters (DH 3A, 3B) control the flow rates and electrical output of Back Pressures Turbines No. 2 and No. 1 respectively. The steam flow demand indices for the peaking heaters and back-up heater control their associated steam flow (temperature) control valves.

Low and high level in each heater is alarmed. In the event that a heater can not drain properly because of tube leak, valve malfunction, or high water level in the downstream heater shell, the motor operated valve in the steam extraction line will be closed automatically and, if a back-pressure turbine is connected to the extraction line, it will be tripped. Heaters are taken out of service manually.

The heater drain flowing through the drain cooler is cooled to a set temperature by regulating a three way flow control valve to be provided in the main condensate line to the existing feedwater heaters.

The pressure of the district heating water in the tube side of the heaters is higher than the pressure in the shell sides. In the event of a tube leakage, the district heating water will flow into the shell side of a heater and thereby contaminate the condensate. A water sampling system is provided to monitor continuously the drain flow out of each heater. If abnormal level of impurities is detected in the drain from any heater, an alarm is sounded in the control room, the steam flow to the heater is automatically isolated by the use of motor operated valve and the heater string is manually removed from service.

System Monitoring and Control_

The following monitoirng and control shall be provided as a minimum:

- 1. Flow rates of the steam extracted from cross-overs.
- 2. Pressures and temperatures of steam to the back-pressure turbines and heaters.
- 3. Back-Pressure Turbine Generators No. 1 and No. 2 monitoring
- 4. Pressure and temperature of the exhaust steam from each back-pressure turbine.

- 5. Inlet and outlet temperatures of the district heating water across each heater.
- 6. Flow of the district heating water through the system.
- 7. Pressures and temperatures of the supply and return district heating water.
- 8. High and low temperature (sliding) alarms for the district heating water at the outlet of each heater.
- 9. Control, monitoring and protection of the district heating water circulating pumps.
- 10. Monitoring of the heater drain water quality out of each heater.
- 11. Level monitoring of the water in the shell of each heater and low level/high level alarms
- 12. Monitoirng and control of the electrical equipment in the district heating water building and ties to the switchyard.
- 13. Monitoring and control of the auxiliary systems.

In addition to the above, sufficient instrumentation can be provided to perform the diagnostic and efficiency calculations for the back-pressure turbine-generators and the heaters, but has not been included in the scope of supply for Phase I of the study.

System Backup

The district heating water heating system will be backed up by a 825,000 #/hr auxiliary boiler, in the event that both of the Hudson units are down. Based on past historical data, the probability of both units being down at the same time can not be ignored. The proposed auxiliary boiler will supply one half of the peak output of the district heating system (peak output 1.6 x 10 9 BTU/Hr. When the ambient temperature is 30 degrees F, the indoor air temperature at the user can be maintained at 65 degrees F.

ELECTRICAL - HUDSON

(See Dwg. No. 13222-ESK-H1 & 2)

Power Distribution

Two new turbine-generators, back pressure type, will be installed. The generators will be air or water cooled, 11 and 18 MW, 0.8PF, 13.8KV, 3600 RPM, 3-Phase 60 Hertz. Each Generator will be grounded through its own neutral grounding transformer and resistor.

Each generator output will be connected through its own generator air circuit breaker and one common main transformer to 26KV station switchyard (not shown on drawing).

Generator air circuit breakers will be metal enclosed, switchgear type and will be rated 1200 amperes, 13.8KV, 500MVA. Additional switchgear cubicles will be provided to house potential and current transformers, metering and tie to the auxiliary/start-up transformer.

Main transformer will be outdoor, OA/FA type, 20/25MVA, 26KV Wye-13.8KV Delta, 3-Phase, 60 Hertz, 200KV BIL. Transformer neutral will be solidly grounded on the high side. Bushing current transformers, and lightning arresters will be provided. 15KV, 1600A disconnect switch, grounding type, will be provided for main transformer isolation.

The district heating loads and required auxiliary loads will be supplied from auxiliary/start-up transformer, rated 10/12.5 MVA OA/FA, 13.8KV Delta-4.16KV Wye, 3-Phase, 60 Hertz, 110KV BIL. Bushing current transformers, lightning arresters will be provided for transformer protection, and grounding resistor to limit 4160V ground fault current to 1000 amperes.

Start-up power will be supplied from 26KV switchyard through main transformer, to auxiliary/start-up transformer.

During normal operation, new generators will supply power to this transformer, and excess generator power will be delivered to electrical grid at 26KV switchyard.

One section of 4160V metal clad switchgear, one 480V load center and two 480V motor control centers will be provided and installed to distribute power to auxiliary and district heating loads. 4160V switchgear will consist of 1200A, 350 or 250MVA (as will be required) air circuit breakers, namely, main circuit breaker, feeder breakers as required, and tie breaker to existing station service bus, to provide back-up power to auxiliary load, in case the auxiliary/start-up transformer is out of service.

Each switchgear cubicle will contain current transformers and protective relays as required. Separate switchgear cubicle will be provided to house potential transformers, auxiliary relays and metering.

Power from 4160V switchgear will be supplied to large motors (300Hp and above) and to the load center.

480V load center will supply large 480V loads, including motors 60 Hp and larger. Motor control centers will supply motors 50 Hp and smaller, motor operated valves, lighting and power transformers, welding receptacles.

Load center will consist of adequately sized transformer, dry type, 4160-480V and air circuit breakers with static trip, with long time and short time or instantaneous adjustable trips, as applicable, in order to obtain trip coordination.

125V DC System

For control of the 13.8KV generator breaker, 4.16KV switchgear, 480V load center air circuit breakers and emergency lighting and two 120V D.C. motors for the emergency bearing oil pumps, a 125V D.C. battery, battery charger and D.C. distribution switchboard will be provided. The battery will be of the lead-acid type, adequately sized for 2 hours duty cycle in case of power failure. Battery charger will be of the static type. The 125V D.C. distribution switchboard will contain relays and meters for protection and monitoring of the system.

120/208V Regulated Power Supply

For control and instrumentation circuits requiring regulated safe power, regulated power system will be provided. It will consist of 2-20KVA, 480-208/120V dry type transformers, 2-15KVA voltage regulators, automatic transfer switch mechanical or static type as required, and 120/208V A.C. distribution power panel. One transformer and voltage regulator will be supplied from new motor control center, the back-up power to the other transformer and regulator will be brought from existing 480V motor control center.

Grounding

Grounding will be provided for the new building and equipment. A ground loop consisting of 4/0 bare copper cable and grounding rods will be installed around the perimeter of new building and interconnected with the existing station ground loop. All electrical equipment, building steel etc. will be grounded in accordance with PSE&G grounding standards and practice.

Raceways and Underground Ducts.

Ali main power cable, 15KV and 5KV will be run in galvanized steel conduits Separate galvanized steel trays will be used for 480V power, control and instrument cable, except conduit will be used for local runs from tray to equipment.

Underground ducts consisting of plastic conduit encased in concrete will be used for long runs outdoors as required.

Wire and Cable

All cable will be fire retardant, EPR insulation with neoprene jacket, stranded copper. Insulation levels as follows:

15KV-1/c cable, shielded for all 13.8KV CKTS 5KV-1/c cable, schielded for all 4160V CKTS

All other power cable will be 600V insulation, single or multiconductor,

All control cable will be copper, stranded,600V EPR insulation, neoprene jacket, multiconductor cable. Instrument cable will be shielded, 300V EPR insulation, neoprene jacket, #16 AWG single pair, or #18 AWG multipair.

Thermocouple cable will be c romel-constantan, shielded, 300V insulation.

Lighting

All new indoor areas will be illuminated in accordance with the latest requirements of IES Levels of Illuminations.

High intensity discharge (HID) lamps of suitable type, will be used for all high bay and low bay areas. Incandescent fixtures will be used for other areas and for all emergency lamps.

Illumination will be provided in accordance with current OSHA requirements for all exit facilities and means of egress.

Normal a-c lighting system will be supplied from motor control center through 480-120/208 volt 30KVA transformer, dry type, and lighting distribution panels.

Emergency lights will be supplied from the 125V D.C. battery through separate a-c panel board, which will be automatically energized on a-c power failure.

Egress lighting and exit signs will consist of internally illuminated exit signs which will be normally powered from a-c circuit but on a-c power failure will be automatically transferred to 125V D.C. battery power.

Convenience receptacles will be provided as required. Branch circuits supplying receptacles in wet and conductive areas will be provided with groundfault circuit interrupter (GFCI) protection.

Outdoor areas will be illuminated with high intensity discharge (HID) lamps or incandescent lamps.

Lighting and receptacle wire will be solid copper for No. 12 and No. 10 AWG and stranded for No. 8 AWG and larger and will have XHHW, cross-linked polyethylene, 90°C insulation, moisture and heat resistant, 600V rating.

All lighting conduit will be minimum 3/4 inch and will be aluminum, EMT for indoor areas, and rigid galvanized steel for outdoor areas.

Public Address System

Public address system will be installed and connected to the existing system. The paging system will match the existing system as to paging and party-line channels.

Raceways and space for public telephones will be provided, as per requirements to be established.

B-31

SYSTEM DESCRIPTION DISTRICT HEATING RETROFIT KEARNY GENERATING STATION

System Design

The district heating water heating system at the Kearny Generating Station provides for three stages of feed heating of the district heating water. A single extracting back-pressure turbine takes steam from the main turbine cross-unders at the steam condition of about 200 psia and 917 degrees F. Steam is extracted from the back-pressure turbine at about 35 psia for the second stage heater. The exhaust steam from the back-pressure turbine, at about 17 psia, is condensed in the first stage heater. During the periods when the ambient temperature is 30 degrees F or above, a maximum district heating water temperature of 238 degrees F can be maintained at the outlet of the second stage heater by operating the back-pressure turbine. During the periods when the ambient temperature is below 30 degrees F, the district heating water is further heated in one of two peaking heaters to a temperature up to 290 degrees F. Steam to the peaking heater is taken from the main unit cross-unders through a pressure reducing valve which maintains the final district heating water temperature at the desired level.

It is estimated, subject to further study and approval by the turbine manufacturer, that approximately 490,000 pounds of steam per hour can be extracted from the cross-unders of Unit No. 7 during full load operation, with the provision of extracting the same amount of steam from the Unit No. 8 cross-unders as a back-up. Recently General Electric Company, which built the turbine-generators at Kearny Generating Station, informed us that approximately 200,000-400,000 pounds of steam per hour can be extracted from the main unit cross-unders of each unit without requiring replacement of the turbine thrust bearing. We have been discussing with G.E. this problem in order to determine if it is feasible to extract 490,000 pounds steam

per hour from the cross-unders, and what will be the cost of retrofiting each turbine. If 490,000 pounds per hour of steam can be extracted from each main unit, approximately 4,900,000 pounds of district heating water per hour (or 10,600 gpm) can be heated from a return temperature of 170 degrees F to the maximum required temperature of 290 degrees F.

The district heating water heating system at Kearny Station provides for two base load heaters arranged in series and a pair of peaking heaters arranged in parallel. Individual by-pass is provided for each of the two base loaded heaters. During normal operation, only one peaking heater is needed, with the other peaking heater serving as back-up. In the event that the back-pressure turbine is down or that both of the base loaded heaters are taken out of service, the two peaking heaters operating together can meet the district heating water temperature requirement for any ambient temperature condition considered in the system design.

brains from heaters are cascaded successively to the next lower pressure heater. The drain from the lowest pressure heater is normally cooled in one of two external drain coolers, by condensate, before being returned to the condenser hot well of the unit which supplies the heating steam. (i.e. The drain cooler of Unit 7 is cooled by the condensate of Unit 7 and drains to the Unit 7 condenser. The drain cooler of Unit 8 is cooled by the condensate of Unit 8 and drains to the Unit 8 condenser. Only one drain cooler will be operating at a given time.)

Emergency drain lines to both condensers are provided for each heater. In the event of extremely high heater water level, one of the lines will open to discharge the heater drain flow to the condenser of the unit which supplies the heating steam.

The district heating water heating system at the Kearny Station has been designed to provide complete back-up in the event that any one of the heaters or the back-pressure turbine is taken out of service. Each piece of equipment can be by-passed and isolated by valves, for maintenance purposes without reducing the heating capacity of the district heating water heating system.

B - 33

The final temperature of the district heating water leaving the plant will vary inversely with the outside ambient temperature. During the periods when the outside temperature is below 30 dgrees F, both the back-pressure turbine with its associated heaters and one peaking heater will be in operation. During the periods when the outside temperature is above 30 degrees F, the peaking heater will not extract steam from the cross-unders, and no heating will be done through the peaking heater. During the periods when the outside temperature is above 50 degrees F, extraction from the back-pressure turbine will be reduced to zero, leaving only the first stage heater operating.

During the periods of full district heating load, a very small portion (ie, 15%) of the normal low-pressure turbine steam flow is condensed in the condenser. The condenser will be operating at low load and very low absolute pressure, (i.e., 0.5 inch Hg.). In order to adequately remove the oxygen leaking into the condenser, the capacity of the existing condenser air removing equipment must be increased.

Building

The building housing the district heating water equipment measures approximately 90 feet long by 85 feet wide. It consists of two levels. The back-pressure turbine generator is located on the upper level, or the operating level. In the lower level are located the district heating water heat exchangers, and district heating water circulating pumps. The building is equipped with an overhead crane and a monorail system of sufficient capacities to service the turbine-generator and the heaters. The roof of the upper level is at elevation 72 ft above grade. The building is constructed of structural steel frame with insulated corrugated metalic sidings and long span joist with a built-up roof. It is located tentatively

adjacent to the new auxiliary package boilers. Access to the plant through the existing roadway and the location of a portion of the earthened-dyke of fuel oil tank No. 4 will have to be relocated to accommodate this scheme. An alternative location for the district heating water equipment is next to Unit No. 7, inside the existing Unit 6 building. Locating the new equipment in this area would probably reduce the retrofit cost by eliminating the costs of the new building. However, demolition cost within the Unit No. 6 building would have to be considered.

Operation

The district heating water heating system is designed primarily for automatic operation with minimum operator interface. The extraction steam, back-pressure turbine generator, and electric power distribution are monitored and controlled from the plant main control room. The district heating water heat exchangers, water distribution system, heater drains, and other auxiliary systems are controlled from a control room in the building housing the district water heating equipment. Only trouble alarms and critical parameter indications are brought to the plant main control room.

The district heating water flow through the system is essentially constant. District heating load demand is satisfied by varying the district heating water supply temperature, based on the outside ambient temperature. The steam flow to each heater is controlled based on a demand index computed from the following parameters:

- a. Water temperature at the inlet to the heater this varies depending upon the outside ambient temperature and the number of heaters in service.
- b. Desired water temperature at the outlet of the heater (Set Point) set point for the desired water temperature at the outlet of a heater is a sliding number based on the outside ambient temperature and the number of heaters in service.

c. Water flow through the heaters.

The extraction steam pressure is controlled by the use of the backpressure valves PV21A and PV21B. The demand for extraction steam to the district heating system must be satisfied first, and the balance of steam flow is
sent to the low pressure turbine. The computed steam flow demand indices for
the first stage heater (DH3) and second stage heater (DH2) control the flow rate
(and electrical output) of the back-pressure turbine. The computed steam flow
demand indices for the peaking heaters DH1A and DH1B control their associated
steam flow (temperature) control valves.

The normal drain from each heater is sent to the next lower pressure heater at a rate controlled by a normal level controller. If the level in a heater shell rises beyond the range of the normal level controller, emergency drain to the condenser of the unit supplying the steam is initiated by an emergency level controller. High and low level in each heater is alarmed. In the event that a heater cannot drain properly because of heater tube leak, valve malfunction, or high level of water in the downstream heater shell, the motor operated valve in the steam extraction line will be closed automatically and, if a back-pressure turbine is connected to the extraction line, it will be tripped. Heaters are taken out of service manually.

The heater drain flowing through the drain coolers is cooled to a set temperature by regulating a three way flow control valve to be provided in the main condensate line to the existing feedwater heaters.

The pressure of the district heating water in the tube side of the heater is higher than the pressure in the shell side. In the event of a tube leakage, the district heating water will flow into the shell side of the heater and thereby contaminate the condensate. A water sampling system is provided to

monitor continuously the drain flowing out of each heater. If abnormal level of impurities is detected in the drain from any heater, an alarm is sounded in the control room, the steam flow to the heater is automatically isolated by the use of motor operated valve, and the heater is manually by-passed.

System Monitoring and Control

- 1. Flow rates of the steam extracted from cross-overs.
- Pressures and temperatures of the steam to the back-pressure turbine and heaters.
- 3. Back-pressure turbine generator monitoring and control.
- 4. Pressures and temperatures of the extraction steam and the exhaust steam from the back-pressure turbine.
- 5. Inlet and outlet temperatures of the district heating water across each heater.
- 6. Flow of the district heating water through the system.
- 7. Pressures and temperatures of the supply and return district heating water.
- 8. High and low temperature (sliding) alarms for the district heating water at the outlet of each heater.
- Control, monitoring and protection of the district heating water circulating pumps.
- 10. Monitoring of the drain water quality out of each heater.
- 11. Level monitoring of the water in the shell of each heater and low level/high level alarm.
- 12. Monitoring and control of the electrical equipment in the district heating water building and ties to the switchyard.
- 13. Monitoring and control of the auxiliary systems.

In addition to the above, sufficient instrumentation can be provided to perform diagnostic and efficiency calculations for the back-pressure turbine generator and the heaters, but has not been included in the scope of supply for Phase I of the study.

ELECTRICAL - KEARNY

(See Dwg. No. 13222-ESK-K7 & 8)

Power Distribution

A new turbine-generator, back pressure type, will be installed. The generator will be air or water cooled, 20 MW, U.8 PF, 13.8 KV, 3600 RPM, 3-Phase 60 Hertz. Generator will be grounded through neutral grounding transformer and resistor.

The generator output will be connected through generator air circuit breaker and main transformer to 132KV station switchyard (not shown on drawing).

Generator air circuit breaker will be metal enclosed, switchgear type and will be rated 1200 amperes, 13.8KV, 500MVA. Additional switchgear cubicle will be provided to house potential and current transformers, metering and tie to the auxiliary/start-up transformer.

Main transformer will be outdoor, OA type, 20 MVA, 132KV-Wye-13.8KV Delta, 3-Phase, 60 Hertz, 650KV BIL. Transformer neutral will be solidly grounded on the high side. Bushing current transformers and lightning arresters will be provided. 15KV, 1200A disconnect switch, grounding type, will be provided for main transformer isolation.

The district heating loads and required auxiliary loads will be supplied from auxiliary/start-up transformer, rated 5/6.25 MVA OA/FA, 13.8 KV Delta-4.16KV Wye, 3-phase, 60 Hertz, 110KV BIL. Bushing current transformers and lightning arresters will be provided for transformer protection, and grounding resistor to limit 4160KV ground fault current to 1000 amperes.

Start-up power will be supplied from 132KV switchyard through main transformer, to auxiliary/start-up transformer.

During normal operation, new generator will supply power to this transformer, and excess generator power will be delivered to electrical grid at 132KV switchyard.

One section of 4160V metal clad switchgear, one 480V load center and one 480V motor control center will be provided and installed to distribute power to auxiliary and district heating loads. 4160V switchgear will consist of 1200A, 350 or 250MVA (as will be required) air circuit breakers, namely, main circuit breaker, feeder breakers as required, and

tie breaker to existing station service bus, to provide back-up power to auxiliary load in case the auxiliary/start-up transformer is out of service.

Each switchgear cubicle will contain current transformers and protective relays as required. Separate switchgear cubicle will be provided to house potential transformers, auxiliary relays and metering.

Power from 4160V switchgear will be supplied to large motors (300Hp and above) and to the load center.

480V load center will supply large 480V loads, including motors 60 Hp and larger. Motor control center will supply motors 50 Hp and smaller, motor operated valves, lightning and power transformers, welding receptacles.

Load center will consist of adequately sized transformer, dry type, 4160-480V and air circuit breakers with static trip, with long time and short time or instantaneous adjustable trips, as applicable, in order to obtain trip coordination.

125V DC System

For control of the 13.8KV generator breaker, 4.16KV switchgear, 480V load center air circuit breakers, emergency lighting and 120V D.C. motor for the emergency bearing oil pump, a 125V D.C. battery, battery charger and D.C. distribution switchboard will be provided. The battery will be of the lead-acid type, adequately sized for 2 hours duty cycle in case of power failure. Battery charger will be of the static type. The 125V D.C. distribution switchboard will contain relay and meters for protection and monitoring of the system.

120/208V Regulated Power Supply

For control and instrumentation circuits requiring regulated safe power, regulated power system will be provided. It will consist of 2-20KVA, 480-208/120V dry type transformers, 2-15KVA voltage regulators, automatic transfer switch mechanical or static type as required, and 120/208V A.C. distribution power panel. One transformer and voltage regulator will be supplied from new motor control center, the back-up power to the other transformer and regulator will be brought from existing 480V motor control center.

Grounding

Grounding will be provided for the new building and equipment. A

ground loop consisting of 4/0 bare copper cable and grounding rods will be installed around the perimeter of new building and interconnected with the existing station ground loop. All electrical equipment, building steel etc. will be grounded in accordance with PSE&G grounding standards and practice. Raceways and Underground Ducts

All main power cable, 15KV and 5KV will be run in galvanized steel conduits Separate galvanized steel trays will be used for 480V power, control and instrument cable, except conduit will be used for local runs from tray to equipment.

Underground ducts consisting of plastic conduit encased in concrete will be used for long runs outdoors as required.

Wire and Cable

All cable will be fire retardant, EPR insulation with neoprene jacket, stranded copper. Insulation levels will be as follows:

15KV-1/c cable, shielded for all 13.8KV CKTS

5KV-1/c cable, shielded, for all 4160V CKTS

All other power cable will be 600V insulation single or multi conductor.

All control cable will be copper, stranded, 600V EPR insulation, neoprene jacket, multiconductor cable. Instrument cable will be shielded 300V EPR insulation, neoprene jacket, #16 AWG single pair, or #18 AWG multipair.

Thermocouple cable will be chromel-constantan shielded, 300V insulation. Lighting

All new indoor areas will be illuminated in accordance with the latest requirements of IES Levels of Illuminations.

High intensity discharge (HID) lamps of suitable type, will be used for all high bay and low bay areas. Incandescent fixtures will be used for other areas and for all emergency lamps.

Illumination will be provided in accordance with current OSHA requirements for all exit facilities and means of egress.

Normal a-c lighting system will be supplied from motor control center through 480-120/208 volt 30KVA transformer, dry type, and lighting distribution panels.

Emergency lights will be supplied from the 125V D.C. battery through separate a-c panel board, which will be automatically energized on a-c power failure.

Egress lighting and exit signs will consist of internally illuminated exit signs which will be normally powered from a-c circuit but on a-c power failure will be automatically transferred to 125V D.C battery power.

Convenience receptacles will be provided as required. Branch circuits supplying receptacles in wet and conductive areas will be provided with ground-fault curcuit interrupter (GFCI) protection.

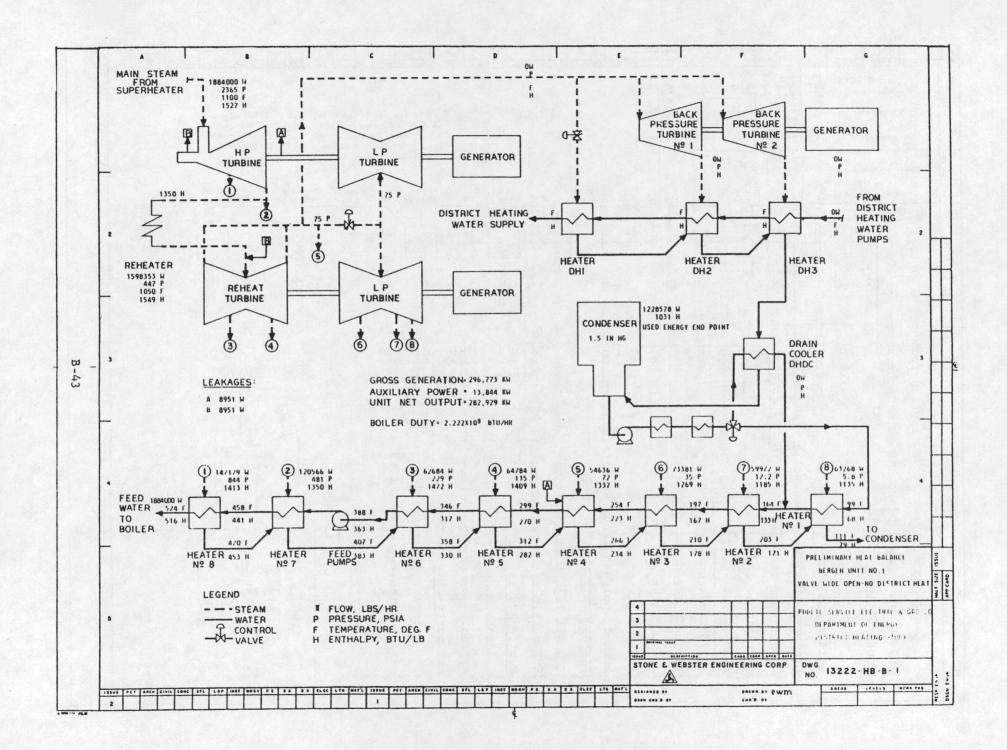
Outdoor areas will be illuminated with high intensity discharge (HID) lamps or incandescent lamps.

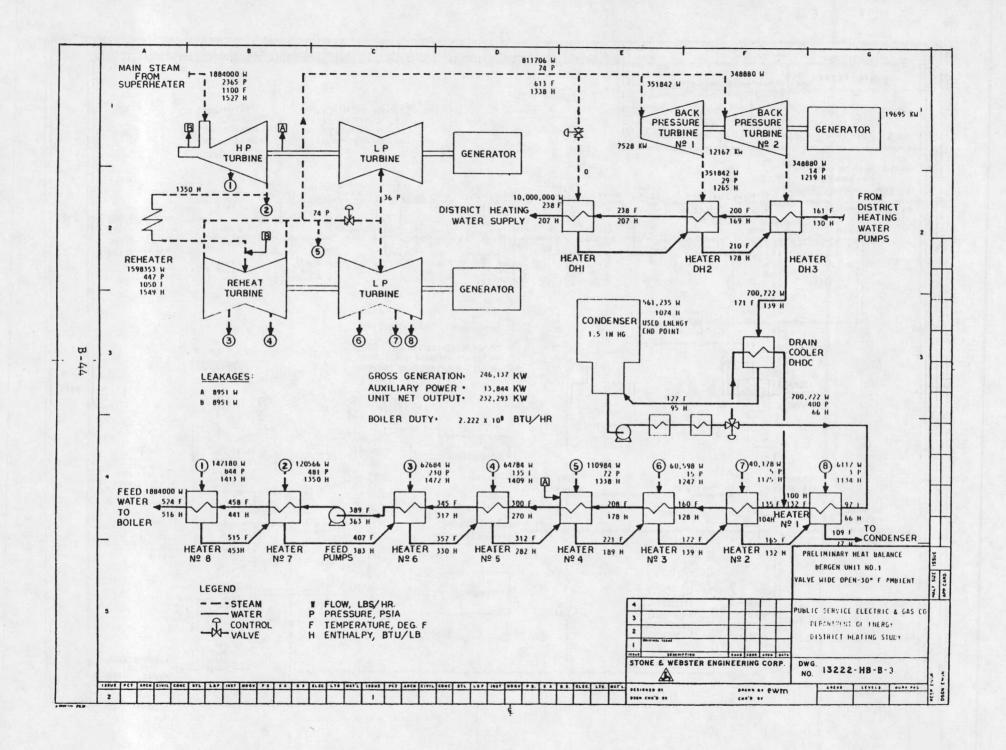
Lighting and receptacle wire will be solid copper for No. 12 and No. 10 AWG and stranded for No. 8 AWG and larger and will have XHHW, crosslinked polyethylene, 90° C insulation, moisture and heat resistant, 600V rating.

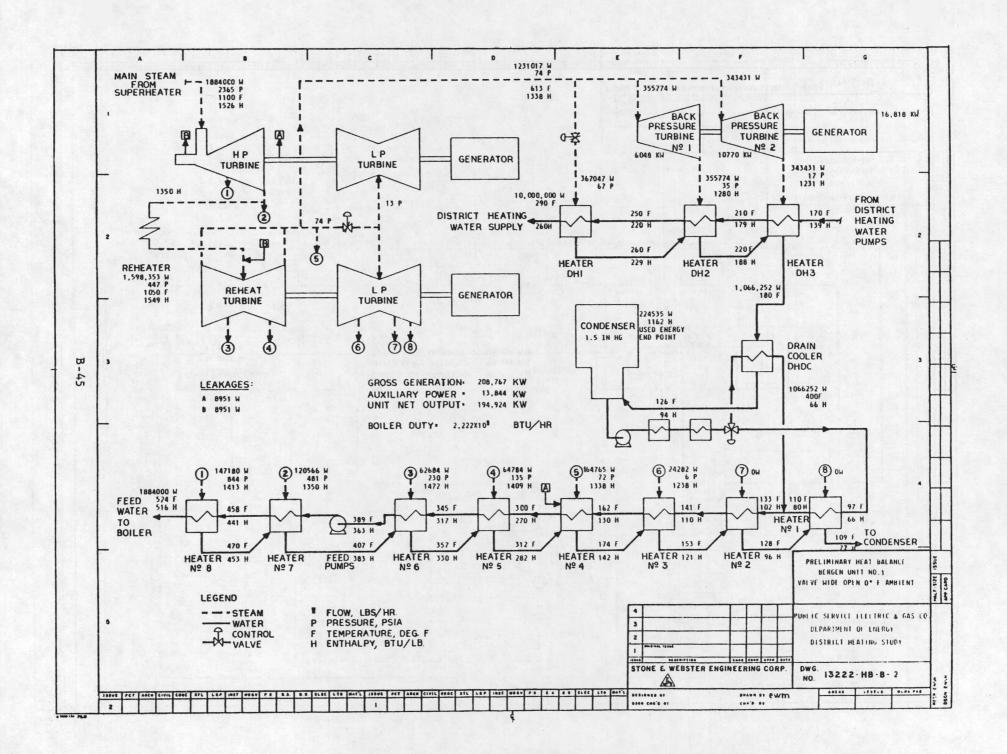
All lighting conduit will be minimum 3/4 inch and will be galvanized steel EMT for indoor areas, and rigid galvanized steel for outdoor areas. Public Address System

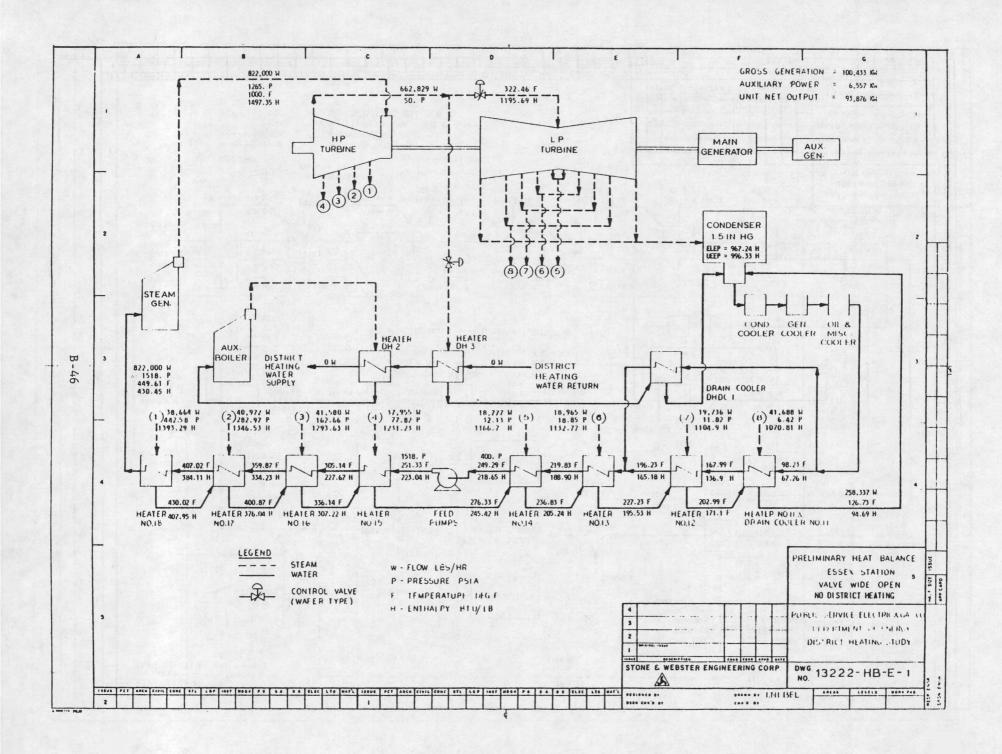
Public address system will installed and connected to the existing system. The paging system will match the existing system as to paging and party-line channels.

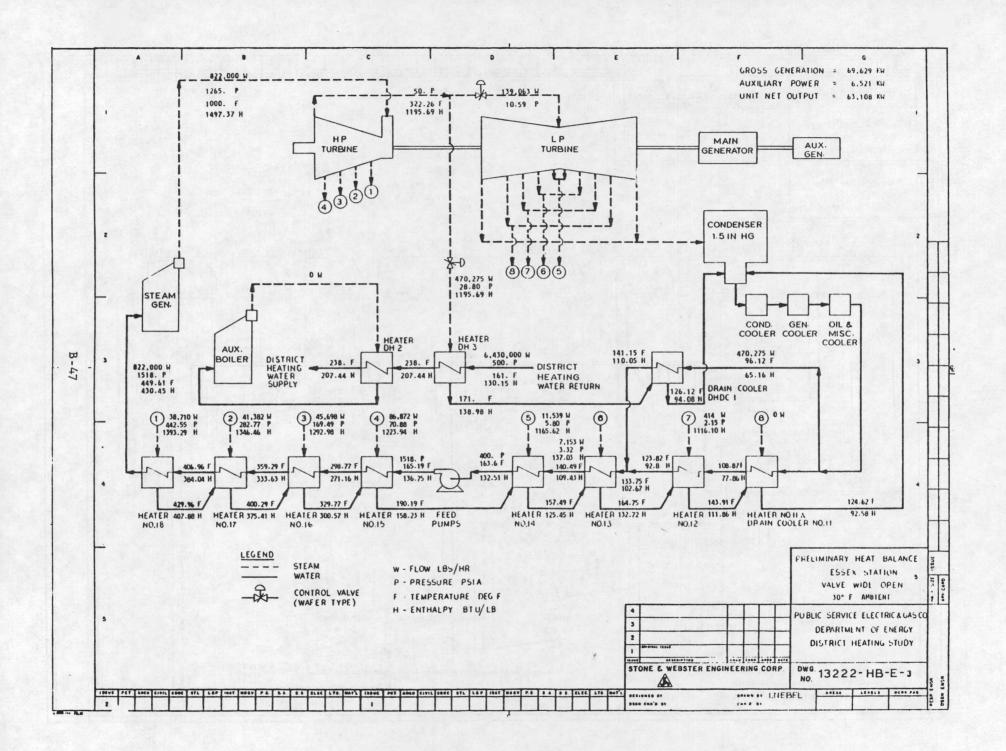
Raceways and space for public telephones will be provided, as per requirements to be established.

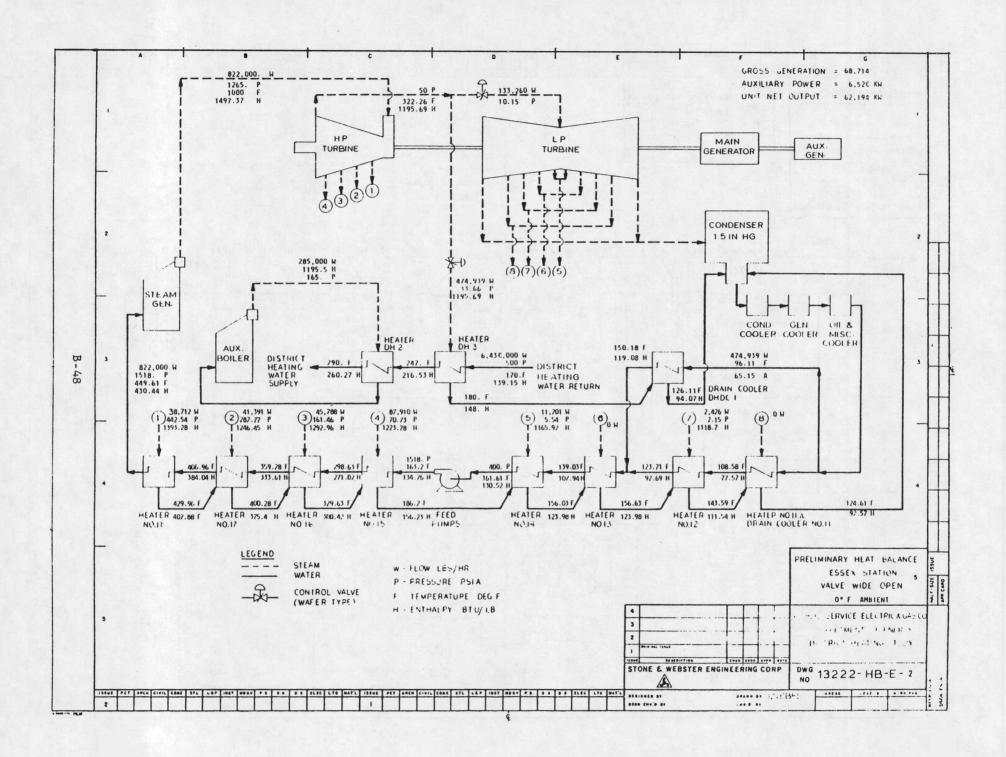


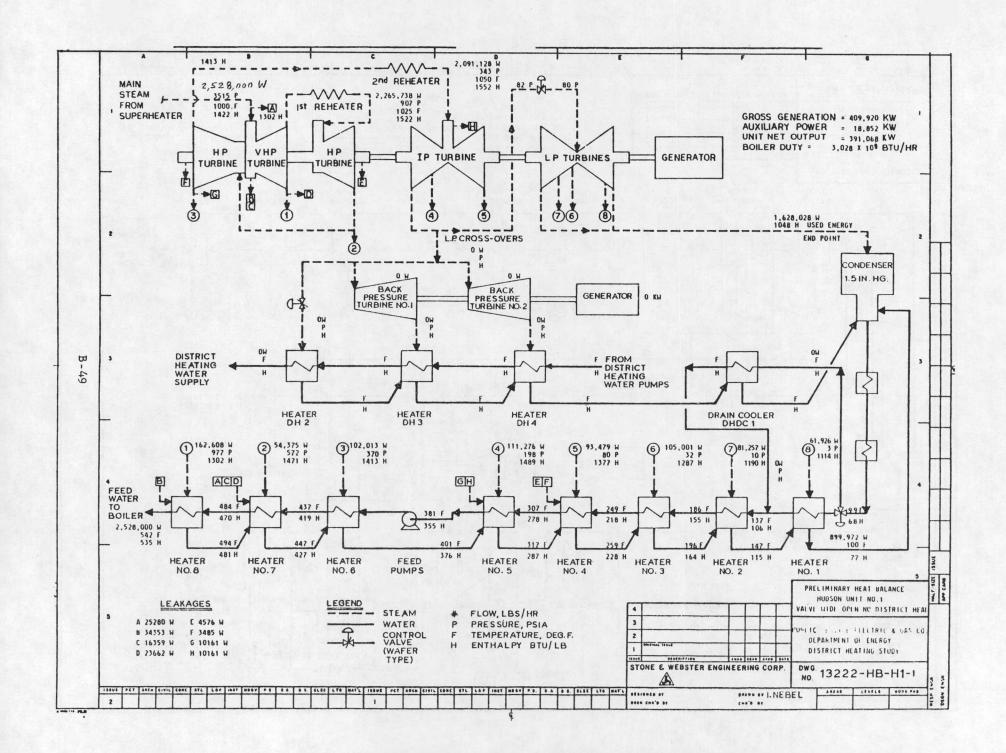


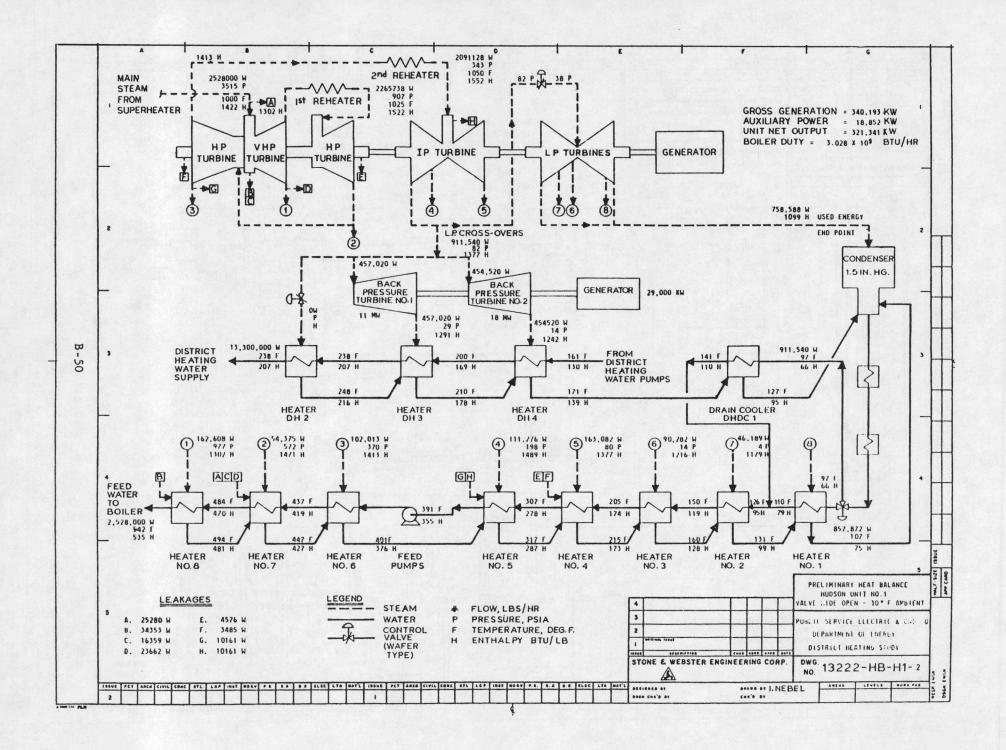


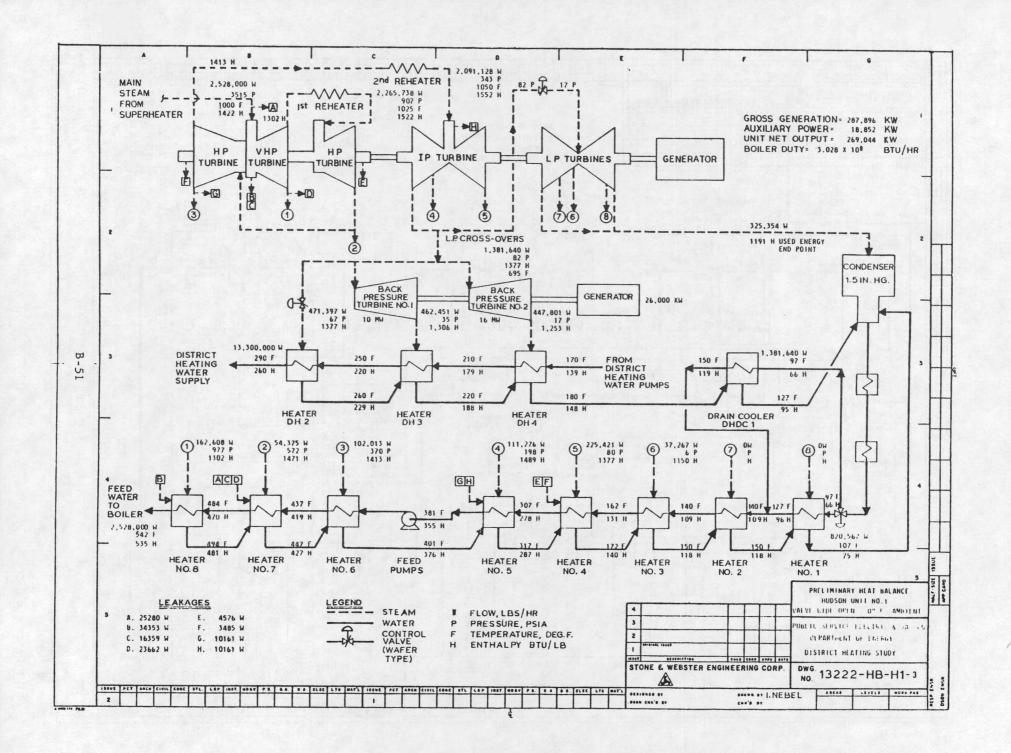


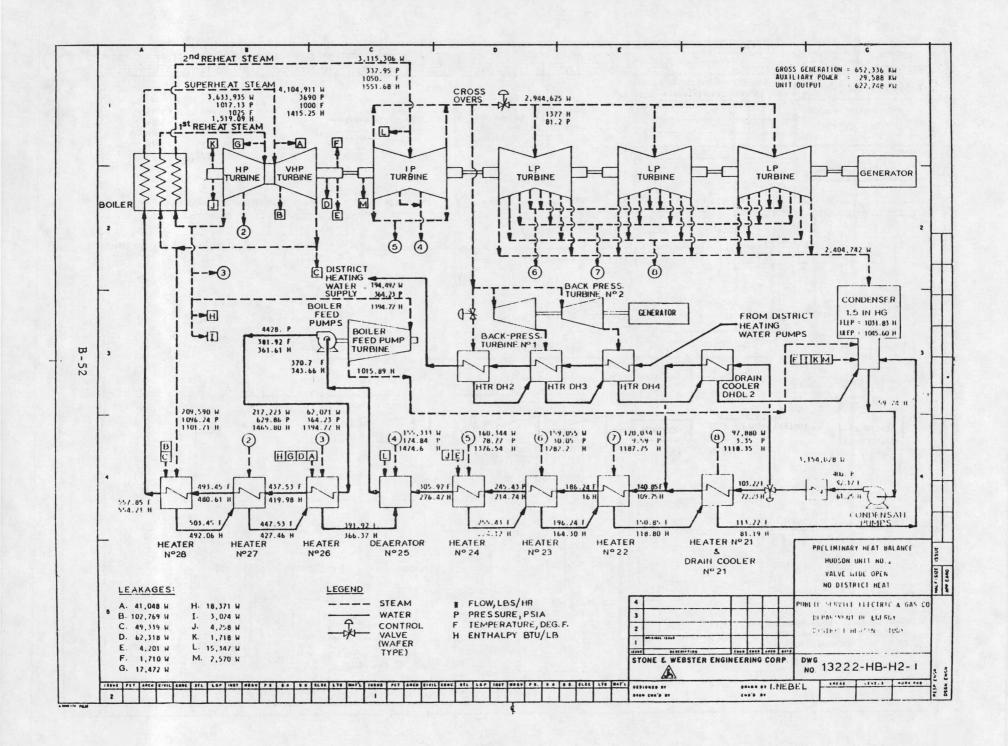


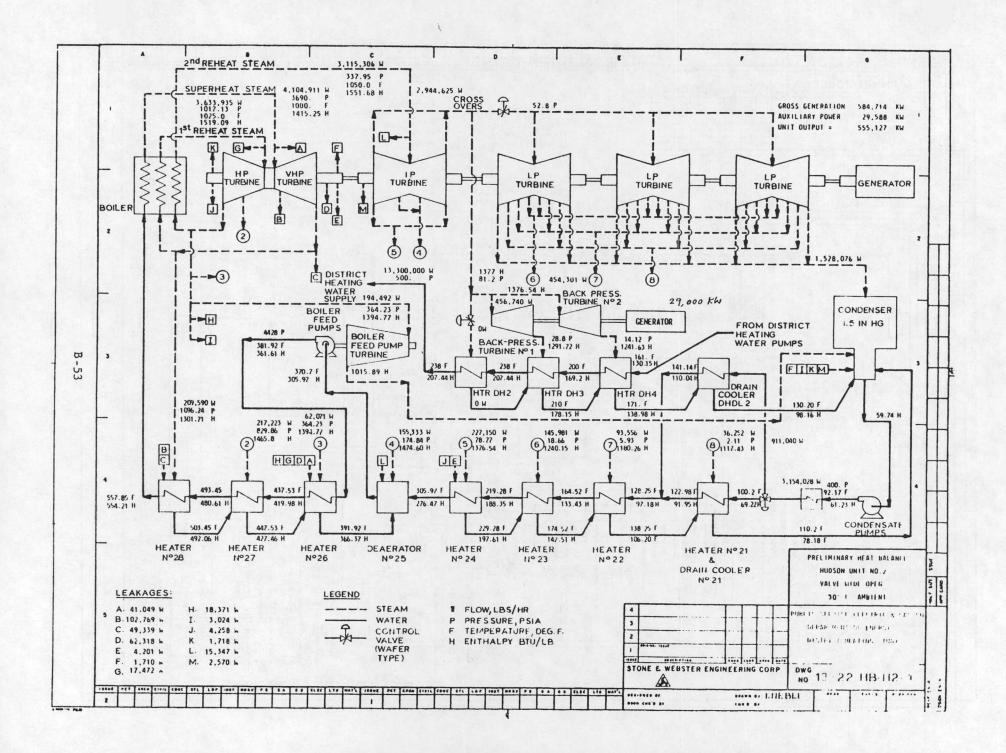


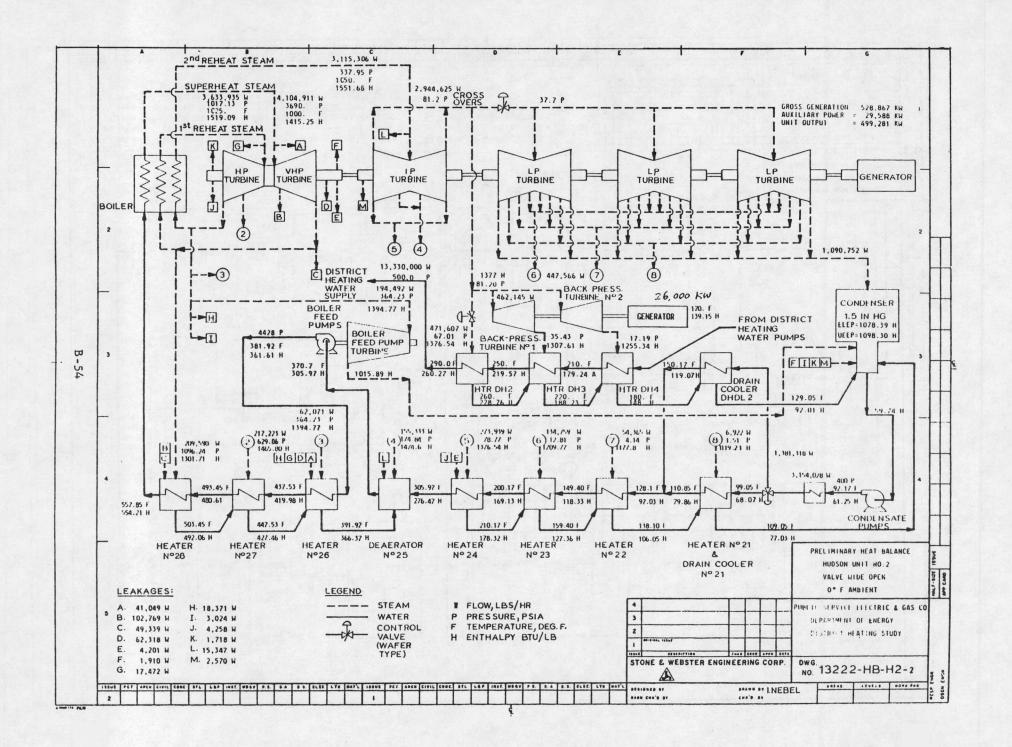


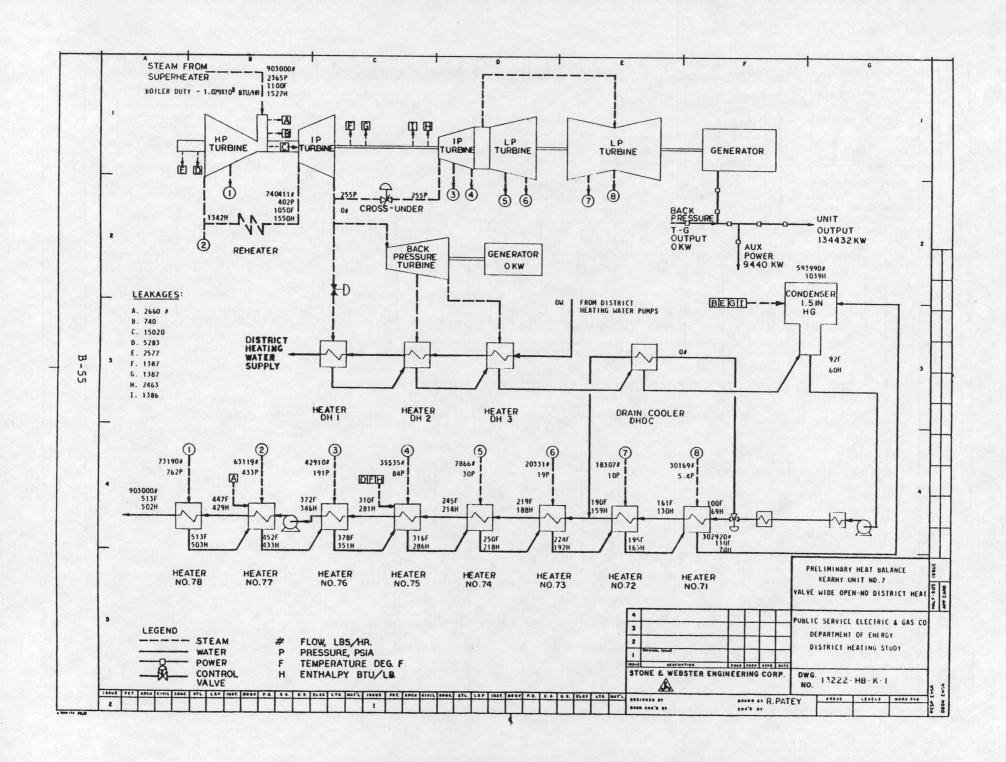


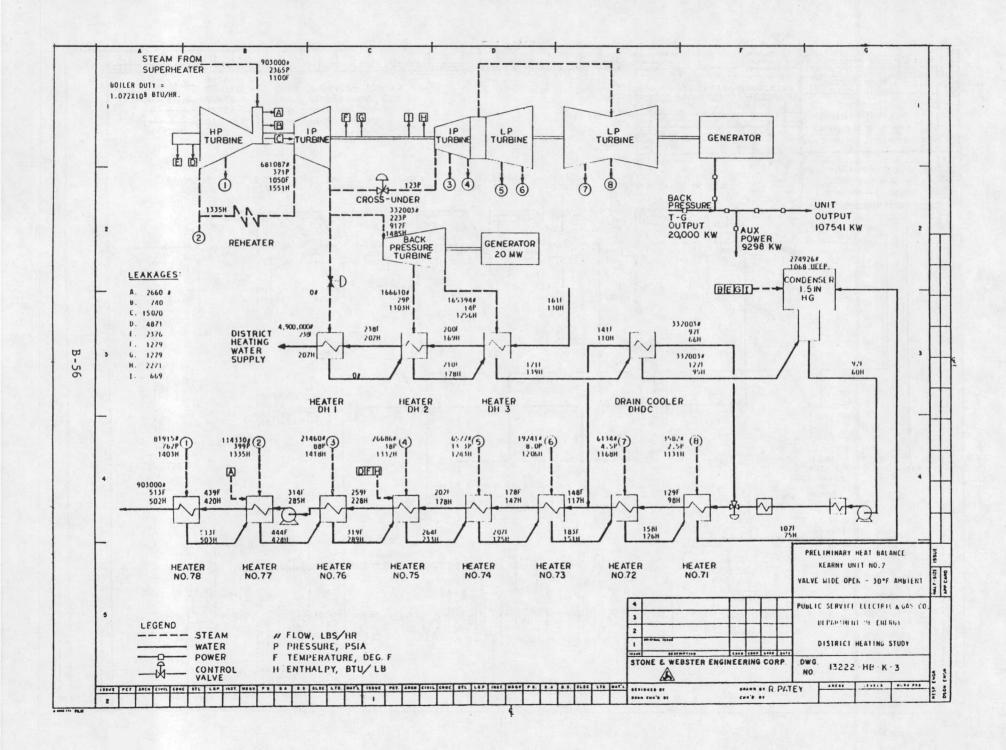


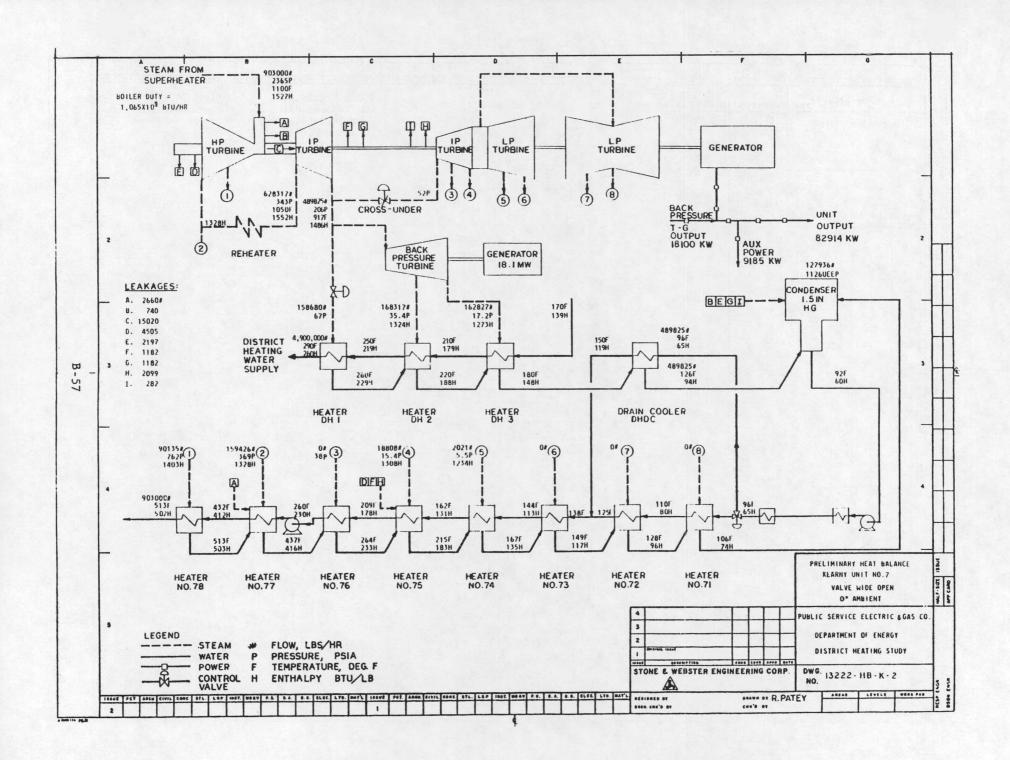












APPENDIX C - ELECTRICAL LOAD CAPABILITY CURVES

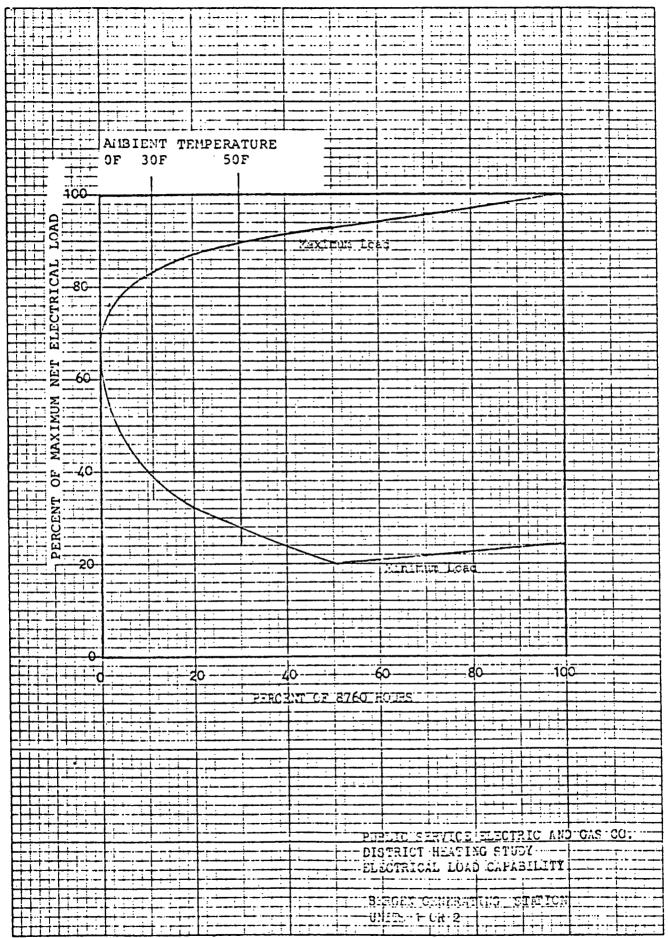
One characteristic of an ideal generating station is its ability to operate at any load, from 0 percent to 100 percent. Due to the limitations of equipment, this is not possible. Boilers, for example, usually experience unstable operation below 25 percent load. Once-through boilers are more sensitive, and often require maintaining loads above 50 percent.

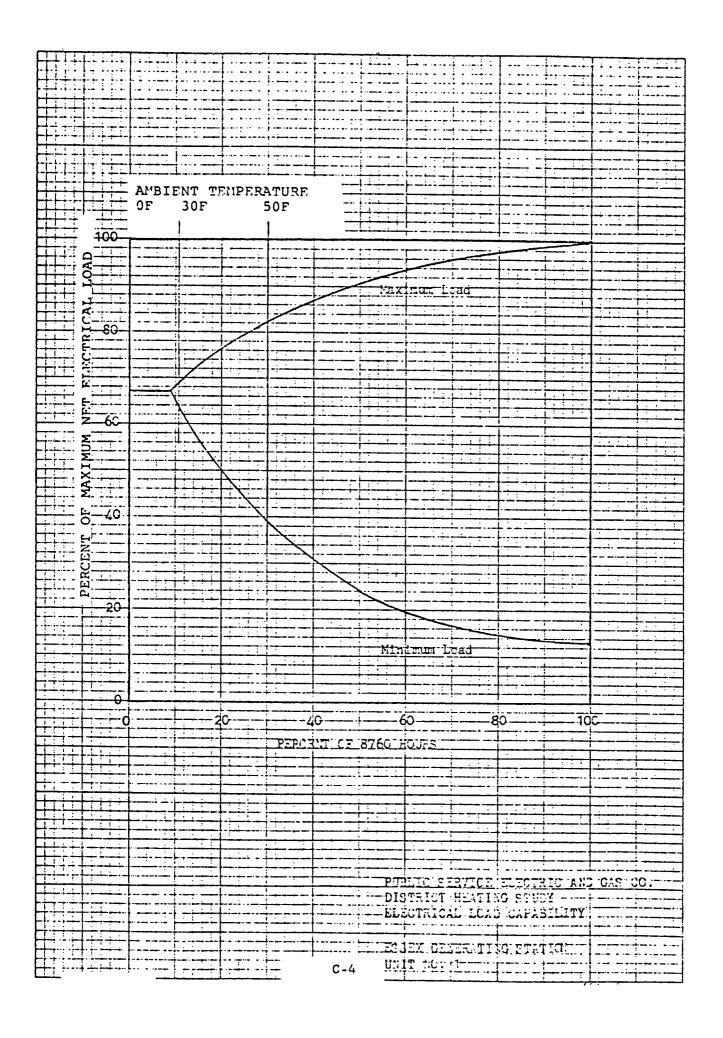
Retrofitting a station for district heating will affect the electrical loading capabilities of the station. Extracting steam from the cycle ahead of the low pressure turbine will reduce the maximum potential electrical output of the station below 100 percent. The greater the extraction, the greater the loss in maximum generating capability. The minimum load at which the unit must operate may either be increased or decreased by district heating requirements. If the steam requirements of the district heating system are large the boiler duty will increase above the minimum to generate the required steam. If the district heating steam requirements are less than the boiler's minimum output, the flow through the high pressure turbine will be unchanged, while the flow through the low pressure turbine will decrease resulting in reduced output.

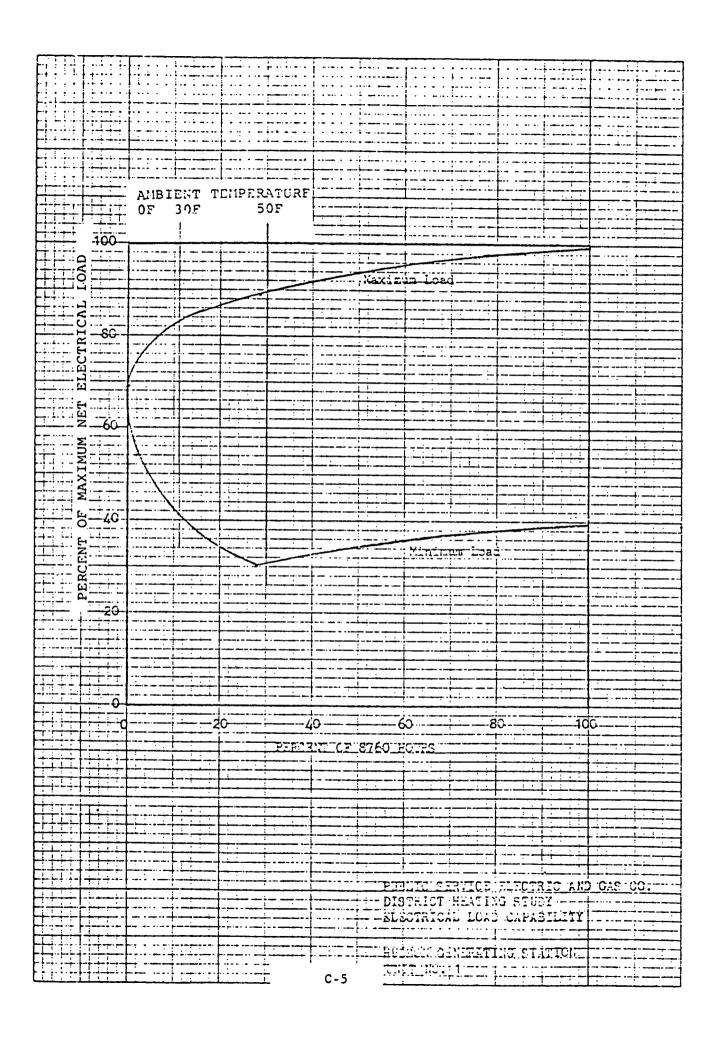
The enclosed figures show the maximum possible and minimum required electrical load on each of the units over the entire year. The percentage of the year during which ambient temperatures of $0^{\circ}F$, $30^{\circ}F$, and $50^{\circ}F$ are not exceeded, are noted on the curves.

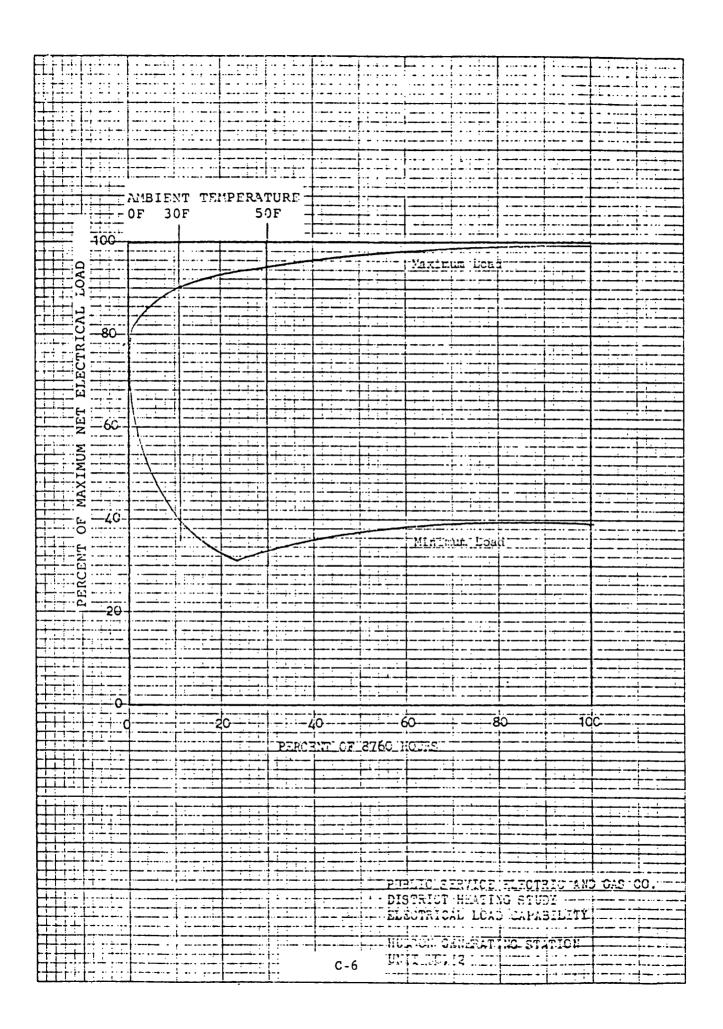
It can be seen that district heating reduces the maximum possible load at each unit for the entire year, but the reduction is most severe for relatively short periods of extreme cold weather. It can further be seen that the minimum required electrical load on each unit is increased as the ambient temperature gets colder (and more district heating load is required).

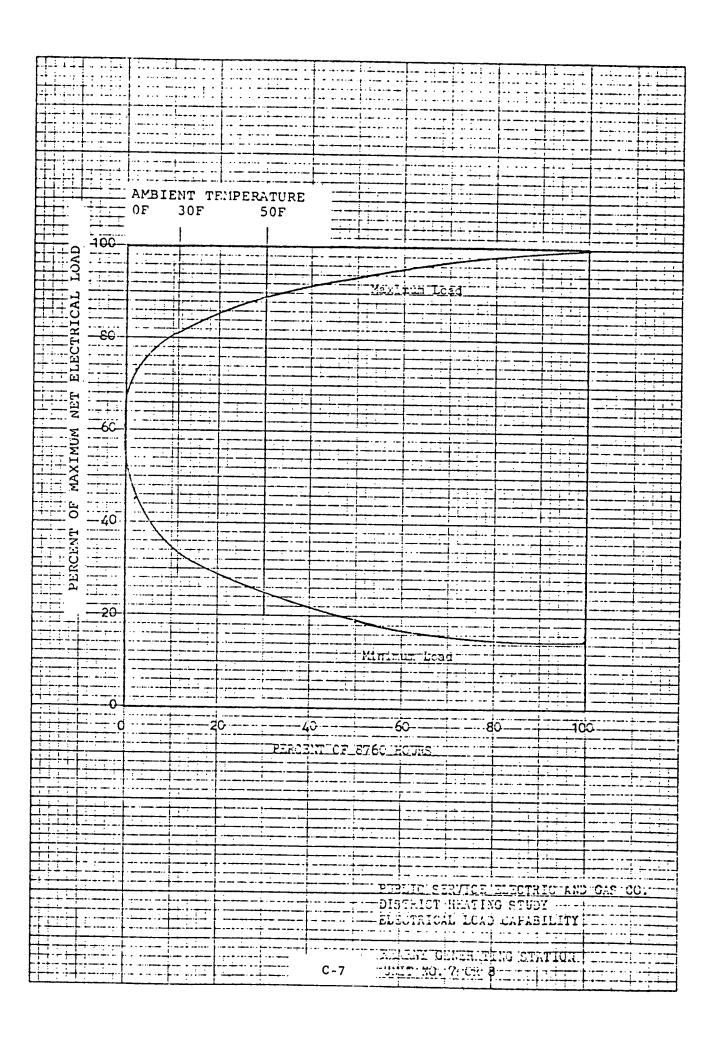
At units with once-through boilers (such as Hudson), the minimum required electrical load is somewhat reduced by district heating over a large portion of the year.











APPENDIX D

HEAT CARRYING MEDIA CRITERIA

A wide range of heat carrying media were identified as conceivably applicable for intermediate energy transport for the district heating study. The actual heat transfer distance was unknown, so it was assumed that it might be as great as 10 miles. The following criteria was the basis for selecting the types of media for the study:

Toxicity - The medium must not be toxic when inhaled or ingested nor should contact with the skin be injurious. The major cause for réjection of a heat carrying medium would be its toxicity if ingested, since several food industries are served by the district steam system and leakage of this medium into the secondary process steam system is a possibility.

Stability - The medium should not present any hazard from the viewpoint of either flammability or explosion, by itself or when mixed with water, and should not contribute to the effects of a civil or natural disaster.

Temperature Range - The range of permissible working temperature for the medium must be compatible with the intended service for both generation of steam and return to the source. The medium should be stable up to 500°F.

Types.

The following types of heat carrying media have been considered for the study. They represent a broad spectrum of media, ranging from those most commonly used for energy transport today to those of a more complex nature.

Mobiltherm Light
Mobiltherm 603

Mercury
Organic Compounds
Freon 12

Ammonia
Sodium-Potassium Alloy (NaK)

Glycols

Heat Transfer Oil

Molten Inorganic Salts

Water

Steam

Temperature Ranges

The following temperature ranges representing heating conditions were considered for the district heating system.

	Supply OF	Return ^O F	Temp Diff OF
Fróm Plant to Sub-Station	390	270	120
From Plant to End User	390	190	200
From Plant to Substation	290	230	60
From Plant to End User	290	170	120
From Plant to Sub-Station	230	190	40
From Substation to End User	200 .	180	20

DISCUSSION

The following discussions present pertinent information on each medium considered. More extensive data for each fluid is shown on Table B-1:

Mobiltherm Light and Mobiltherm 603 are aromatic mineral oils which have lower viscosities than conventional mineral oil and are able to withstand relatively high temperatures without breaking down. Mibiltherm Light has an operating range of -15°F to 400°F which makes it unsuitable for transferring the energy required to produce steam at temperatures above 400°F, but Mobiltherm 603 is satisfactory in this respect since its upper operating limit is 600°F. (Ref.1) However, both products are toxic if ingested and, therefore, unsuitable for this reason. (Ref.2)

Mercury is a stable, non-corrosive liquid usually used in the range of 600° F to 1000° F. However, it is expensive and extremely toxic and therefore unsuitable for these reasons. (Ref. 2&3)

Organic Compounds have been developed and applied specially in the chemical processing industries. The main difference between steam and organic compounds are as follows:

- a. Vapors are heavier than air.
- b. The fluids are flammable.
- c. It will not cause scaling, nor corrosion in standard piping systems.
- d. The products contract rather than expand, upon freezing.
- e. Material can be regenerated after years of use.

The following organic compounds were considered:

Therminol 55, a synthetic hydrocarbon mixture, and Therminol 66, a modified terphenyl, have operating ranges of $0^{\circ}F$ to $600^{\circ}F$ and $0^{\circ}F$ to $650^{\circ}F$, respectively. However, both must be rejected because they are slightly toxic to humans. (Ref. 4)

Dowtherm A, the dominant medium in indirect process heating between 400° F and 750° F, is a cutectic mixture of diphynyl oxide and diphenyl. Tests performed on rats with this mixture indicate that it is potentially harmful to humans when ingested. (Ref. 5)

Dowtherm E, a specially processed o-dichlorobenzene, boils at 350°F but has an upper operating limit of 500°F. (Ref.1)

Organic compounds are extremely expensive as compared to hot water or steam and are potentially harmful to humans and therefore unsuitable for these reasons.

Freon 12, a common refrigerant, decomposes into highly toxic substance at 400° F and therefore unsuitable for this reason. (Ref. 6)

Ammonia and sodium-potassium alloy (NaK) are extremely corrosive to the throat and lungs of humans and can even cause death if ingested. For this reason, they are eliminated from further consideration. (Ref.2)

Glycols, Aqueous solutions of either ethylene glycol or propylene glycol inhibited for corrosion control are commonly used for heating and cooling systems requiring freeze protection. These solutions are expensive, toxic and require a monitoring program to assure that undesirable inhibitor depletion is avoided. For these reasons, they are eliminated from further consideration.

Heat Transfer Oil is very commonly used in specialized applications such

as in snow melting systems. The heat transfer oils, such as S/V Sovaloid S as manufactured by Socony - Vacuum Oil Co., have similar characteristics as water glycol solutions such as toxicity, more expensive than water and in addition have a poor heat transfer coefficient.

Molten inorganic salt mixtures were also considered for this purpose, but they must be used in continuous operations where high temperatures can be maintained throughout, since they have a relatively low melting point of 288°F. Another objectionable feature of these salts is the necessity for blanketing them with nitrogen to prevent their reacting with carbon dioxide and water vapor. These factors make it difficult to utilize these materials for long distance heat transmission.

<u>Gas</u> as a heat carrying medium agent was also investigated. Compressed air at a temperature of 1000°F and a pressure of 1000 pounds/square inch was evaluated as a transport fluid, and it was determined that for a velocity of 250 feet/second at the above thermodynamic conditions, the required pipe diameter would be about 3.5 feet. The major drawback in this concept is the loss of heat through friction, causing a pressure drop of approximately 400 pounds/square inch/mile. (Ref.7) The compressors necessary to maintain pressure under these conditions would render such a system economically unfeasible.

<u>Water</u> as a medium for use in district heating systems has been used for many years in both the U.S. and Europe. High thermal capacity, widespread availability, low price and its non-polluting characteristics are a few of the reasons for its widespread use.

The hot water required for space heating and other heating applications requiring moderate supply temperatures, 210°F to 390°F (100°C-200°C), make water the most desirable medium for district heating for communities and industrial areas. The varying temperature difference between supply and return water realize smaller pipe sizes as the difference increases to a maximum of 200°F thus the use of water can be made economically attractive.

The transport of heat in a hot water system can be easily controlled by the adjustment of the supply water temperature, thus, depending upon the total demand of the district heating customers the flow in the system can be controlled between almost zero and design flow.

Due to thermal inertia in a hot water piping system, cooling due to the thermal losses takes place very slowly and restarting of the system normally involves no complicated start-up procedures.

Steam is used very extensively in the United States for central and/or district heating purposes and is also the desirable medium wherever required for industrial processes or power generation.

The piping system used for the transmission of low-pressure steam is larger than hot water for the same heat transport capacities, and therefore higher in first cost.

In a steam system, the minimum permissible flow is restricted, since condensation due to thermal losses must be avoided, therefore control of the supply temperature of the steam can not have as wide a user demand range as the hot water system.

RESULTS OF INVESTIGATION

Ranking Criteria

The media which passed the selection criteria screening can be arranged in order of suitability and desirability by testing each against the following ranking criteria:

<u>Cost</u> - The cost of the medium per unit mass should be a minimum. Consideration of cost at this point will be based on the assumption of zero makeup and zero waste treatment but will include the initial cost of charging the system.

<u>Degree of Suitability</u> - The medium should provide the required amount of energy at the required conditions at the lowestpressure and highest density from plant to end user.

Ranking Summary

Because all media other than water and steam failed one or more of the selection criteria, no effort was expended in attempting to rank them. To determine whether water or steam would be the more economical medium, the exact conditions of the energy transfer system must be known. Trucking and barging were not analyzed because it would not be a continuous and reliable means of supply during those periods of the year when it would be needed the most. Therefore, only pipe transport means will be considered.

CONCLUSIONS

Based upon the preceeding discussions, it appears that the only heat carrying media that are satisfactory in all respects for the intended service are water and steam, and therefore this report will investigate these two media only.

REFERENCES

- 1. Mobiltherm Product Data Mobiltherm Light, 600, 603. Movil Research and Development Corp., New York, N.Y.
- Sax, N. Irving. Dangerous Properties of Industrial Materials. 4th Edition, Van Nostrand Reinhold Company, New York, N.Y. p. 362-1101.
- 3. Perry, R.H. and Chilton, C.H. Chemical Engineers' Handbook, 5th Edition, McGraw Hill Book Co., New York, N.Y. 1973, p. 9-41-44.
- 4. Monsanto. A Guide to the Selection of Therminol Heat Transfer Fluids. St. Louis, Missouri.
- 5. The Dow Chemical Company. Dowtherm A and E Handbook. Midland, Michigan.
- 6. Danning of Dupont, Notes of Telephone Conversation with K.S. Howells, September 12, 1978.
- 7. Howells, K.S. Compressed Air as a Heat Transfer Fluid Calculation. J.O. No. 13091, October 18, 1978.
- 8. Gilbert/Commonwealth Engineers and Consultants. WEPCO-Generation Planning Studies: Data Base. Reading, Pennsylvania, July 27, 1977.
- 9. Smith, J.M. and Van Ness, H.C. Introduction to Chemical Engineering Thermodynamics. McGraw-Hill Book Company, New York, N.Y. 1975, p. 577-579.

				TOXICIT	45 0 0							
		FLUIDS	λcute Local	Acute Systematic	Chronic Iocal	Chronic Systematic			·			
	- Charles - Char	FLUIDS	Irritant Inhalation Ingestion	Inhaletion Ingestion	Irritant Allergen	Inhalation Ingestion Irritant	Atmospheric Boiling Pt,	Atmospheric Melting Pt,	Saturated Pressure at 500°F, PSIA	Chemical Stability Range, "F-	Flash Pt.,	Critical Temp
	1.	Water 9		Non-to	xic		2 12	32	680.8		лк	
	2.	Steam*		Non-to	xic		212	32	680.8		KA	
	3.	Freon-12*	000	10	00	100	-21	-253	above criti cal	<400		400
	4.	Ethylene Glycol	low	03	10	020	387					
j	5.	Dowtherm		toxic if inge	sted ≥ 0.6	x	496	53.6	15.65	<750	255 '	927
1	6.	Dowitherm		•			352	-6.7	86.6	<500	155	
	7.	Fused Salt-Hi Tech ² (Na NO ₂ , Na NO ₂ , KNO ₃)		Non-to	xic			288		<850		
	8.	Mobiltherm 6031		very to	xic		610	20pp#	•	5-600	380	
•	9.	Mobiltherm Lights		very to	xic		450	-20pp		<400	250	
	10.	Therminol 55*				•	734	-40pp		0-600	355	655
	11.	Mercury	. 30	33	23	33	674	39		<1000	ии	
	12.	NáK³	333	U	2-	u	1518	65				
	13.	Compressed Air*		Non-to	xic							
	14.	Ammonia ²	333	U	1	บ	-29	-108	above critical		N.	270
	. 15.	Therminal 66*	-u-	22	-U-		668	-18pp	CLICICAL	0-650	355	705

NOTES:

[•] pp = pour point

^{** 0 *} non-t xic to 3 - deadly

APPENDIX E

HEAT LOADS AND DISTRIBUTION PIPING COSTS

- I. Summary of Heat Loads by Scheme and Area
- II. Breakdown of Distribution Piping Costs by Scheme and Area

I. SUMMARY OF HEAT LOADS BY SCHEME AND AREA

SCHEME NO. 1 JERSEY CITY, HOBOKEN & THE SOUTHERN PORTION OF THE HACKENSACK MEADOWLANDS AREA

1. Jersey City & Hoboken

Area W

3096 apartments x 20,000 BTUH ea =

Office Buildings 1000×10³ FT²
×25 BTUH/FT²=

62x106 BTUH

 $\frac{25\times10^6}{87\times10^6}$ BTUH

Use 100x10⁶ BTUH

Area X

2265 apartments x 20,000 BTUH ea =

46x10⁶ BTUH

Use 50x10⁶ BTUH

Area Y

642 apartments x 20,000 BTUH ea =

13x10⁶ BTUH

Office Bldgs. 400x103 FT²

x 25 BTUH/FT²

10x10⁶ BTUH

23x10⁶ BTUH

Use 25x10⁶ BTUH

			•	
	Area Z			
	3003 apartments x 20,000 BTUH ea :	=	61×10 ⁶	втин
	Office Bldgs. 800x10 ³ FT ² x 25 BTUH/FT ² =	=	20×106	BTUH
			81×10 ⁶	BTUH
			<u>Use 85x10⁶</u>	BTUH
	Area A-A			
	2000 apartments x 20,000 BTUH ea =	=	40x106	втин
			Use 40x106	BTUH
2.	Hackensack Meadowlands (Southern I	Portion)		
	Area A	•		
	Hotel Office Commercial District	=	20x10 ⁶	BTUH
	Cultural Center	=	38x10 ⁶	втин
	School Site	=	15×10 ⁶	BTUH
	Berrys Creek Center	=	5×10 ⁶	BTUH
	Residential (Parkside)	=	11×10 ⁶	BTUH

Use 89x10⁶ BTUH

Awa a B		
Area B	47×10 ⁶ втин	
Light Industrial		
Residential (Island)	17×10 ⁶ BTUH	
Neighborhood Shopping District	10×10 ⁶ втин	
School Site	<u> 10×10⁶ втин</u>	,
	Use 84x10 ⁶ BTUH	
Area C		
Light Industrial	136×10 ⁶ BTUH	
	Use 136x10 ⁶ BUTH	
	000 130.110	•
Area D	161×10 ⁶ BTUH	
Light Industrial		
Heavy Industrial	54x10 ⁶ BTUH	•
	<u>Use 215×10⁶ BTUH</u>	•
Area E		
Residential (Parkside)	36×10 ⁶ BTUH	i
Neighborhood Shopping District	20×10 ⁶ BTUH	[
School Site	20×10 ⁶ BTUH	[
Community Shopping District	_5x10 ⁶ BTUE	<u> </u>
	Use 81x10 ⁶ BTUE	<u>I</u>
Area F		
Residential (Parkside)	14x10 ⁶ BTUF	ł
School Site	10x10 ⁶ BTUF	ł
Neighborhood Shopping District	_5×10 ⁶ _BTU	ł
Reignborhood Shopping District	<u>Use 29×10⁶ BTU</u>	
	USE ZAKIO BIOI	=
Area G	6	
Light Industrial	40×10 ⁶ BTU	
Residential (Island)	14x10 ⁶ BTU	
School Site	10x10 ⁶ BTU	
Neighborhood Shopping District	10×10 ⁶ BTU	<u>H</u>
	E-4 Use 74x10 ⁶ BTU	H

Light Industrial 73x10 ⁶ BTUH Heavy Industrial 108x10 ⁶ BTUH Use 181x10 ⁶ BTUH Area I School Site 15x10 ⁶ BTUH Residential (Parkside) 27x10 ⁶ BTUH Area J School Site 5x10 ⁶ BTUH Neighborhood Shopping District 10x10 ⁶ BTUH Residential (Parkside) 17x10 ⁶ BTUH Area K School Site 5x10 ⁶ BTUH Neighborhood Shopping District 5x10 ⁶ BTUH Neighborhood Shopping District 5x10 ⁶ BTUH Residential (Parkside) 3x10 ⁶ BTUH Hetal/Office/Commercial District 119x10 ⁶ BTUH	Area H	
Heavy Industrial 108x10 ⁶ BTUH		73x10 ⁶ BTUH
Use 181x10 ⁶ BTUH		108×10 ⁶ BTUH
Area I School Site		Use 181×10 ⁶ BTUH
School Site 15x10 ⁶ BTUH Neighborhood Shopping District 5x10 ⁶ BTUH Residential (Parkside) 27x10 ⁶ BTUH Marea J Use 47x10 ⁶ BTUH Neighborhood Shopping District 10x10 ⁶ BTUH Residential (Parkside) 17x10 ⁶ BTUH Marea K School Site 5x10 ⁶ BTUH Neighborhood Shopping District 5x10 ⁶ BTUH Neighborhood Shopping District 5x10 ⁶ BTUH Residential (Parkside) 3x10 ⁶ BTUH	Area I	
Residential (Parkside) 27x10 ⁶ BTUH Marea J Use 47x10 ⁶ BTUH School Site 5x10 ⁶ BTUH Neighborhood Shopping District 10x10 ⁶ BTUH Residential (Parkside) 17x10 ⁶ BTUH Area K Use 32x10 ⁶ BTUH School Site 5x10 ⁶ BTUH Neighborhood Shopping District 5x10 ⁶ BTUH Residential (Parkside) 3x10 ⁶ BTUH		15x10 ⁶ втин
Residential (Parkside) 27x10 ⁶ BTUH Marea J Use 47x10 ⁶ BTUH School Site 5x10 ⁶ BTUH Neighborhood Shopping District 10x10 ⁶ BTUH Residential (Parkside) 17x10 ⁶ BTUH Area K Use 32x10 ⁶ BTUH Neighborhood Shopping District 5x10 ⁶ BTUH Neighborhood Shopping District 3x10 ⁶ BTUH Residential (Parkside) 3x10 ⁶ BTUH	Neighborhood Shopping District	5×10 ⁶ втин
Area J 5x10 ⁶ BTUH Neighborhood Shopping District 10x10 ⁶ BTUH Residential (Parkside) 17x10 ⁶ BTUH Use 32x10 ⁶ BTUH Area K 5x10 ⁶ BTUH Neighborhood Shopping District 5x10 ⁶ BTUH Residential (Parkside) 3x10 ⁶ BTUH	_	27×10 ⁶ BTUH
Area J 5x10 ⁶ BTUH Neighborhood Shopping District 10x10 ⁶ BTUH Residential (Parkside) 17x10 ⁶ BTUH Use 32x10 ⁶ BTUH Area K 5x10 ⁶ BTUH Neighborhood Shopping District 5x10 ⁶ BTUH Residential (Parkside) 3x10 ⁶ BTUH		Use 47×10 ⁶ BTUH
School Site 5x10 ⁶ BTUH Neighborhood Shopping District 10x10 ⁶ BTUH Residential (Parkside) 17x10 ⁶ BTUH Use 32x10 ⁶ BTUH Area K School Site 5x10 ⁶ BTUH Neighborhood Shopping District 5x10 ⁶ BTUH Residential (Parkside) 3x10 ⁶ BTUH	Area J	
Residential (Parkside) 17x10 ⁶ BTUH Use 32x10 ⁶ BTUH Area K School Site 5x10 ⁶ BTUH Neighborhood Shopping District 5x10 ⁶ BTUH Residential (Parkside) 3x10 ⁶ BTUH		5x10 ⁶ BTUH
Residential (Parkside) 17x10 ⁶ BTUH Use 32x10 ⁶ BTUH Area K School Site 5x10 ⁶ BTUH Neighborhood Shopping District 5x10 ⁶ BTUH Residential (Parkside) 3x10 ⁶ BTUH	Neighborhood Shopping District	10x10 ⁶ BTUH
Area K School Site 5x10 ⁶ BTUH Neighborhood Shopping District 5x10 ⁶ BTUH Residential (Parkside) 3x10 ⁶ BTUH		17×10 ⁶ BTUH
School Site 5x10 ⁶ BTUH Neighborhood Shopping District 5x10 ⁶ BTUH Residential (Parkside) 3x10 ⁶ BTUH		Use 32x10 ⁶ BTUH
School Site 5x10 ⁶ BTUH Neighborhood Shopping District 5x10 ⁶ BTUH Residential (Parkside) 3x10 ⁶ BTUH	Area K	
Residential (Parkside) 3x10 ⁶ BTUH		5×10 ⁶ втин
Residential (larkside)	Neighborhood Shopping District	5×10 ⁶ втин
6		3×10 ⁶ втин
Hotel, dilice, commercial product	Hotel/Office/Commercial District	119×10 ⁶ BTUH

Use 132x10⁶ BTUH

SCHEME NO. 2 DOWNTOWN NEWARK

Area B-B	
3230 apartments x 20,000 BTUH ea =	65×10 ⁶ втин
•	Use 70×10 ⁶ BTUH
Area C-C	
350 apartments x 20,000 BTUH ea =	7×10 ⁶ втин
N.J. College of Medicine =	113×10 ⁶ BTUH
	Use 120x10 ⁶ BTUH
Area D-D	
2068 apartments x 20,000 BTUH ea =	42×10 ⁶ BTUH
Office Bldgs. $1400 \times 10^3 \text{ FT}^2$ $\times 25 \text{ BTUH/FT}^2 = -$	35×10 ⁶ BTUH
	77x10 ⁶ BTUH
	Use 85x10 ⁶ BTUH
Area E-E	
2100 apartments x 20,000 BTUH ea =	42×10 ⁶ BTUH
	Use 50x10 ⁶ BTUH
Area F-F	
1105 apartments x 20,000 BTUH ea =	21×10 ⁶ BTUH
Future development =	<u> 25×10⁶ втин</u>
	46x10 ⁶ BTUH
	Use 50x10 ⁶ BTUH
Areas G-G & H-H	
2000 apartments x 20,000 BTUH ea =	40×10 ⁶ втин
Office Bldgs. $2600 \times 10^3 \text{ FT}^2$ $\times 25 \text{ BTUH/FT}^2 =$	65×10 ⁶ BTUH
	105×10 ⁶ втин
	Use 55x10 ⁶ BTUH
	For EA Area

Areas I-I & J-J

Industrial Areas

Use 50x10⁶ BTUH ea

SCHEME NO. 3

This scheme is the same as Scheme No. 1 and No. 2 with the addition of the northern portion of the Hackensack Meadowlands area.

1. Hackensack Meadowlands Area (Northern Portion)

Area L	
Residential (Island)	7×10 ⁶ в т ин
School Site	10×10 ⁶ втин
Light Industrial	13×10 ⁶ BTUH
Neighborhood Shopping District	<u> 5×10⁶ втин</u>
	Use 85x10 ⁶ BTUH
Area M	
Residential (Island)	8×10 ⁶ BTUH
School Site	5×10 ⁶ втин
Neighborhood Shopping District	5×10 ⁶ BTUH
Heavy Industrial	36×10 ⁶ BTUH
·	Use 54x10 ⁶ BTUH
Area N	•
Light Industrial	81x10 ⁶
Residential (Island)	27×10 ⁶ BTUH
School Site	10×10 ⁶ BTUH
Neighborhood Shopping District	<u>10×10⁶ BTUH</u>
	<u>Use 128×10⁶ BTUH</u>
Area O	
School Site	10×10 ⁶ втин
Neighborhood Shopping District	10×10 ⁶ втин
Residential (Island)	24×10 ⁶ BTUH
	Use 44x10 ⁶ BTUH

Area P	_
Light Industrial	55x10 ⁶ BTUH
Heavy Industrial	20×10 ⁶ втин
Residential (Island)	18×10 ⁶ BTUH
School Site	5x10 ⁶ BTUH
Neighborhood Shopping District	5x10 ⁶ BTUH
•	Use 103x10 ⁶ BTUH
Area Q	
Light Industrial	27×10 ⁶ BTUH
School Site	10x10 ⁶ BTUH
Neighborhood Shopping District	5×10 ⁶ BTUH
Community Shopping District	7×10 ⁶ ВТИН
Hotel-Office-Commercial District	100x10 ⁶ BTUH
Residential (Parkside)	<u> 18×10⁶ BTUH</u>
	<u>Use 167x10⁶ BTUH</u>
Area R	
Residential (Island)	13×10 ⁶ BTUH
School Site	10×10 ⁶ втин
Neighborhood Shopping District	5×10 ⁶ ВТИН
Residential (existing)	<u> 10×10⁶ втин</u>
	<u>Use 38x10⁶ BTUH</u>
Area S	
Residential (Island)	14×10 ⁶ ВТИН
School Site	5x10 ⁶ втин
Neighborhood Shopping District	5x10 ⁶ ВТИН
Hotel-Office-Commercial District	100x10 ⁶ BTUH
Light Industrial	7×10 ⁶ BTUH
	Use 131x10 ⁶ BTUH

A	re	a	T

Light Industrial	47×10 ⁶ BTUH
Community Shopping District	28×10 ⁶ BTUH
Hotel-Office-Commercial District	160×10 ⁶ BTUH
	<u>Use 235x10⁶ BTUH</u>
Area U	·
Light Industrial	13×10 ⁶ BTUH
Hotel-Office-Commercial District	20×10 ⁶ втин
Berrys Creek Center	5×10 ⁶ втин
	<u>Use 38x10⁶ BTUH</u>
Area V	•
Light Industrial	27×10 ⁶ втин
School Site	15×10 ⁶ BTUH
Residential (Parkside)	2x10 ⁶ BTUH
Community Shopping District	5×10 ⁶ втин
Hotel-Office-Commercial District	60×10 ⁶ втин
	Use 109x10 ⁶ BTUH

II. BREAKDOWN OF DISTRIBUTION PIPING COSTS BY SCHEME AND AREA

1. Scheme No. 1

a)	Summary - Hudson Station to Jersey	City & Hoboken
	1) Main Piping	\$ 5,892,800
	2) Area Piping -	
	Area W	2,250,900
٠	Area X	1,019,000
	Area Y	1,019,000
	Area Z	2,158,800
	Area A-A	1,019,000
•	•	\$ 7,466,700
٠.		e 13 359 500

b) Summary - Hudson Station to Meadowlands

1)	Main Piping	\$ 14,061,400

2) Area Piping

Area Piping	
Area A	1,807,800
Area B	1,825,500
Area C	1,931,500
Area D	2,682,100
Area E	1,825,500
Area F	823,100
Area G	1,735,800
Area H	2,345,500
Area I	823,100
Area J	823,100
Area K	1,931,500
	\$ 18,554,500

\$ 32,615,900

c) Total - Scheme No. 1

Main Piping	Area Piping	Total
5,892,800	7,466,700	13,359,500
14,061,400	18,554,500	32,615,900
		\$ 45 975 400

2.	Sche	eme_i	No. 2 - Summary Ess	ex Stati	on to Newark	
	a)		n Piping		\$ 11,596,000	
	ь)	Are	a Piping			
		Ar	ea B-B		2,158,600	
		Ar	ea C-C		2,404,600	
		Ar	ea D-D		2,250,900	
		Ar	ea E-E		1,019,000	
		Ar	ea F-F		1,019,000	
		Ar	ea G-G		2,289,200	
		Ar	ea H-H		2,289,200	
		Ar	ea I-I		1,019,000	
		Ar	ea J-J		1,019,000	
					\$ 15,468,500	
	c)	Tot	al - Scheme No. 2	:	\$ 27,064,500	
3.	Sch	eme	No. 3			
	a)	Sum	mary - Bergen Stat	ion to N	orthern Part of	the Meadowlands
		1)	Main Piping		\$ 19,960,900	
		2)	Area Piping			
			Area L		823,100	
			Area M		823,100	
			Area N		1,807,800	
			Area O		823,100	
			Area P		1,807,800	
			Area Q		2,316,800	•
			Area R		823,100	

Area S

Area T

1,807,800

2,777,500

	Area U		823,100	
	Area V		1,807,800	
	•	,	\$ 16,441,000	
			\$ 36,401,900	
ъ)	Summary - Hudso	n Station to J	Jersey City and Hoboken	
	1) Main Piping		5,892,800	
٠	2) Area Piping		7,466,700	
			\$ 13,359,500	
c)	Summary - Hudso	n Station to S	Southern Part of the Meadowland	<u>s</u>
	1) Main Piping	•	\$ 14,061,400	
	2) Area Piping		18,554,500	
			\$ 32,615,900	
d)	Summary - Essex	Station to Ne	ewark_	
	1) Main Piping		\$ 11,596,000	
	2) Area Piping		15,468,500	
			\$ 27,064,500	
e)	Total - Scheme	No. 3		
	Main Piping	Area Piping	<u>Total</u>	
	19,960,900	16,441,000	\$ 36,401,900	
	14,061,400	18,554,500	32,615,900	

7,466,700

15,468,500

13,359,500 27,064,500

\$109,441,800

5,892,800

11,596,000

Total Scheme No. 3

APPENDIX F

CONSIDERATION OF DIFFERENT TYPES OF COOLING PLANTS

The cooling plants or chilled water plants can be of two (2) types, using two basic refrigeration cycles:

- A. Vapor Compression Refrigeration Cycle Plant
- B. Absorption Refrigeration Cycle Plant
- A. Vapor Compression Refrigeration Cycle Plant
 Vapor compression machines, used for compressing the refrigerant for absorbing heat from the medium being cooled, are of two types:
 - 1. Reciprocating, and
 - 2. Centrifugal

General

The factors involved in the selection of a compression refrigeration machine are load, chilled water quantity and temperature, condensing medium, quantity and temperature of condensing medium, type and quantity of power available, fouling factor allowance, amount of usable space available, and the nature of the load, whether variable or constant. The final selection is usually based on the least expensive combination of machine and heat rejection device as well as a reasonable machine operating cost.

The selection of multiple machines for a common load is usually based on the following:

- Availability limitations to the physical size it is economical to produce.
- Reliability the need to handle a portion of the load when one machine may be down for service.
- Flexibility ability to more efficiently match compressor capacity to partial load requirements.

The optimal machine selection involves matching the correct machine and cooling tower as well as the correct entering chilled water temperature and water rise. A selection of several machines and cooling towers often results in finding one combination having a minimum first cost.

1. Reciprocating Refrigeration Machines

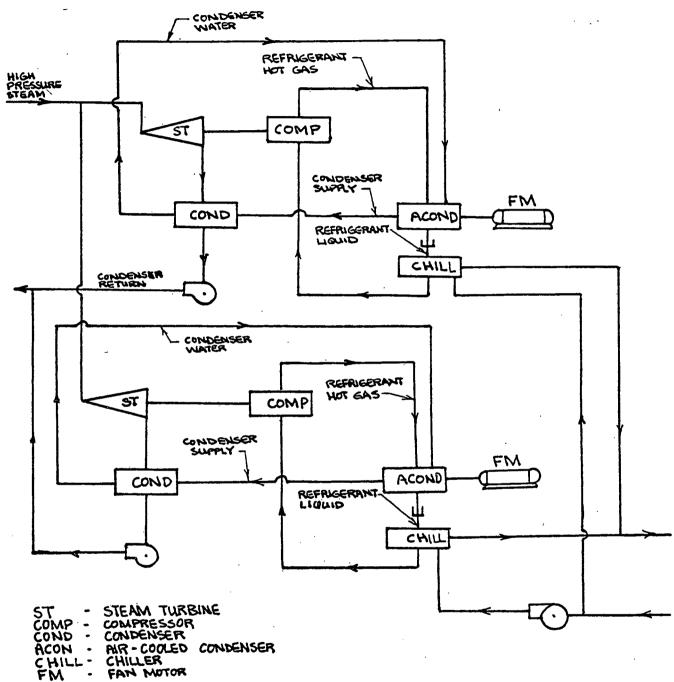
The main component of these machines is the reciprocating compressor which is a positive displacement device employing refrigerants having low specific volumes and relatively high pressure characteristics. A reciprocating refrigeration machine may be classified as one of the following:

- a. Compressor unit consisting of a compressor, motor and safety controls mounted as a unit for refrigeration applications up to 60 tons.
- b. Condensing unit consisting of a compressor plus an interconnected water cooled or air-cooled condenser mounted as a unit for refrigeration applications between 60-200 tons.
- c. Water chilling unit consisting of either a compressor unit or condensing unit plus an interconnected water cooler and operating controls. This type of unit can handle refrigeration applications above 200 tons and can be obtained complete with or without water cooled condensers. This unit can also be used with air-cooled or evaporative condensers.

Compressors may be classified as either open or hermetic. An open compressor requires an external drive and may be direct driven through a coupling or belt driven to operate at a specific speed, depending on load requirements. The type of drive may be an electric motor, steam turbine or internal combustion engine. A hermetic compressor consists of an electric motor and compressor built into an integral housing and utilizing a common shaft and bearings. Hermetic compressors minimize installation problems, maintenance requirements and refrigerant leakage problems often associated with open compressors. Compressor operating limits depend on the refrigerant used and horse-power output of the motor. Generally, horsepower output is matched to a compressor and refrigerant. All compressor units must be combined with a device to condense the refrigerant.

American Refrigeration Institute (ARI) standards for reciprocating liquid chilling packages establish Standard Rating Conditions (SRC) for a water cooled model of a leaving chilled water temperature of 44°F, chilled water range of 10°F, entering condenser water temperature of 95°F and condenser water rise of 10°F.

Figure 1 shows a flow diagram of a typical reciprocating refrigeration machine using the vapor compression cycle with turbine drive compressors.



CHILL

Vapor Compression Cycle Plant with

Turbine Driven Compressor Reciprocating Refrigerating Machine Cycle

FIGURE 1

2. Centrifugal Refrigeration Machines Centrifugal refrigeration equipment is built for heavy duty continuous operation and has a reputation for dependability in all types of commercial and industrial applications.

A centrifugal refrigeration machine consists basically of a centrifugal compressor, a cooler and a condenser. The compressor uses centrifugal force to raise the pressure of a continuous flow of refrigerant gas from the evaporator pressure to the condenser pressure. A centrifugal compressor handles high volumes of gas and, therefore, can use refrigerants having high specific volumes. The cooler is usually a shell-and-tube heat exchanger with the refrigerant in the shell side. The condenser is also a shell-and-tube type utilizing water as a means of condensing. It may be an air-cooled or evaporative condenser for special applications.

Centrifugal refrigeration machines may be classified as open compressor or hermetic compressor type.

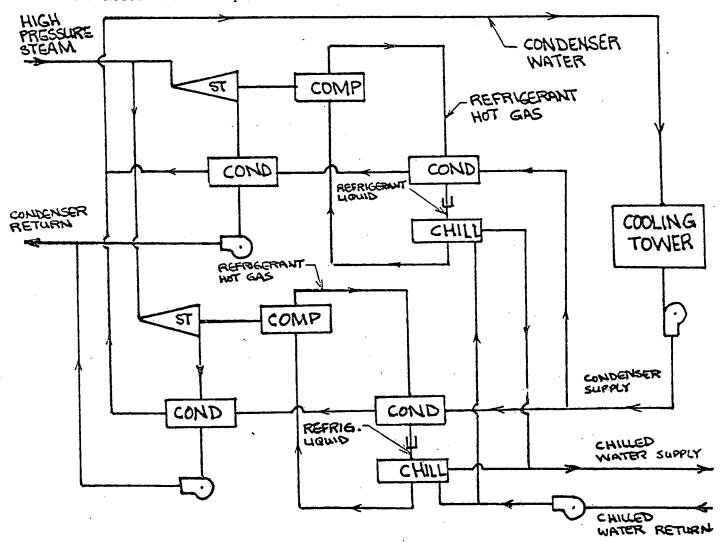
- a) Open Machines may be used for refrigeration duty in single units up to about 4500 tons capacity at air conditioning temperature levels. Compressors are usually driven at speeds above 3000 rpm and may operate up to 18,000 rpm. The centrifugal drive may be an electric motor, diesel engine or gas turbine. These machines are essentially multi-purpose machines and are used in special and industrial applications requiring higher temperature lifts than normally encountered at air conditioning levels. They are flexible in regard to speed selection and staging, and are used for standard water chilling applications where one or more large capacity machines are required, or where a steam turbine, gas turbine, diesel engine or special motor drive is desired.
- hermetic Machines may be obtained in single units up to 2000 tons capacity and are normally designed with either one or two stages and driven at a single speed. Hermetic machines are single purpose machines generally used for water chilling applications. They can be installed easily and quickly with a minimum of field problems involving motor mounting, coupling and alignment.

There are four types of drives in general use for centrifugal compressors:

- a. Steam turbine
- b. Variable speed motor
- c. Constant speed motor
- d. Constant speed engine

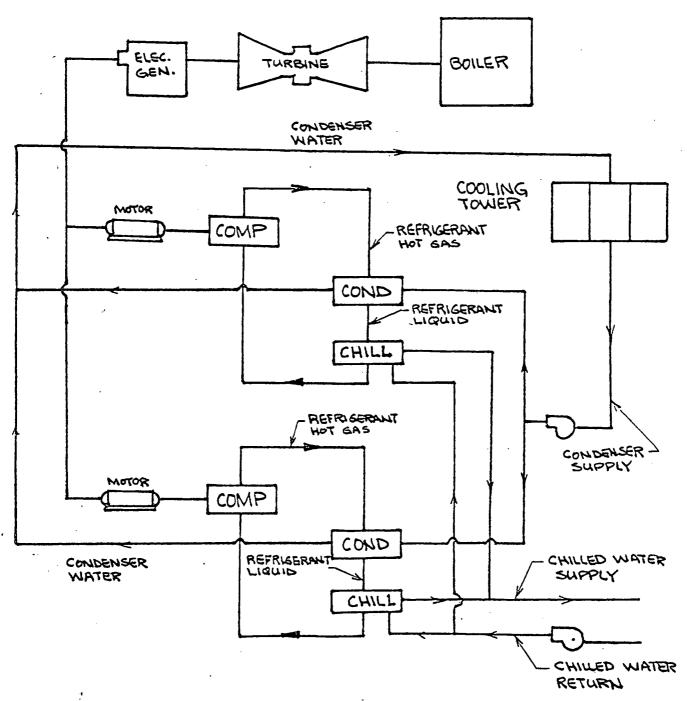
Steam turbines are ideally suited for centrifugal compressors. They afford variable rpm, permitting the compressor to operate at a minimum speed and brake horsepower. They usually have a good efficiency characteristic over the required speed range with economy of operation. Variable speed motors of the wound rotor type are used for open centrifugal machine whereas hermetic compressors use only induction type motors.

Figure 2 shows a flow diagram of a typical centrifugal refrigerating machine using the vapor compression cycle with turbine driven compressors. Figure 3 shows the same refrigeration machine using electric motor driven compressors.



VAPOR COMPRESSION CYCLE PLANT WITH TURBINE DRIVEN COMPRESSOR CENTRIFUGAL REFRIGERATION MACHINE CYCLE

FIGURE 2



VAPOR COMPRESSION REFRIGERATION
CYCLE WITH
ELECTRIC MOTOR DRIVEN COMPRESSOR

FIGURE 3

B. Absorption Refrigeration Cycle Plant

The absorption refrigeration machine is a water chilling package which uses heat directly without the use of a prime mover. Because of its compactness and vibrationless operation, it can be installed anywhere space and a heat source is available, from basement to roof. It uses the cheapest, safest and most available of all refrigerants, ordinary tap water. Its absorbent is a simple salt.

Since heat in the form of steam or hot water is generally the operating force of an absorption machine, the following situations are favorable to the application of absorption refrigeration machines:

- 1. Where low cost fuel is available, as in natural gas regions.
- 2. Where electric rates are high.
- 3. Where steam or gas utilities are desirous of promoting summer loads.
- 4. When waste steam is available.
- 5. Where there is a lack of adequate electric facilities for installing a conventional compression machine. Since the absorption machine uses only 2-9% of the electric power required by compression type equipment, its use becomes attractive where emergency stand-by power is required, as in hospitals.
- 6. Where low pressure heating boiler is largely or wholly unused during the cooling season.

The absorption machine uses water as a refrigerant and a salt solution such as lithium bromide as an absorbent. It operates on the simple principle that under low absolute pressure, water will boil at low temperatures. There are two shells which uses heat to efficiently produce refrigeration. The lower shell is divided into absorber and evaporator sections while the upper shell consists of generator and condenser sections. The evaporator section contains the refrigerant, water. A coil through which the cooling system water circulates, is inserted into the evaporator to establish a heat exchange.

The refrigerant gains heat from the cooling system water, and because of low pressure maintained in the evaporator, quickly reaches the saturation temperature and vaporizes, cooling the system water. The affinity of lithium bromide for water causes the refrigerant vapor to be absorbed by the strong solution in the absorber section. The diluted solution is pumped into the generator where steam or hot water is used to drive the water out of the solution as a vapor. The vapor passes into the condenser and changes back to liquid which returns to the evaporator to be reused. Meanwhile, the strong solution left in the generator flows back to the absorber.

A single-stage absorption machine operates with a temperature range of 170°F to a maximum of 270°F . A two-stage unit requires a range of 270°F to 400°F . As a rough approximation, a two-stage unit operating at a higher temperature will produce at least twice the refrigeration capacity of a single-stage machine operating at a lower temperature.

In a large district cooling system and whenever possible, at least two absorption units should be installed. This allows for flexibility in reducing the output or shutting down one unit during low cooling demands instead of operating one large unit for minimum cooling.

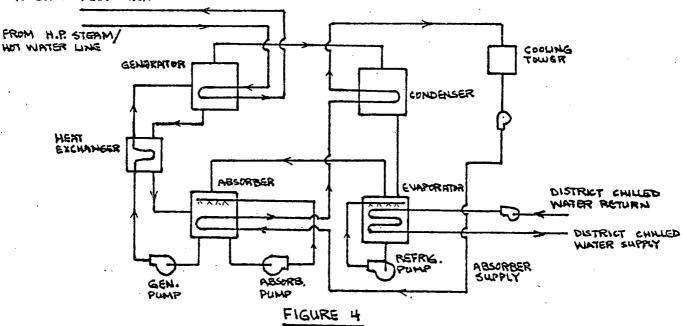
The equipment cost for a water cooled electric centrifugal machine is about 10% higher than a comparable single-stage absorption unit per nominal ton of refrigeration capacity. The additional costs for electrical lines and switching stations must also be factored into the total cost of an electric centrifugal unit.

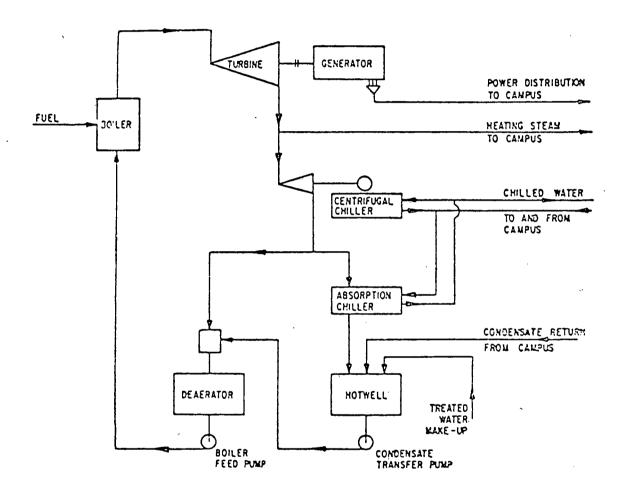
A two-stage absorption unit costs almost twice that of a single-stage unit. Although a two-stage unit is more expensive, it uses less steam per hour per ton. Subsequently, the additional cost will be recovered after only a few years of operation. Installation costs for the above units are about the same.

Absorption machines can be installed in practically any location in a building where the floor is of adequate strength and reasonably level. In outdoor installations, a simple heated structure enclosing the machine is generally preferred, and erection of the enclosure may be less costly than the precautions that may be required to make the machine suitable for outdoor installation. The absorption machine can also use as its heat source the steam or hot water made in a waste heat boiler or the jacket cooling water from a gas engine (250°F or higher).

The absorption cycle is shown in Figure 4. Figure 5 shows a combination absorption/centrifugal machine refrigeration cycle.

TO BOILER FEEDWATER





COMBINATION ABSORPTION/CENTRIFUGAL REFRIGERATION MACHINE CYCLE

FIGURE 5

Thermal Energy Requirements for Air Conditioning Systems The Department of Housing and Urban Development (HUD) financed a study conducted by Oak Ridge National Laboratory (ORNL) to determine the thermal energy requirements to operate air conditioning systems in conjunction with an electric power production and district heating facility. Calculations were performed to determine the energy required for air conditioning by both the compression and absorption methods discussed above.

Results indicated that, for a power plant with a compression refrigeration machine, more total energy is required to operate an electric motor-driven compressor using electricity produced by the plant than for a turbinedriven compressor using steam that would ordinarily be discharged as waste heat. The electricity produced by the electric generator is the most valuable commodity we have, and every kilowatt produced should be delivered to the area where it can do the most good. It is highly desirable, wherever possible to minimize the use of this electricity for secondary and auxiliary systems. Suppose that steam is extracted from the steam turbine, then the thermal energy required to operate the same compressor will be produced at a higher overall efficiency. This in turn will minimize overall efficiency losses as experienced by a motor-driven compressor and, at best, increase the average efficiency at which the total power output of the system is generated. The reason why this extracted steam produces power at a lower fuel cost than that of power produced using electricity from the electric generator, can be explained by the fact that, even for the best modern condensing turbine power plants, about two-thirds of the heat present in the steam at the turbine inlet is left in the steam at the turbine exhaust. This means, only one-third of the heat in the fuel can be turned into electric power. If however, we extract a portion of the steam from the turbine and use it to operate the absorption system. not all of the heat in this steam will be wasted. The system must be properly designed and retrofitted to assure that steam extraction does not result in substantial or excessive loss of primary electric power produced in comparison to the power generated by the extracted steam.

Results also indicate that an absorption refrigeration machine, using steam supplied from the turbine, requires approximately the same amount of thermal energy as a turbine-driven compression machine to produce the same refrigeration capacity. Both systems, for example, would require about 5700 Btu/hr, equivalent to 1.67 Kw, to cool water from 54°F to 44°F for recirculation in air conditioning systems. The compressor would require an input of about 2.24 HP, while the absorption machine uses the heat directly to produce one ton of refrigeration or 12,000 Btu/hr.

In comparison, an electric motor-driven compression machine requires about 8,800 Btu/hr, or 2.58 Kw, to generate one ton of refrigeration. The compressor would need an input of about 3.46 Hp.

D. <u>Cooling System Conversion</u>

The end user conversion costs for a district cooling system involve the retrofitting of an existing central air conditioning system. In large office buildings and apartment houses which have existing electric centrifugal or reciprocating machines, an economic evaluation of the existing electric vs. new absorption equipment powered by district hot water will have to be performed on a case by case basis. In smaller structures such as single and multi-family dwellings the use of a substation containing either an absorption or electric centrifugal machine will be used. The total amount of cooling which can be handled by this substation will be determined by the connected cooling load in the buildings served by the substation. Separate chilled water piping will be run from the substation to the individual buildings (i.e., two pipes for heating and two pipes for cooling).

Again the conversion costs for each building will have to be evaluated on a case by case basis; the cost of each conversion will have to be based upon whether a building has its own central cooling system or individual electric window units which will have to be replaced by a central system. Generally however, the conversion costs for a single family building will be approximately \$1,500 for a building with existing central cooling system and \$3,000 to \$4,000 for installing a new cooling system. In a multi-family dwelling these figures will increase by a factor of two hundred and fifty percent.

E. Selection of the Most Desirable Refrigeration System Electric centrifugal refrigeration machines were developed to fill the need for single refrigeration units of large capacity. A single centrifugal machine can be used in place of several reciprocating machines. They are known for:

- 1. Reliability
- 2. Compactness
- 3. Low maintenance costs
- 4. Long life
- 5. Ease of Operation
- 6. Quietness

Generally, compression machines are more efficient than comparable absorption refrigeration units. Current manufacturer's data show the coefficient of performance (COP) for a water cooled electric centrifugal machine to be about 4.0 and 0.68 for a comparable absorption machine. Past experiences with both systems has showed that compression machines have a longer operating life cycle over absorption systems according to manufacturer's data. However, turbine driven compression machines carry much higher capital and maintenance costs. Absorption machines do not

require a prime mover. The absence of heavy moving parts practically eliminates vibrations and reduces noise pollution levels to a minimum. Electric motor-driven units will need, in addition to all the required piping, an electric transmission network and switching stations not required by an absorption unit. The anticipated life spans for absorption machines is only 12 to 15 years due to problems with the corrosive refrigerant and leaks. Fairly extensive overhaul and replacement efforts are necessary to maintain the operating efficiency of these systems after the 12 to 15 year cycle. Since electrical rates have increased less than steam rates, the economics of compression refrigeration is again becoming more feasible and practical.

The component efficiencies used in the ORNL eight year old, empirical study appear to be relatively high and may not be considered to be representative of the efficiencies of current equipment designs. For a more accurate comparison of the different systems, to minimize overestimating the component efficiencies and to minimize underestimating the penalty on a power plant due to heat extraction, component efficiencies based on SWEC computer runs were used. Based on these preliminary estimates, computer data and existing installed equipment, a compression system may be more desirable over an absorption system depending on the application. Therefore, in order to determine the best refrigeration system, a case by case study should be conducted for the load regions considered. The case by case study should include an evaluation of initial capital expenditures, operating and maintenance expenses, existing installed equipment and long term economic impact on the overall district heating program.

APPENDIX G

CONSIDERATION OF DIFFERENT OPTIONS FOR TRANSFERRING HEAT FROM STEAM TO A DISTRIBUTION MEDIUM

In order to select the best system to efficiently and economically transfer heat from steam to a distribution medium, a review was performed on several parameters which directly and indirectly influences the final choice. These parameters are as follows:

	Direct		
a)	Temperature	Ranges	

- b) Heat Transfer mechanism
- c) Carrying media
- d) Heat Losses

Indirect

- a) Heat Source
- b) Pipe sizes and installation
- c) Distribution Network
- d) Impact of heat extraction on overall system
- e) Overall first cost

The information resulting from this review can be summarized as follows:

The temperature ranges considered for the district heating system which represent heating conditions were:

	Supply OF	Return ^O F	Temp Diff OF
From Plant to Sub-Station	390	270	120
From Plant to End User	390	190	200
From Plant to Sub-Station	290	230	60
From Plant to End User	290	170	120
From Plant to Sub-Station	230	190	40
From Sub-Station to End User	200	180	20

The 390°F temperature level was eliminated because steam would have to be extracted from a higher energy source such as the main steam pipes, the high pressure turbine, the cold reheat, the hot reheat or the intermediate pressure turbine resulting in a measurable and undesirable loss of electric power generation. Although the heat exchangers would be smaller, the higher pressure rated materials required, per square foot of surface area for 390°F operation, are more expensive. In addition temperatures above 290°F would require the use of more expensive insulation to minimize heat losses to acceptable design levels. Safety concerns would become an issue because potential pipe ruptures would present definite hazards to the public due to the much higher temperature involved.

The $230^{\circ}F$ and $200^{\circ}F$ temperature levels were also found to be undesirable and were eliminated for the following reasons:

- The lower temperature rise (supply minus return temperature) would require higher flow rates. Thus, substantially larger, higher cost pipe diameters would be required.
- The associated heat transfer equipment such as the heat exchangers and pumps would increase considerably in size for the higher flow rates thus, again, higher costs.

- 3. Although the heat transfer system would have better performance at the lower temperature from a thermodynamic standpoint, the increased benefit in performance is not overwhelming and not considered substantial to justify the increased cost.
- 4. No material advantage is realized in operating at lower temperature levels since the heating system would basically be using the same materials.
- 5. The district heating systems in European countries operate at 250-260°F temperature levels in cities where the heating load is more severe. The degree of usefulness of a 250°F or 290°F system depends on frequency of usage. Since the capacity factor in New Jersey is not as severe as in European countries, the added investment for using 290°F temperature is considered justifiable to improve the efficiency of the overall system.
- 6. Field installation would become more costly due to deeper and wider trenches, possible interference problems with existing lines and other distribution/transmission networks and the increased time and labor required.

The 290°F temperature level was considered adequate to meet district heating demands while simultaneously striking a reasonable balance between initial costs and resulting performance.

After selecting the temperature level considered most adequate, additional studies were conducted to determine the most desirable temperature range (i.e., $290^{\circ}-230^{\circ}$ F or $290^{\circ}-170^{\circ}$ F). The 290° F- 170° F range was selected for the following reasons:

- 1. The total volume of water needed will be reduced by approximately one-half the volume of water of the lower temperature differential. Since water is being returned at a lower temperature (i.e., temperature differential of 120°F), a large quantity of water is not required due to the lower thermal energy content. Essentially, the lower the temperature or thermal energy, the lower the volume of water required. Subsequently, the amount of make-up water will also be reduced. As a result, capital and maintenance costs for water conditioning systems, including chemicals and filters may also be reduced.
- 2. Large pumps and pumping systems will not be required due to the lower water volume. Thus, pumping costs will be reduced.
- 3. Pipe diameters and accompanying insulation will be reduced. Thus, lower piping costs.
- 4. An overall increase in power plant performance will be realized because power will be produced at a lower back-pressure. Steam at a higher back-pressure will be required to heat 230°F water to 290°F.

5. There is no substantial difference in cost when using a heat exchanger designed for a temperature range of 290°-170°F as compared to a heat exchanger designed for 290°-230°F. This latter temperature range was considered because it is commonly used in medium hot water pressure systems.

As discussed in Task 3.1, water was considered the best medium for distribution of heat to the community. Water as a medium for use in district heating systems has been used for many years in Europe. High thermal capacity, widespread availability, low price and its non-polluting characteristics are a few of the reasons for its selection and widespread use.

The steam extracted from the power plant will be passed through a district water heat exchanger similar in characteristics to a feedwater heater. A common design for the plant heat exchanger utilizes stainless steel tubes inside a carbon steel shell. Several exchangers can be used for producing district heating water. Heat exchanger shape is also an important economic consideration to assure the highest possible efficiency and overall fitup in the available spore in the system. These exchangers can range in size up to 6 feet in diameter and 50 feet long.

The heated water is then piped to a substation/heat exchanger producing the hot water for the consumer. Two of the most common types of heat exchangers for this application at the consumer end are the multi-stream plate-fin and shell-and-tube exchangers.

Plate-fin heat exchangers are commonly used by European countries in district heating systems. They are commonly used in hotels, hospitals, schools, sports facilities and commercial and industrial establishments. They are compact providing large heat transfer surfaces per unit volume, are relatively light in weight and are quite dependable for continuous operation. They play a key role in the production of cryogenic temperatures in the gas producing and petrochemical industries. A plate heat exchanger is very suitable for heating and district cooling applications because of the following features:

- 1. Maintenance is very easy to perform.
- 2. The patterns of the plates and the high induced turbulence prevents fouling or clogging.
- 3. Requires less space then shell-and-tube heat exchangers.
- 4. No interleakage and less weight.

Shell-and-tube heat exchangers are also commonly used. The European design utilizes finned tubes, spun in a spiral into a heat exchanger coil, to ensure the highest possible heat transfer capacity in a minimum of space and at the lowest possible cost. The coils are made entirely of copper, whereas the shell is made of steel. The design permits high working pressure, especially on the tube side. This type of exchanger is also quite insensitive to fouling. The tubes are periodically cleaned using suitable chemicals injected through special connections.

Many variables must be given proper consideration to select and correctly proportion a heat exchanger to assure meeting the efficiency and cost requirements for specific district installations. In view of the above, both types of heat exchangers appear adequate for transferring heat from water to district heating water (at the consumer end) at a temperature range of 290° - 170° F. Ultimately, the type, size and number of heat exchangers used at the consumer end depends on the location, load demand and specific applications involved.

APPENDIX H

Consideration and Selection of Storage Possibilities

A. General

Thermal storage can be an effective energy conservation tool capable of minimizing the cost of energy in several important ways. When applied to buildings with significant interior heat gain, thermal storage can save fuel and reduce electric cooling demand and electric utility investment.

Storage sites may be located wherever space is available and where existing structure and flooring is adequate to withstand the weight of water. Otherwise, such structures must be strengthened or new ones built. The most cost effective location is on top of large buildings, since the cost of pumping energy is eliminated. However, initial capital investment may be higher if the structure has to be modified. Another possibility is to interconnect the storage and cooling/heating system to normalize peak demands. This is expensive, both in terms of hardware and the loss in cooling storage temperature range. As the range is narrowed (i.e., 41F to 50F), there must be correspondingly more storage volume to produce the equivalent effect. Another solution, if open storage is not topside or connected with the cooling/ heating system, is to use transfer pumps. These may be the only pumps for the building water circuits, or they may merely inject water into closed pump loops. Separate transfer pumps will be needed for both hot and cold "legs" of storage.

Several considerations are associated with thermal storage. With open storage, enough surface is presented to the atmosphere to require increased chemical concentration for corrosion control. Another consideration is bulk; the high volume of water storage requires large floor areas. There is also the serious problem of temperature blending. Care is needed to design the storage tank with the proper valves and gates.

B. Hot Water Storage

Storage tanks are generally recommended for storage of hot water. This water can be stored in separate individual tanks for supply to the system. The capacity and number of the tanks shall be determined as required such as for peak load demand and/or standby capacity. To meet this demand without storage, a turbogenerator has to supply more steam, thus sacrificing electricity generation. Hot water storage can be advantageous to supply this kind of demand. As the hot water is removed from the storage tanks, the cold makeup water could be heated to replace and maintain the hot water tanks at full capacity. A schematic diagram is shown in Figure 1.

C. Chilled Water Storage

Similar to hot water, storage can also be used in the case of chilled water. The storage capacity can be used as standby in case of shutdown of any of the chillers. The capacity and number of tanks shall depend on the peak load demand and standby arrangement.

The peak load demand in the installed air conditioning system occurs during the hottest month. Part of this peak load or the full amount of this excess power demand can be offset by storage tanks instead of increasing chilling equipment capacity. Even for base load conditions, some of the storage tanks can be used to cut the power demand in chillers.

Cooling is an intermittent process on most commercial and institutional buildings. Demand can vary from zero to a small amount at night during periods of occupancy. The storage system, installed for recycling waste heat in the winter, can cerve to supply chilled water in the summer. Many chillers operate only 10 hours a day, averaging less than 80 percent load, even during peak days. With storage, the same load can be furnished in a 24-hour run-cycle with a chiller of one-third the size and electric demand. The reduction of demand by two-thirds can reduce overall electric cost by more than half.

Buildings today use both hot and chilled water storage; with cool morning starts, up to 15 percent of a typical chiller demand may be cut. With a water reservoir, greater savings can be made without any change in space temperature. For greatest peak cut, storage should be sized to handle the entire occupied load and the chiller sized to regenerate storage at night to meet the daytime electric demand. For the lowest first cost, the chiller should be sized to process the maximum daily cooling requirement or continuous full load operation. The storage is smaller too, because it gets help from the chiller all day long. The ideal size for chiller and storage may fall between these parameters for lowest owning cost. The best storage economics will result when the storage is used seasonally for both heating and cooling.

A schematic diagram of a chilled water storage system is shown in Figure 2.

D. Alternatives

A large fraction of the world's land area, is underlain by aquifers, which are layers of sand, gravel, or porous rock saturated with ground water. There are sedimentary layers in which the water flows readily (sand and gravel), and layers in which flow is difficult (clay and shale). Often these alternate so that a permeable layer confined above and below by impermeable layers is isolated from other aquifers. For storage purposes, a deep confined aquifer (say 500-1500 ft) is preferred: first, because the water is under sufficient pressure to prevent injected hot temperature water from flashing to steam; and second, because this water may be brackish or slightly saline and not useful for urban or irrigation purposes. This alternative has been identified as a potentially and economically viable hot and cold storage system on the basis of computor modelling studies and prototype systems are presently being tested. It is a possible alternative for water storage.

We cannot immediately utilize the waste heat and waste cold that is available. Typically in winter there is an excess of waste cold and in summer there is an excess of waste heat. If suitable aquifers are available, we simply inject the excess cold water produced in winter into the ground so that it will be available the following summer for cooling. In summer, the situation is just the reverse. We draw down our store of cold water and build up the store of hot water. Figure 3 shows a schematic of typical aquifer flow patterns for summer and winter.

E. Estimated Storage Tank Sizes

Preliminary calculations were performed to estimate the storage tank size required for meeting the anticipated peak hot/chilled water demands for both 4, 8 and 12 hour periods. Assuming a peak heating load of $740. \times 10^6$ Btu/Hr and a temperature difference of 120° F, the estimated hot water storage tanks required would be as follows:

```
4 hours - Height: 40 feet; Diameter: 115 feet
8 hours - Height: 40 feet; Diameter: 160 feet
12 hours - Height: 40 feet; Diameter: 222 feet
```

The hot water is strictly for heating and domestic hot water use and not for use in absorption refrigeration.

For chilled water storage the estimated tank sizes are as follows:

1. Assuming a maximum load of 130. \times 10⁶ Btu/Hr and 20^oF temperature difference (about 20% of assumed peak heating load):

```
4 hours - Height: 40 feet; Diameter: 116 feet
8 hours - Height: 40 feet; Diameter: 163 feet
12 hours - Height: 40 feet; Diameter: 228 feet
```

2. Assuming a minimum load of 1.26 x 10⁶ Btu/Hr and 20^oF temperature difference (about 1.0% of assumed maximum chilled water load):

```
4 hours - Height: 40 feet; Diameter: 12 feet
8 hours - Height: 40 feet; Diameter: 16 feet
12 hours - Height: 40 feet; Diameter: 23 feet
```

The tank sizes for minimum chill load is shown to allow for comparison of tank sizes for maximum load and are not representative of actual dimension.

From the above figures it can be concluded that tank sizes for hot and chilled water storage for meeting district peak load demands are identical in size based on the loads and temperature differences described. Although the peak cooling load is much lower than the peak heating load, the lower temperature difference for cooling results in insignificant difference in tank sizes. However, for minimum cooling demands, storage tank sizes are significant smaller for 4, 8 and 12 hour supply conditions. Such tanks can be utilized in supplying chilled water for small load and/or isolated areas or as the application demands.

F. Summary

There are primarily three reasons for considering hot/cold (chilled) water storage at the plant or at a substation:

- To reduce capacity of water chilling/heating equipment to be installed;
- b. To reduce the electrical energy cost by reducing the demand for power;
- c. To provide stand-by chilled/hot water capacity without installing additional primary equipment.

Much has been written concerning thermal storage. Hot/chilled water systems have been designed and redesigned. Much of the required technology is not new and is readily available.

G. Conclusions

Based on the estimated tank sizes shown above, it appears that hot/chilled water storage may not be feasible as a means of reducing both initial capital costs and operating existing installations. A more detailed study of water storage systems will be conducted in Phase II of the district heating program.

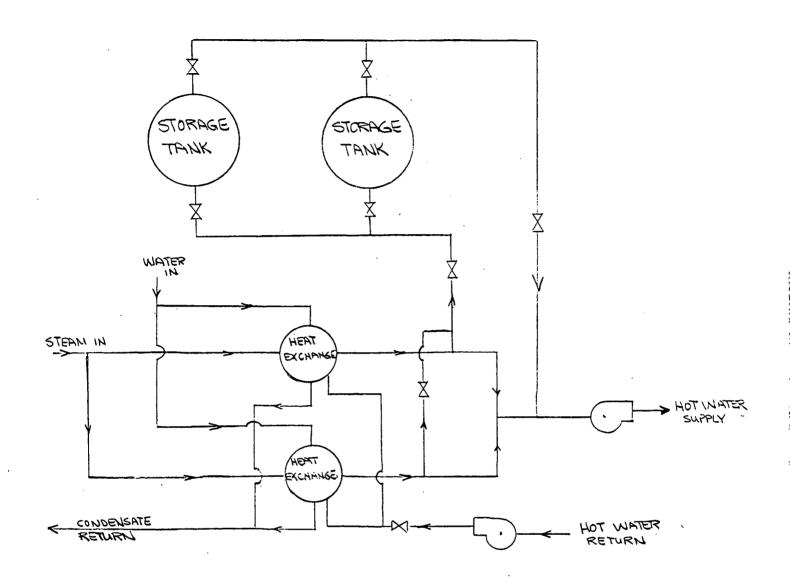


FIGURE 1

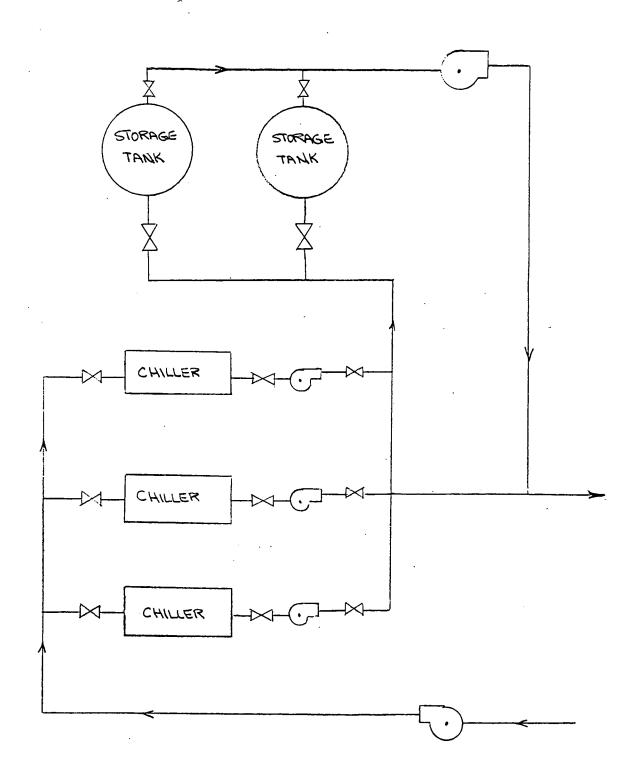
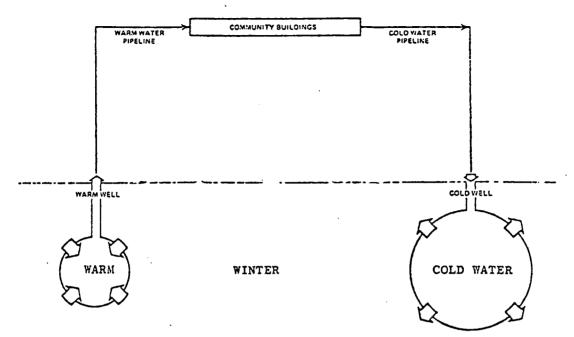
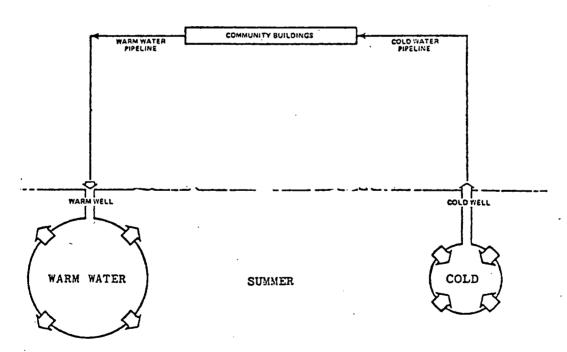


FIGURE 2



Aquifer Flow Pattern in Winter



Aquifer Flow Pattern in Summer.

FIGURE 3

APPENDIX I

DEVELOPMENTS OF DISTRICT HEATING SYSTEMS

The following existing systems have been considered:

- 1. Consolidated Edison System New York City
- 2. Boston Edison Steam System
- 3. Philadelphia Steam Heating System
- 4. Minneapolis/St. Paul Area District Heating
- 5. Swedish District Heating System
- 6. Soviet Union

1. CONSOLIDATED EDISON STEAM SYSTEM

Historical Background

The first attempt to supply steam to a community from a central steam station was by a man named Birdsill Holly at Lockport, New York in 1879. He placed a boiler in his house at Lockport and from it he ran a $1\frac{1}{2}$ inch pipe around his back yard, across adjoining property to a nearby house and then back into his own house. A direct quote from a book titled "Fifty Years of New York Steam Service" in Con Ed's library reads as follows: "The pipe was insulated with asbestos, felt and paper, encased in long wooden boxes measuring ten inches by 12 inches filled with sawdust and buried to a depth of about three feet. When the steam was turned on, the contrivance worked." With this initial success behind him Mr. Holly went on to form the Holly Steam Company. A man named Wallace C. Andrews, an associate of John D. Rockefeller in the original Standard Oil Company, became so interested in central station steam heating that he sent an eminent engineer to study Mr. Holly's work. Other prominent people of the time also became interested in district heating and there were several attempts at forming steam distribution companies in New York City. Mr. Andrews managed to consolidate the other efforts with his own so that in September 1881 the New York Steam Company was incorporated. New York Steam promptly started laying steam mains in the streets of lower Manhattan and built its first steam sendout station at Greenwich and Cortlandt Streets (today's part of the site of the World Trade Center). In March of 1882 the steam company started suppling steam to its first customers. This steam was used for heating, motive power for elevators, printing presses and electric generators. After World War I, the New York Steam Company ran into financial difficulties. After a refinancing

operation the company was reformed in 1921 as the New York Steam Corporation. In 1931, 74% of the New York Steam Corporation was acquired by the Consolidated Gas Company of New York. Consolidated Gas, the New York Edison Company and several other electric and gas utilities of New York were subsequently combined to form the Consolidated Edison Company of New York, (Con Ed).

General Design

There are special construction items required in the case of a steam pipe line that are not ordinarily provided for in water or gas pipe line construction. For example:

- 1. Provisions for pipe expansion
- 2. Intermediate anchors
- 3. Thrust anchors
- 4. Valve and drain manholes
- 5. Insulating coating to minimize heat losses.
- 6. Mechanical Protection (housing or enclosing structure)

The present steam carrier pipe design consists of all welded construction as per ANSI B31.1.0 design criteria. Most of the distribution system is designed for 200 psig steam at 400°F. There are, however, three transmission mains which were designed for 400 psig steam at 500°F. The evolution of steam main design over the past fifty years have left few components of the system unchanged. The system being installed today is essentially a pre-fabricated installation of welded steel pipe, fittings, and valves. The pre-fabricated unit consists of the pressure pipe, thermal insulation, pipe supports, and the steel conduit. Experience in Con Ed has established 40 feet as the longest single length that can be lowered in the trench.

Steam System Characteristics

Con Ed steam is not only used for heating and hot water, but also for air conditioning. The summer and winter peak of these buildings are nearly the same. However, the steam system load peaks are in the winter. The peak hour load of 12,570,000 lbs/hr occurred on February 2, 1971. On the other hand, the large commercial buildings that provide air conditioning may have a greater summer demand than a winter demand. Steam is supplied at an average pressure in excess of 125 psig. When services are supplied from the 400 psig transmission mains, a pressure reducing valve station is used. There are 2,500 plus steam customers connected to the distribution mains by 20 miles of service pipes varying in sizes from 1" to 20" in diameter.

Production of Steam

In 1971 Con Ed sold 42 billion pounds of steam to its customers. The steam is produced in three types of generating plants:

1. Steam Plants
The existing steam plants specifically designed to generate steam for
the steam system and their rated capacities for sustained operation are:

Kips Bay	-,,	
Ravenswood	940 M	lbs/hr
60th Street	600 M	lbs/hr
Woolworth	120 M	lbs/hr
East 59th Street	1,210 M	lbs/hr
East River	850 M	lbs/hr
TOTAL	5,470 M	lbs/hr

2. Electric Generating Stations

Steam is used as a sub-product of the electric generation. There are times, however, when this capacity is limited because of summer overloads on the electric system.

The following generating stations deliver steam to the mains in the quantities shown:

East River	2,475 M	lbs/hr
Hudson Avenue	2,000 M	lbs/hr
Waterside	3,000 M	lbs/hr
59th Street	500 M	lbs/hr
74th Street	900 M	lbs/hr
TOTAL	8,875 M	lbs/hr

3. Leased Boiler Plants

These plants are located in buildings that once generated their steam. These leased plants supply the building and the steam distribution system. Con Ed presently leases 25 plants which have a total capacity of 633 M lbs/hr.

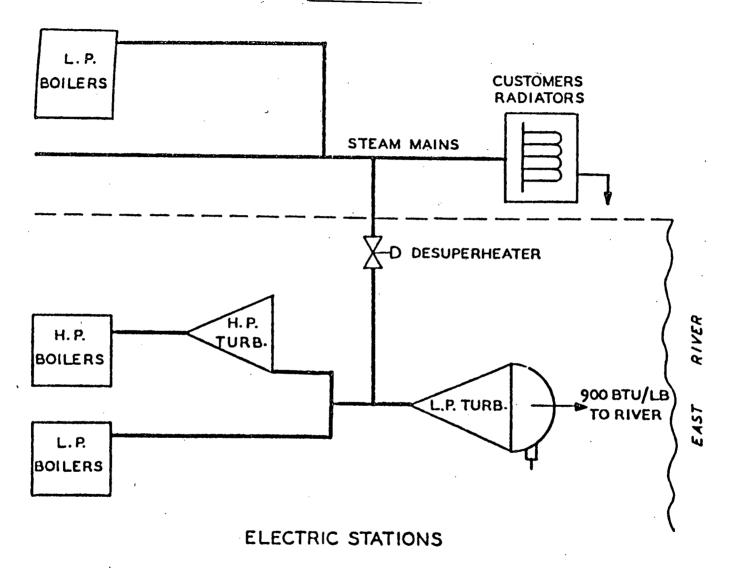
The steam sendout is regulated from the various generating stations to maintain the required pressures at the points of lowest pressure. The total operation of the steam system is controlled by the steam dispatcher. The dispatcher varies the load allocation at the stations in accordance with pressure conditions on the system and he will direct the individual station operation to increase or decrease the pressure at their individual controls as required by system conditions. The maximum allowable sendout pressures and sendout capabilities of the steam generating stations are tabulated as follows, where the maximum sendout from a station must be quoted along with its pressure capability:

•	Max - Press	Max Sendout
	(PSI)	M lbs/hr
Station	Uptown	
Waterside	200	3,000
Kips Bay - Ave. C Line	200	.1,750
- "N" & "S" Lines	200	
59th Street	200	1,710
60th Street	200	600
East River - 14 th St. Line	200	1,400
- 15th St. Line	200	925
74th Street	2 00 ¢	900
Ravenswood	. 300	940

	Max - Press (PSI)	Max Sendout M_lbs/hr
Station	Downtown	
Hudson Avenue	400	- 2,000
East River	375	1,000
Woolworth	165	120
		14,345

The following pages illustrate the Con Ed Steam Grid Distribution System:

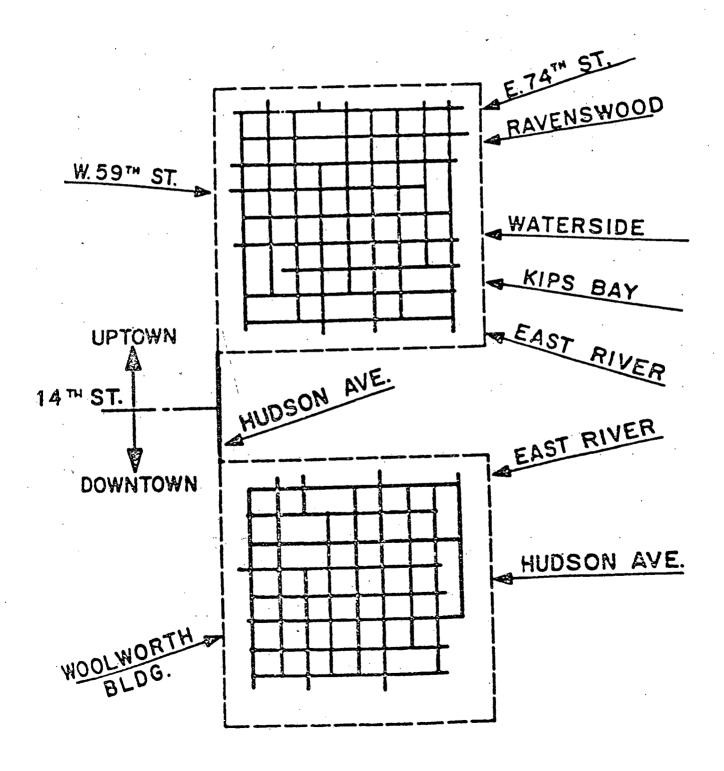
STEAM PLANTS



CONSOLIDATED EDISON CO. INC.

Figure 10

STEAM SOURCES FOR THE STEAM
DISTRIBUTION SYSTEM



2. BOSTON STEAM SYSTEM

The area supplied with steam by the Boston Edison Company is, in general, the downtown business district of Boston. The 1976 statistics by the International District Heating Association cites 6,939 M lb of steam delivered to 26 miles of mains to serve 512 customers at a maximum plant sendout pressure of 300 psi, and an average service pressure of 125 psi. The estimated winter peak load is about 2,000,000 lbs of steam per hour.

The system is supplied principally from four power plants:

- 1. Plant located at Elk St. Old plant with three boilers and a steam turbine.
- 2. Plant located at Kneeland St. Four boilers with no steam turbine.
- Plant located at Minot St. Two boilers.
- 4. Scotia Plant Three boilers.

There are also some relatively small basement plants which are under lease. The customers supplied include all types of buildings, such as department stores, hotels, clubs, loft buildings, churches, schools, and apartment houses. Among the better known buildings supplied are the Boston and Maine Railroad Terminal and its associated buildings; the Manger Hotel, the Parker House, the Christian Science Church, the Publishing House, the Original Mother Church, and the Massachusetts State House.

The largest customer served, in annual sales uses approximately 200,000,000 lbs plus, the smallest about 50,000 to 60,000 lbs per year. Steam is employed for industrial purposes such as the manufacture of clothing, hats, and process steam is used in many buildings for restaurant needs. There are no unusual industrial uses. Also, no exhaust steam is used in the district heating system. As of 1976 statistics, the boiler capacity was adequate for new customers, however, the distribution system may not be.

3. PHILADELPHIA STEAM HEATING SYSTEM

The Philadelphia Electric Company operates a district steam system in the central and downtown area of Philadelphia. There are 673 steam customers with a total annual steam consumption of 7.6 billion pounds fed from 35.7 miles of steam mains with an approximate annual revenue of 45 million dollars. The peak steam demand registered on January 22, 1977 totaled 2,796,000 lbs/hr.

The steam is supplied from three locations: (1) Willow Steam Plant which supplies steam at 175 psi; (2) Edison Steam Plant, also at 175 psi; and (3) Steam is also supplied from a topping turbine at the Schuylkill Electric Generating Station. The pressure from this unit is 225 psi. There are approximately twenty-eight steam pressure regulating stations located at various points on the steam system which calculate steam pressure for billing purposes based on 140 psi.

The customers supplied are largely commercial, although there are some industrial and a number of loft buildings and restaurants. The commercial buildings include department stores, specialty shops, banks, and office buildings. Uses, other than space heating and hot water, include cooking, dry cleaning and laundry, as well as a number of miscellaneous processes. Among the customers are John Wanamaker and Gimbel Brothers Department Stores, the Jefferson Medical College and Hospital, the Federal Reserve Bank, the United States Mint and the Philadelphia Inquirer Newspaper plant.

The largest customer uses a maximum of 31,000 lbs/nr plus with an annual consumption of 113,000 M lbs versus the smallest with an annual consumption of 120 M lbs of steam. The boiler capacity as well as the distribution system have the capability to service new customers.

The following pages illustrate the development of the steam system in I-10

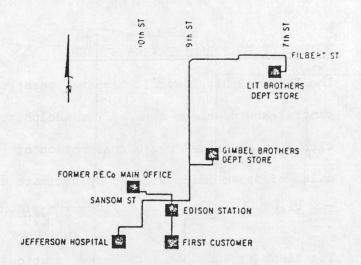


Fig. 2 - Steam distribution system in 1921.

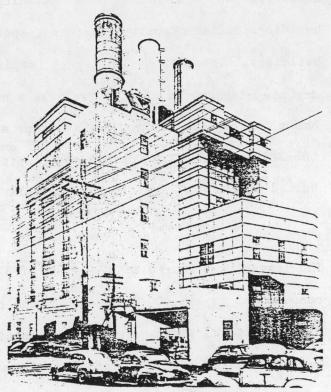


Fig. 3 - Willow steam plant.

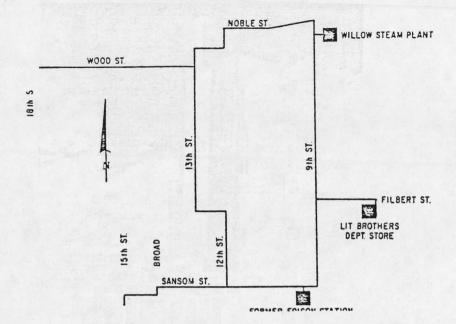
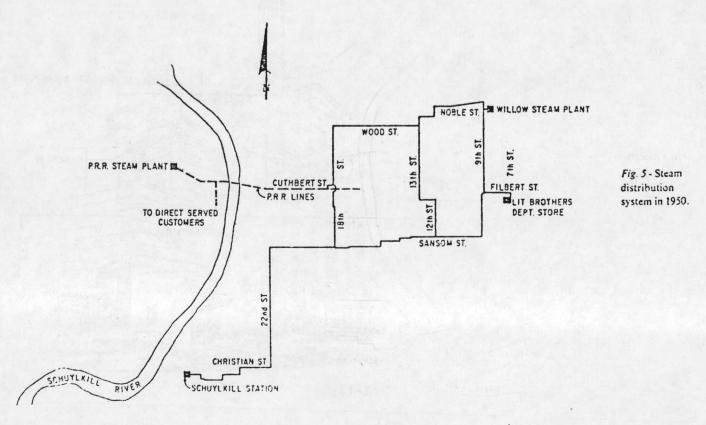


Fig. 4 - Steam distribution system in 1932.



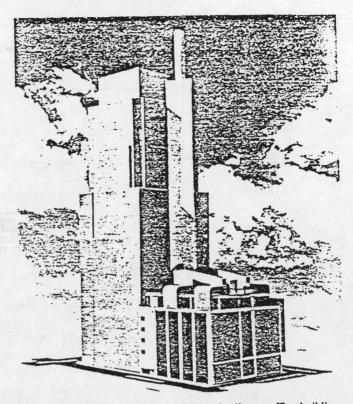
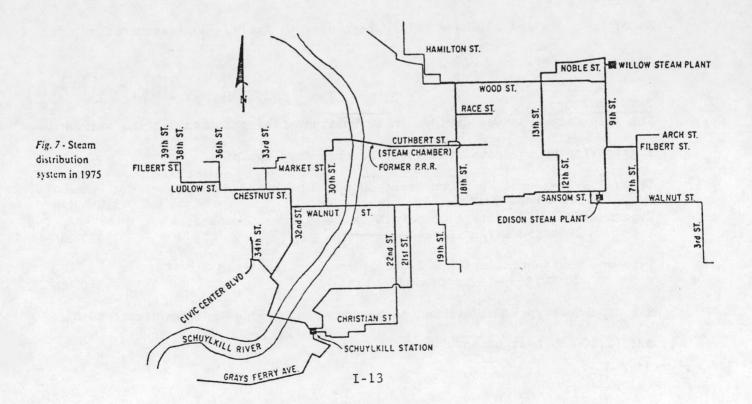


Fig. 6 - Model of Edison steam plant and adjacent office building.



4. MINNEAPOLIS/ST. PAUL AREA DISTRICT HEATING

History

In 1975 the Swedish Consultants StudsVik, in conjunction with the Oak Ridge Laboratory were awarded a proposal for studying the applicability of district heating in a suitable metropolitan area. The Twin City area, Minneapolis/St. Paul was selected as the subject for the study.

The Twin City area is mainly formed of two concentrated downtown areas in Minneapolis and St. Paul spaced about 7 miles from one another. Around the same there is a region of mostly industrial sites and residential dwellings. There is a population of around 800,000 people in the two city boundaries raising to 1,000,000 when the suburbs are taken in consideration.

The heating demand at present is mostly provided with natural gas. Large customers switch to oil in the winter. Steam from two old boilers is used for heating in downtown St. Paul and a new small boiler provides steam for heating in the Minnesota University.

As of now, gas and oil have mainly been used as fuels. No co-generation was used so far.

Swedish Proposal

The Twin City area was divided in 40 subareas taking in account the surroundings. Five homogeneous areas were further developed:

Types 1 & 2 - Dense downtown areas 50 to 70 MW/Km²
Heat Demand

Type 3 - Medium density - Commercial and Apartment house area
20 to 50 MW/Km²_Heat Demand

1,417 MW

Type 4 - Residential Areas - 2 family houses, less than
20 MW/Km² - Heat Demand 540 MW

83% of above types was assumed to be connected giving an approximate total of: 2,600 MW heat demand.

Type 5 - Less dense residential area (1 family house)
10 to 20 MW/Km² - Heat Demand
It was assumed 70% connected giving a total of 1,400 MW heat demand.

2,000 MW

The final total connected maximum Heat Demand

4,000 MW+

A) Metropolitan Area

- i) Cogeneration was proposed for most modern turbines. To achieve this it is suggested to connect a steam pipe to the crossover pipe between the intermediate and low pressure cylinders. Regulating valves are also suggested. Temperatures of a least 295°F (146°C) can be obtained.
- ii) Backpressure turbines connected in series with the larger units on the water side, in order to achieve a two stage heating process. After conversion the water can be heated up to 190°F (88°C) with a return temperature of 140°F (60°C).
- B) Outside of Metropolitan Area
 Required a more substantial addition of new cogeneration capacity.

 It is assumed that this will be accomplished with plants built at some
 distance from the load, which will incur in additional heat transport
 capacity costs. To obtain units of economic size, it was assumed
 that only half of the turbine steam should be used at a maximum heating load
 demand. On the other hand, in the event of a pipeline breakdown at a time
 of a heating peak demand, a reduction of supply loads are acceptable when
 it is considered that a main can usually be repaired in one day. Nevertheless,
 the installation of these plants is to be delayed as long as possible to
 study the feasibility of this arrangement further.

Present and Future District Heating

The present district heating system covers part of the densest area with a heat load of 60 MW supplied by two parallel steam systems for 75 psig and 8 psig respectively fed from an old boiler. The Swedish proposal provides for a hot water two pipe system (out & return), providing service for the sections not yet supplied by the existing steam systems and gradually taking over on the sections supplied now by District Heating steam. Buildings will gradually be converted to hot water systems and the steam pipe systems would be shut down.

The heating demands were estimated as follows:

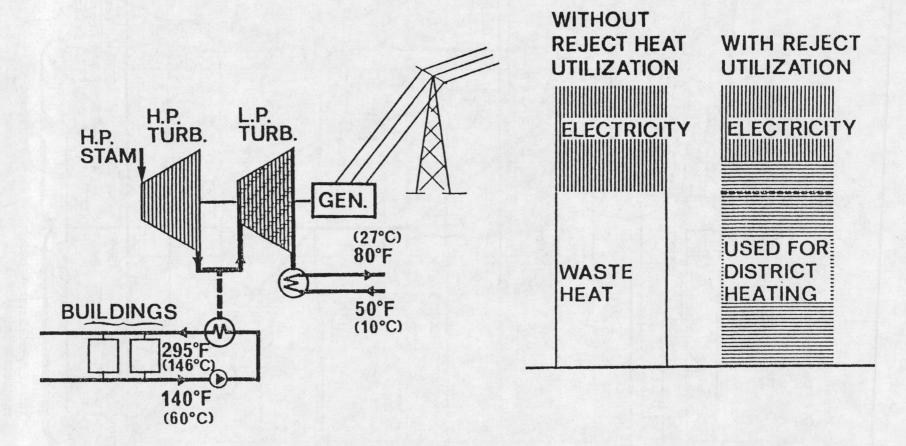
- 1) 25% of buildings built prior to 1960 use steam.
- 2) 25% of buildings built from 1960 to 1970 use a combination of hot water system and electric window units for heating.
- 3) 50% of buildings built from 1970 up will be using a hot water system throughout.

Costs
The conversion of turbines was estimated to cost less than installing new heating capacity boilers. Swedish estimates were used and varied as:

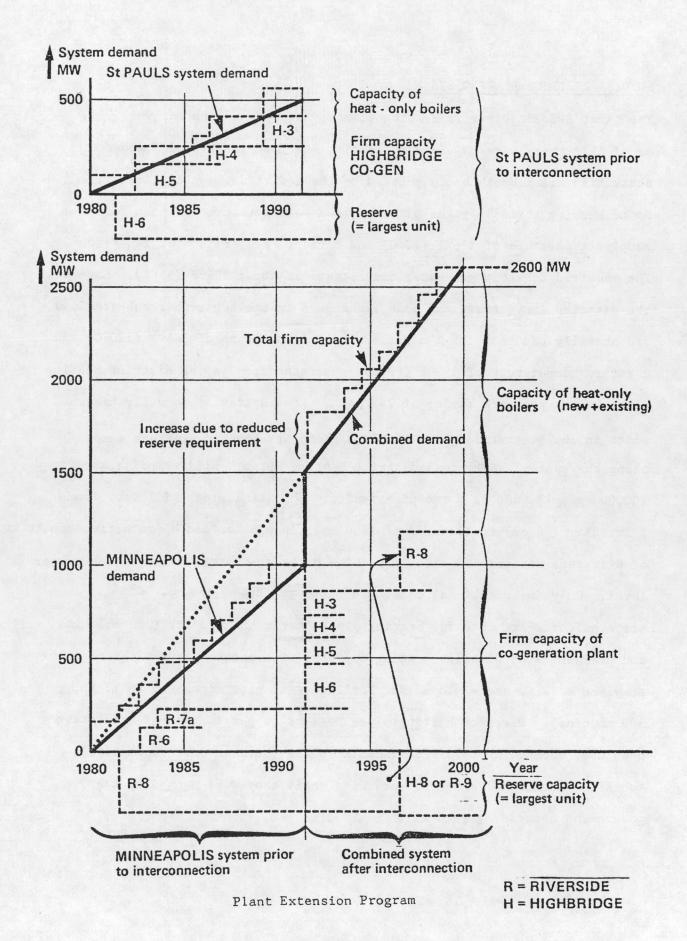
\$20/Kw, \$81/Kw, \$103/Kw of district heating output depending on the work required to complete the conversion.

The following pages illustrate the proposed Minneapolis/St. Paul District Heating System.





Influence of turbine conversion on heat utilization



5. SWEDISH DISTRICT HEATING SYSTEM

The first Swedish District Heating plants date back to the early 1950's. As of 1977 there were 55 district heating stations in operation whose activities are independently pursued by the individual municipalities. Space heating normally takes place by means of radiators designed for a supply temperature of 176°F (80°C) and a return temperature of 140°F (60°C). The required domestic hot water temperature is about 131°F (55°C). However, the distribution network and heat exchangers in the subscriber sub-stations are normally designed for a maximum supply temperature of 248°F (120°C) and a return temperature of 158°F (70°C). The standard Swedish district heating pipes have a pressure rating of 247 psig. Pressurization normally takes place in the generation plant although there are booster pressure pumps along the system. A typical district heating network will comprise about 100,000 people, and is a two-pipe design. The steel pipes will vary from 1 in. dia. (20 mm) to 32 in. dia. (800 mm), insulation and a protective sheath of different designs and materials. The pipes are normally laid below street level. Only in exceptional cases are pipes run above ground. Concrete culverts are used for heating pipes larger than 12 in. (300 mm) dia., and prefabricated district heating culverts with protective sheaths of polyethylene and PVC are employed for smaller steel pipe sizes (up to 12 in., 300 mm dia.). District heating pipes made of copper instead of steel have been used during the 1970's for smaller sizes (below 3 in., 70 mm dia.). Asbestos cement pipe culverts were used until they were banned by the government because of the health risks involved.

In Sweden as in other northern countries, combined heat and power (CHP) is the main way the heat is being produced. In 1971, the total amount of heat delivered by Swedish district heating companies was 12.4 TWh ⁽¹⁾ and the electricity produced by turbines of the Swedish district heating networks amounted to 2.6 TWh.

Today there are no district heating systems in the world using nuclear heat sources, although a small unit (Agesta) operated with district heat output for about ten years in Sweden. Nevertheless, Sweden was a pioneer in the use of nuclear power for district heating purposes. Farsta was the first town ever heated in this way, and the system worked well for about 16 years. It was scrapped, finally, because it could not compete with the prevailing lower oil prices. Although there is at present the same kind of opposition to the development of nuclear power in Sweden as is found in Great Britain, France, Germany, and the United States, it is forecasted by the Swedish Authorities that by 1990, some 60% of district heat in Sweden will be provided by turbines driven by nuclear power. Already several schemes of this type are either in construction or at the final design stage. A nuclear CHP station of 2000 MW at Haninge will supply heat to the Stockholm suburban area, and the 950 MW CHP nuclear station at Barseback will supply heat and electricity to the two cities of Lund and Malmo.

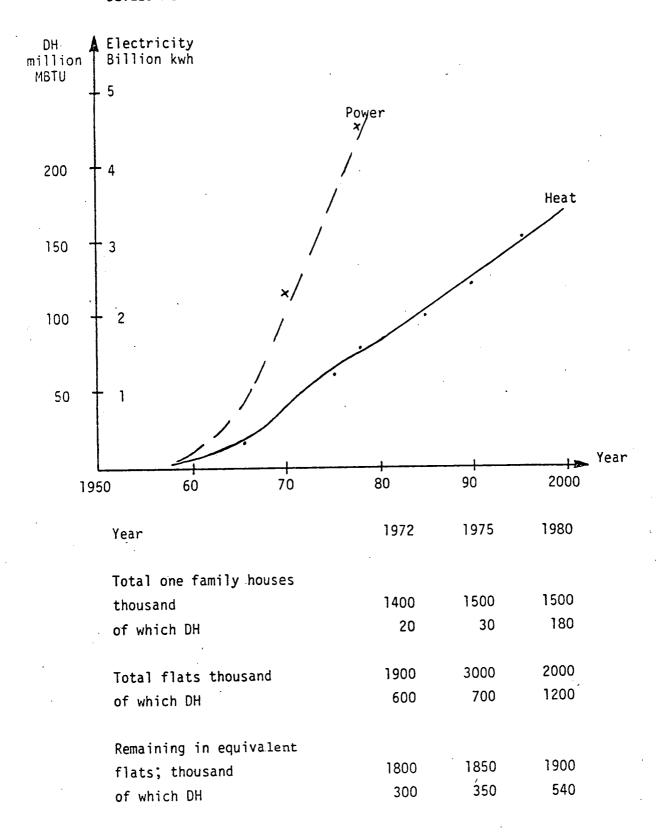
Both are confidently expected to be operational by 1986. Another nuclear CHP station of 800 MW is projected for the Gothenburg area.

It seems clear that the trend in Sweden is to utilize nuclear power as heat source.

The following pages illustrate the development of district heating in Sweden:

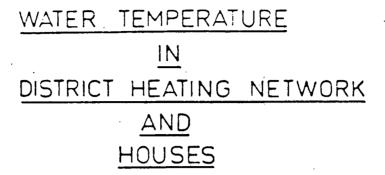
^{(1) 1} TWH = 10^{12} Watthours

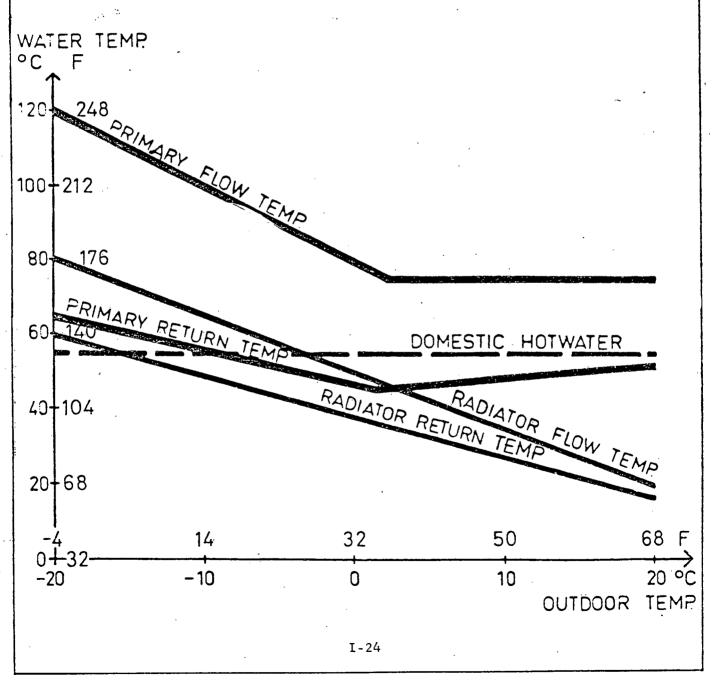
DEVELOPMENT OF DISTRICT HEATING IN SWEDEN

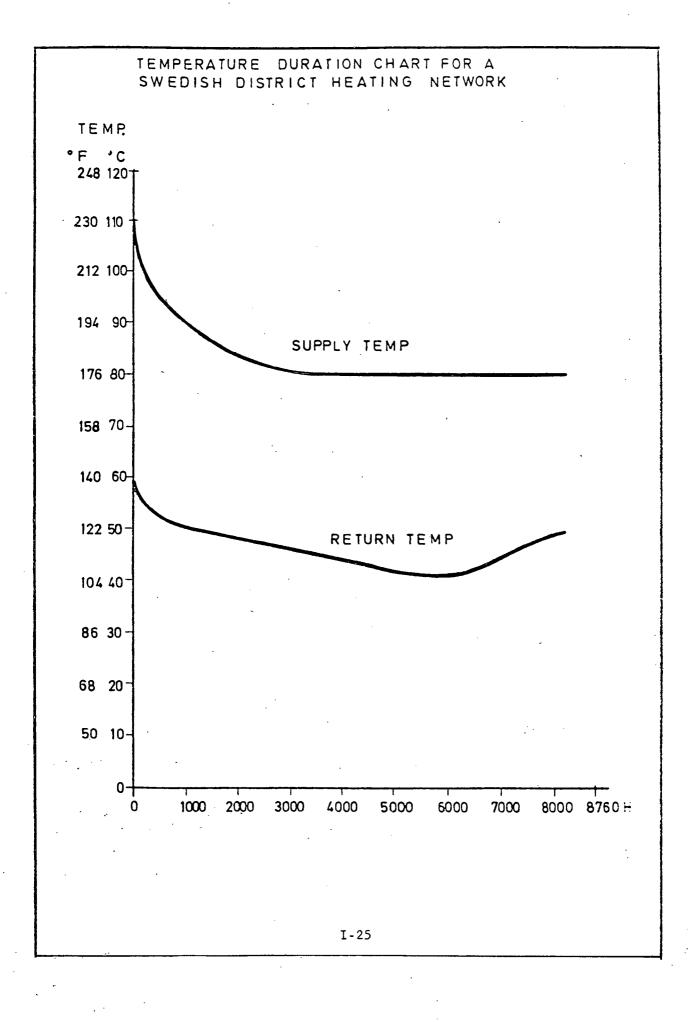


-SPECIFIC HEAT AND ENERGY NUMBERS OF DIFFERENT TYPE OF SWEDISH BUILDINGS

Туре	Heat	Energy	Duration	
	w/m ² Btu/h ·sq ft	kwh/m² an Btu ·10³/sq ftyr	hr/day	hr/yr
Office	120 38	180 57	15	1500
Stores	120 38	180 57	15	1500
Apartments Old	80 25	240 76	21	3000
New	67 · 21	200 63	21	3000
Houses	83 26	2 00 63	18	2400
Hospital	70 22	210 66	21	3000
School	82 26	180 57	18	2200
Industry	167 53	250 79	15	1500

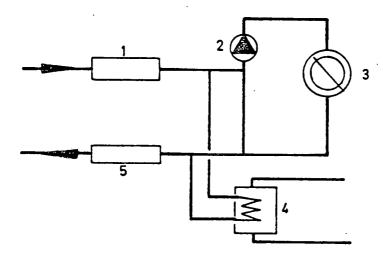






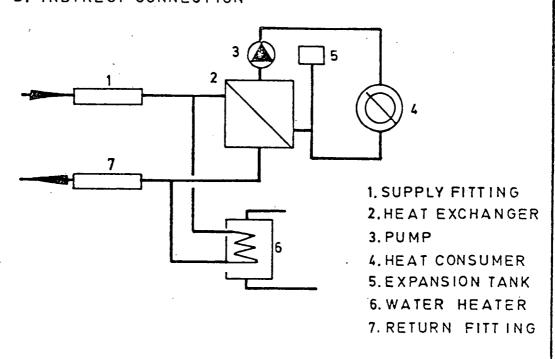
CONNECTION OF SUBSCRIBER INSTALLATIONS TO THE DISTRICT HEATING NETWORK

A. DIRECT CONNECTION



- 1. SUPPLY FITTING
- 2. PUMP
- 3. HEAT CONSUMER
- 4. WATER HEATER
- 5. RETURN FITTING

B. INDIRECT CONNECTION



PRINCIPLE OF THE INSTALLATION IN A SINGLE FAMILY HOUSE DELIVERY BOUNDARY FOR THE DOMESTIC UNIT DELIVERY BOUNDARY FOR THE SUPPLIER

6. SOVIET UNION

The State-Union Institute for the Design and Planning of Industrial Heating and Power Plants (Promeneryoproekt) has carried out a series of interrelated investigations aimed at increasing the efficiency of the chief sources and systems of heat in the immediate future. A general scheme for the development of a centralized district heating for towns in the next 15/20 years has been developed. At present, about 75% of heat consumption in the USSR is covered by centralized heat supply. The rate of development of district heating in the USSR in the past five year period has considerably increased. For instance, by the beginning of 1974 the installed capacity of cogeneration plants (heat and power stations) reached 53 x 10^5 KW and the annual delivery of heat was 3.5×10^{15} Btu (850×10^6 Gcal).

Heat Utilization

The following comments relate solely to the facilities providing hot water space heating and domestic hot water.

Virtually all buildings constructed since World War II are assemblies of factory prefabricated sections and components. Those currently under construction are being equipped with kitchen and bathroom facilities prefabricated as a unitary package.

Apartment construction (page 31) is somewhat modular in design. Four apartments on each floor are accessible from a common entrance. Thus, in a five story structure, 20 units would be so accessible. The modules are constructed so that the total number of apartments housed in a contiguous structure ranges from 80 to 160.

A typical apartment unit contains about 450 square feet of floor area.

All construction is geared towards district heating and appears to be designed in a manner to afford the greatest conservation of materials, particularly metals, speed of erection, and functionality. They are devoid of frills. Because they are prefabricated, their erection necessitates a minimum of skilled mechanics in the field. Closet space is limited, incinerators are not provided, and elevators are installed only in buildings that exceed five stories. Concrete is the predominant material used.

The number of consumers (buildings) is measured in tens of thousands. The chief task at present is not to construct new district heating systems but to extend the existing ones. New mains when installed, however, run 32 in. - 48 in. (800-1200 mm) in diameter and carry loads of $2 \times 10^9 - 3 \times 10^9$ Btu/hr (500-800 Cal/hr) and above.

Russians, however, expect possible and significant technical progress in construction of heating networks with replacement of steel pipes by non-corroding pipes made of heat resistant polymer materials. Polypropylene pipes with heat resistance to $300^{\rm O}{\rm F}$ and pressures up to 175 psi are commonly used.

Consequently, the older the networks, the more often is external corrosion the main cause of breakdown. For example, in the Moscow networks external corrosion is the cause of 90% of breakdowns. It seems that since construction of the first heating networks in the nineteen-thirties to the present

time, great use has been made mainly of gland type expansion joints. The only improvement introduced in the pre-war years consisted in replacing cast-iron expansion pieces by expansion pieces made of steel pipes installed by means of welding, i.e., made without the joining flanges. Russians have also encountered disadvantages in the use of gland type expansion joints because of the excessive maintenance required.

In general, district heating is particularly successful in the Soviet Union where it is based on combined heat and power stations (CHP). These CHP stations carry about 57% of the heating load and the largest has an electrical output in excess of 500 MW. The total capacity at the Russian CHP station is around 45,000 MW versus a total installed electric power capacity of 207,000 MW. In the Soviet Union, of course, power production is nationalized. District heating turbines are produced in the Soviet Union in large amounts, ranging in size from 135 MW to 250 MW.

The USSR has the largest systems of centralized heat supply in the world. The radius of the heating networks in these systems often extends to 6-12 miles (10-20 Km) and above. However, the new single pipe systems which are intended to be used with nuclear stations, which have to be built a long way from urban areas, will be perhaps up to 78 miles (125 Km). By 1980 the total connection of district heating will be as follows:

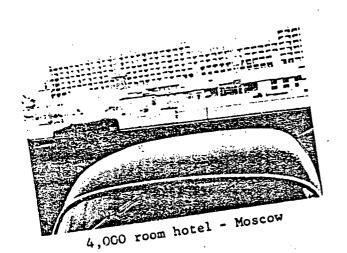
Below 1160 MW Units 668,600 MW

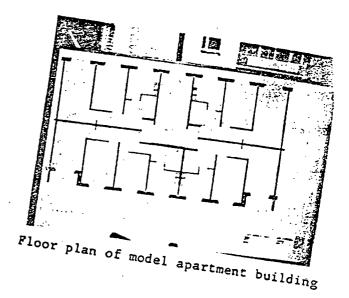
Over 1160 MW Units 576,700 MW

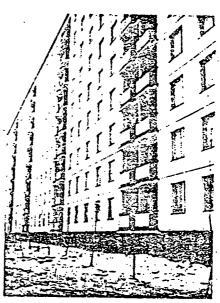
Total 1,245,300 MW

The following pages illustrate typical consumers in the Russian District Heating System.

APARTMENT - DESIGN AND CONSTRUCTION

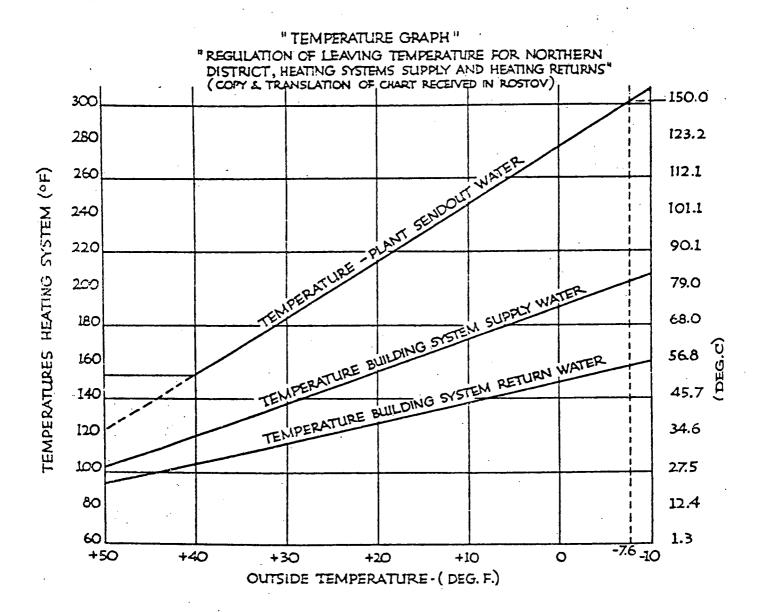




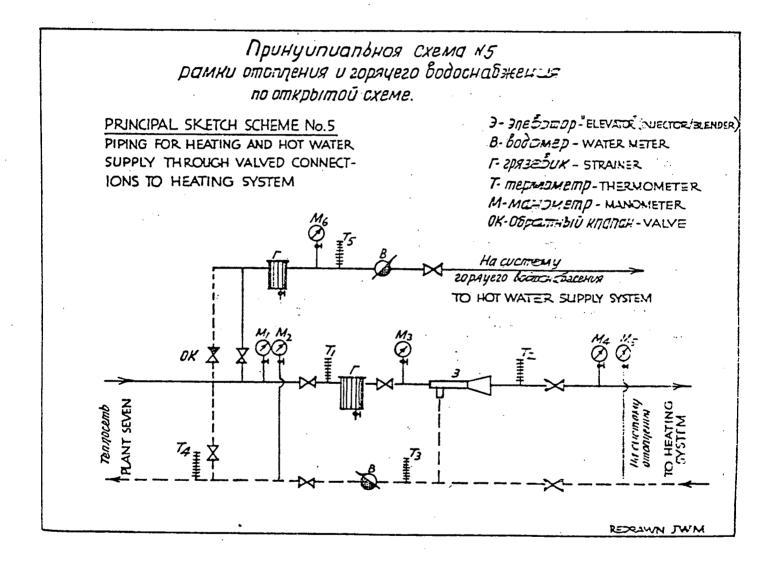


New apartment

TEMPERATURE REGULATION



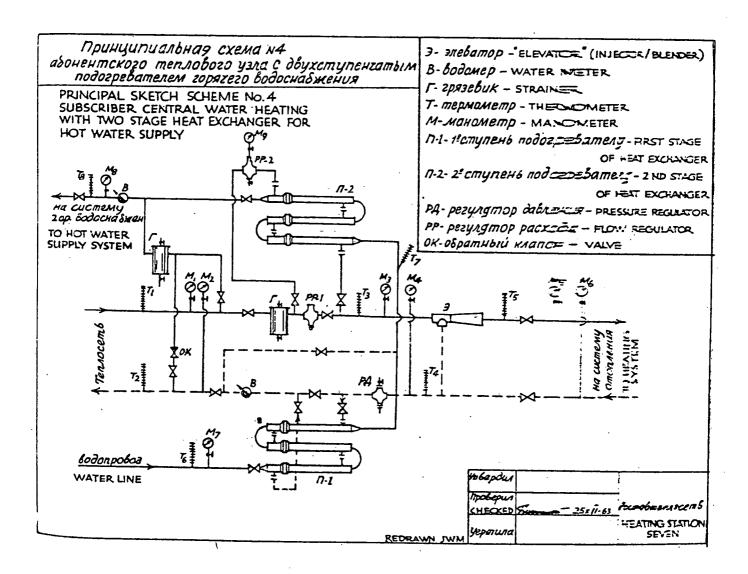
PIPING DIAGRAM



PIPING DIAGRAM

TOUTH SCHEME HELD CONTROL BY MIXING WITH PUMPING B-BODOMEP - WATER METER T- 2p33eBuk - STRAINER T- mephomeme - THERMOMETER M- MAHOMEMP - MANOMETER H- Hacoc - PLAMP OK-Obpamhbit Knanah - Valve

REDRAWN JY



REFERENCES:

- 1. District Heating Handbook, 34th Edition by The National District Association, 1951 Pittsburg, Pennsylvania
- District Heating in the Union of Soviet Socialist Republics -NDHA Report 1964, Pittsburg, Pennsylvania
- 3. R.T. Higgins. Con Edison's Steam Distribution System, February 1971
- 4. N.K. Gromov. Operational Reliability of District Heating Networks and Methods of Increasing It. Teploenergetika, 1975
- 5. A.A. Skvortsov. Main Means of Improving Designs of Heating Networks, Teploenergetika, 1976
- 6. N.K. Gromov. Principles of Arrangements of Heating Networks in Towns, Their Automation and Remote Control. Teploenergetika, 1976
- 7. R.M.E. Diamant. District Heating with Combined Heat and Power Generation. District Heating VOL. 64 Number 1, July-August-September 1978
- 8. C.E. Lind. Setting the Stage, Swedish District Heating Workshop, October 1978, Philadelphia, Pennsylvania
 - E. Wahlman. Energy Conservation Through District Heating A Step by Step Approach. Swedish District Heating Workshop, October 1978, Philadelphia, Pennsylvania
 - L. Lindeberg. District Heating Distribution Systems. Swedish District Heating Workshop, October 1978, Philadelphia, Pennsylvania
- 9. L.S. Lutz. PECO District Steam Heating System, December 1978

CUSTOMER CONVERSION SCHEMES

A. Discussion

The type of customer system varies with each type of building and this will affect the method of connection from the district heating/cooling system. The typical connection from the distribution system will have to be adapted for each system on an individual basis. The following systems are among the more common types encountered:

- a. A steam to hot water heat exchanger.
- b. A one pipe steam heating system.
- c. A two pipe steam heating system.
- d. A two pipe hot water heating system.
- e. Heating with a gas fired forced hot air furnace.
- f. Heating with circulated hot air.
- g. A two-pipe dual-temperature system.
- h. Cooling system conversions.

B. Description of Customer Heating System Conversions:

 A steam to hot water heat exchanger for heating and a steam to hot water exchanger for domestic hot water.

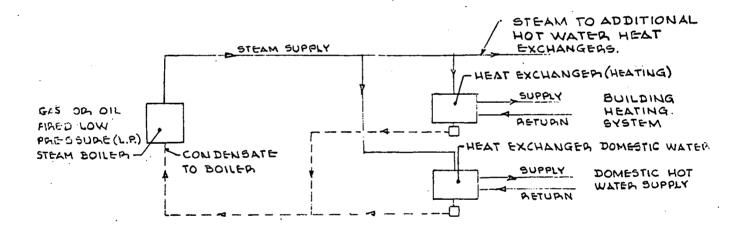


FIGURE 1

A conversion scheme for this system would be to disconnect and replace the existing steam boiler and piping, and to replace the existing steam to hot water heat exchangers with a new hot water to hot water exchanger module, modify the existing steam piping, add air separator and expansion tank, pressure switch, pumps, valves, controls and a domestic water storage tank.

In order for this system to thermally function as before, the existing steam piping will have to be removed and the existing hot water piping modified to accept the new heat exchanger module.

2. A one pipe steam heating system.

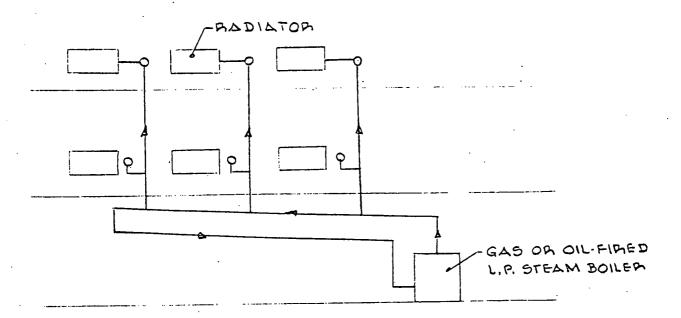


FIGURE 2

A conversion scheme for this system would be to replace the existing gas or oil-fired L.P. steam boiler with a new heat exchanger module, modify the existing steam piping, add air separator and expansion tank, pressure switch, pumps, valves, controls, a domestic water storage tank, and a electric heat booster exchangers.

Because the temperature of the entering district heating hot water varies with outdoor temperature and at times may not allow the one pipe steam system to thermally function as before, the district heating hot water acts to preheat the water in the customers heat exchanger and the electric booster heater would raise the water temperature sufficiently to allow for the hot water to steam heat exchanger to function properly.

3. A two pipe steam heating system.

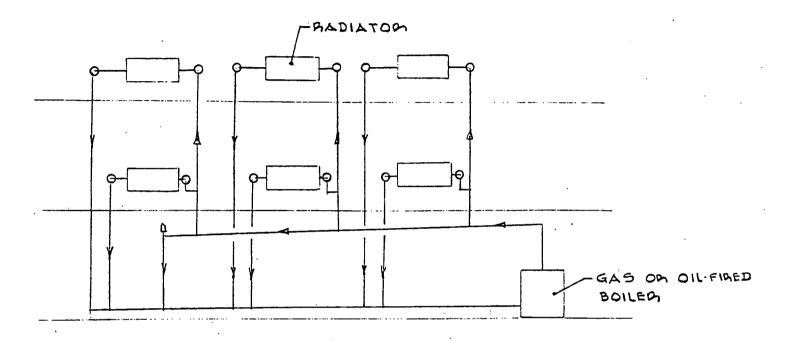


FIGURE 3

A conversion scheme for this system would be to disconnect the existing gas or oil-fired L.P. boiler, replace with a new heat exchanger module, air separator and expansion tank, pressure switch, pumps, valves, controls, a domestic water storage tank.

The existing piping system will also have to be modified from a two (2) pipe steam system to a (2) pipe hot water system. This will be accomplished by removing the existing traps and adding manual vents.

4. A two-pipe hot water heating system.

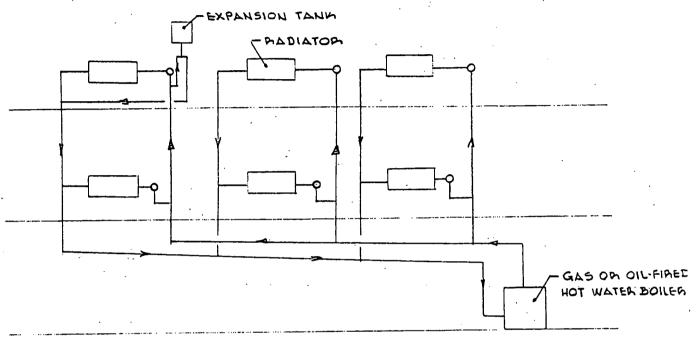


FIGURE 4

A conversion scheme for this system would be to replace the existing gas or oil fired hot water boiler with a new heat exchanger module, domestic water storage tank, valves, air separator, pressure switch, pumps, controls and modify the existing hot water supply and return piping.

The conversion of this system to a district heating system will be the lowest installed cost of all the systems investigated.

5. Heating with a gas fired forced hot air furnace, domestic hot water also heated by gas.

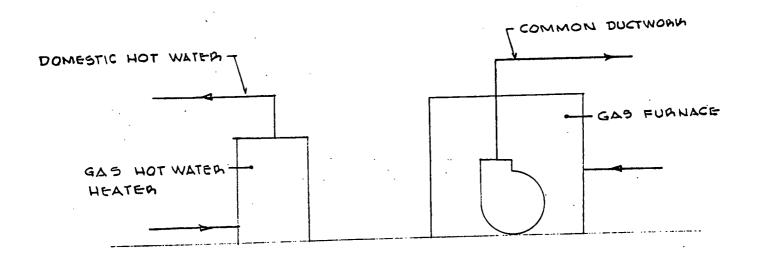


FIGURE 5

A conversion scheme for this system would be to replace the existing gas furnace and install a new hot water heating coil in the ductwork, remove existing hot water gas heater, add new heat exchanger module, air separator and expansion tank, relief valve and pressure switch, pumps, valves, controls, a domestic water storage tank, pressure reducing valve and modify piping.

6. Heating with circulated hot air gas or oil boilers with instantaneous domestic hot water from boiler, air conditioning by a direct expansion coil mounted in the common heating/cooling unit.

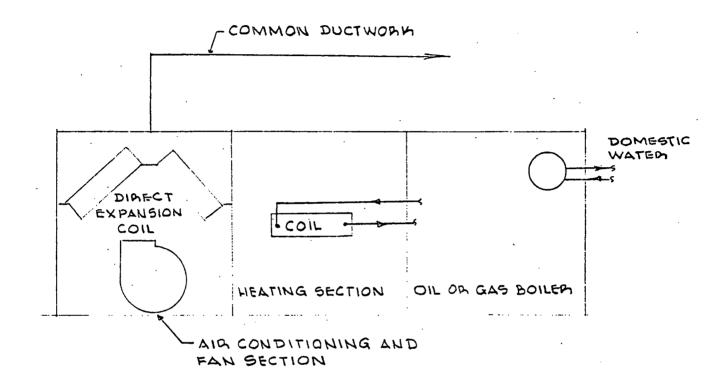


FIGURE 6

A conversion scheme for this system would be to replace the existing oil or gas boiler and install a new heat exchanger module, air separator and expansion tank, relief valve and pressure switch, pumps, valves, controls, a domestic water storage tank and modify domestic water piping.

7. A two-pipe dual-temperature water system and domestic hot water heater.

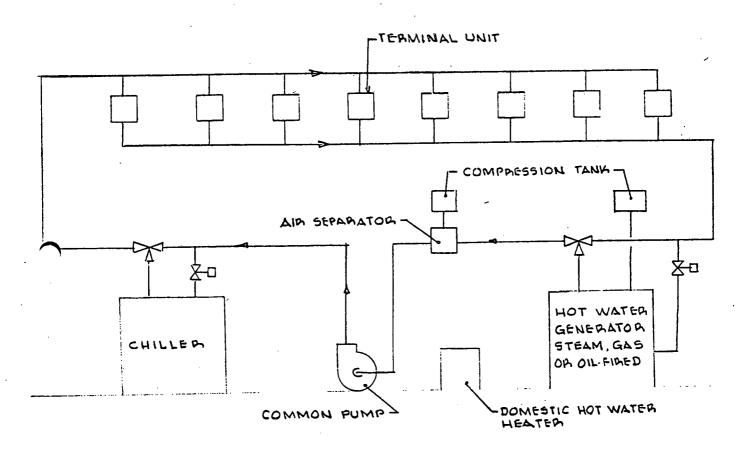


FIGURE 7

A conversion scheme for this system would be to remove existing domestic hot water heater. Disconnect the existing hot water generator and install a new heat exchanger module, relief valve and pressure switches, pumps, valves, controls, a domestic water storage tank.

- C. Description of Customer Cooling System Conversions:
 In addition to the heating systems noted above, buildings using central air conditioning systems, heat pumps and window air conditioning units were also investigated.
 - 1. Central Air Conditioning Systems with direct expansion coil. (Separate from the building heating system).

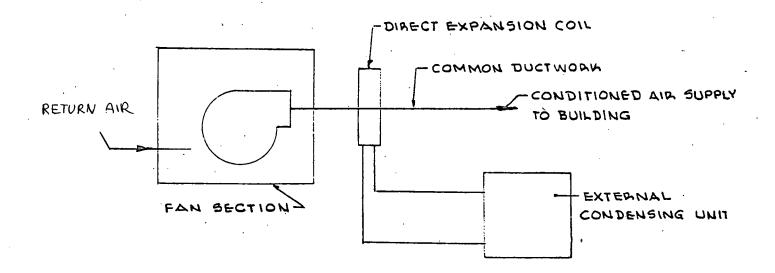


FIGURE 8

A conversion scheme for this system would be to replace the direct expansion cooling coil with a chilled water coil and associated piping supplied with water from the district cooling system. The existing condensing unit would be removed.

2. Central Air Conditioning Systems with chilled water coil.

If a central air conditioning system is supplied with chilled water coils and a source of chilled water supply from an absorption or electric driven refrigeration machine the following conversions schemes may be used:

- a. Absorption Refrigeration disconnect the source of steam or hot water supply to the unit (if the temperature is compatible with the source of district heating water, i.e., maximum of 290°F) and connect directly to the district heating hot water piping.
- b. Electric Refrigeration there is no modification required to this type of system if it proves that the economics justify the electric system over an absorption system.
- 3. Heat pumps and window air conditioning units- there is no modification required for a building with either of these systems, except for the following:
 - a. The existing heat pumps may be replaced by district heating hot water modules for winter operation, and the heat pumps can be used for summer air conditioning.
 - b. Air conditioning by window units in most buildings could remain or be replaced by chilled water fan coil cooling units or individual coil cabinet coolers/heaters with dual temperature depending on heating system. These methods could be combined with heating systems described previously.

APPENDIX K

Capital Costs of Heating/Cooling Supply Meters (Hardware Only, No Installation)

Type A - Energy Meter Counter

The estimated Capital Cost for battery operated BTU meters including platinum resistance thermometers and batteries for single dwelling averages about \$271.00 each. The associated volume or water meter for single family dwelling required for each of the above meters averages about \$110.00 each.

Type B - Energy Meter Counter and Flow Counter

The estimated Capital Cost for BTU meters including platinum resistance thermometers for single family dwellings averages about \$338.00 each. The associated volume or water meter for single family dwelling required for each of the above meters averages about \$110.00 each.

Type C - Central Energy Meter (Degree Day Type)

The estimated Capital Cost for central BTU meters that measure room temperature as well as outdoor temperature for multiple occupance average about \$126.00 per point of measurement including resistance thermometers.

Type D - Central Energy Meter (Simultaneous Distribution Type)

The estimated Capital Cost for central BTU meters including platinum resistance thermometers for multiple occupance dwellings averages about \$240.00 per point of measurement. The associated volume or water meter for each point of measurement required for the above central meter averages about \$110.00 each.

APPENDIX L

CAPITAL COSTS OF CONVERSION SCHEMES

- A. To determine the economic viability of the conversion schemes which are applicable to the various heating and domestic water systems encountered in the District Heating study, the following criteria was established:
 - 1. The supply and return water ranges for the heating systems will be 290°F supply and 170°F return. The supply and return temperatures will vary with the outside air ambient as shown on the enclosed drawings No. 13222-WHT-60M and 13222-WHT-120M.

The domestic water supply temperature will be $140^{\circ}F$ with a $40^{\circ}F$ entering water temperature to the storage heater.

2. Single Family Residence:

a) Heating Load: 60,000 BTUH per average residence

b) Domestic Water Load: 4 persons per average residence, 2 hr peak loads morning and evening, 50 gal storage tank with 27,000 BTUH for each peak load.

3. Multi-Family Dwelling

- a) Heating Load: 40,000 BTUH per average family with 4 families per dwelling, therefore total load per dwelling = 160×10^3 BTUH.
- b) Domestic Water Load: 12 persons per dwelling (3 per family), 3 hour peak usage morning and evening, 120 gal storage tank with 50 x 10^3 BTUH for each peak load.
- 4. Apartment House (100 Families)
 - a) Heating Load: 20,000 BTUH per apartment or a total load of 2 x 106 BTUH.
 - b) Domestic Water Load: 2½ persons per average apartment, 3 hour peak usage morning and evening, 1000 gal storage tank with 976 x 10³ BTUH for each peak load.
- B. The various customer heating systems investigated for this activity are as follows:
 - 1. Hot water heating system with 200°F maximum temperature to finned tube or convector radiation. This system applies to single-family, multifamily and apartment houses. (Fig. #1, #2 and #3 respectively).
 - Warm air heating system with 290°F maximum water temperature to air heating coil. This system applies to single-family and multi-family dwelling only. (Fig. #4)
 - 3. Steam heating systems were not considered for this activity.

C. The components of each system are based upon supplying a factory fabricated module for the hot water heating systems and domestic water systems. The warm air heating systems will be provided with a factory fabricated module for the domestic water system with field assembled components for the warm air heating system. The total physical size of the factory fabricated module will not be larger than a comparible oil or gas fired furnace.

1. Hot Water Heating System Module for Single Family House (Figure #1)

The heating module will provide space and domestic hot water energy requirements for a single family house. This module will monitor and maintain all the space heating and domestic hot water requirements while having the capacity of relieving excessive pressure and shutting down the high temperature, supply and return if a leak is detected within the system.

This module will also provide double wall protection for domestic water.

a) Components

Heat Exchangers (3) Counterflow, tube in tube heat exchangers HE-1, HE-2, HE-3.

The tube side of HE-1 is connected in series to the tube side of HE-2. High temperature water (290° F at 0° F ambient outside air temperature) flows through the tube side of HE-1 and HE-2. This offers two benefits, one will be the savings in regard to heat loss, as the colder of the fluids is facing the ambient air. The second benefit is added protection in case of a leak in the high temperature, high pressure side, it would enter the shell side rather than flash to steam, causing a dangerous situation. Any leak in the tube side will enter the shell side of the heat exchanger and be detected and relieved by relief valves piped to drain. It would also cause the shut down of high temperature, high pressure supply and return via pressure switches and solenoid valves. The shell side of heat exchanger number 2, and the tube side of heat exchanger number 3 form an intermediate loop, offering double wall protection to the domestic water. If there was a high temperature, high pressure leak in heat exchanger number 2, it would be detected and relieved before it could enter the domestic water supply.

<u>Pumps</u>: (3) circulators, P-1, P-2 & P-3
P-1 will circulate hot water for space heating requirements and will be operated by a thermostat located in living quarters. P-2 & P-3 will be operated by an aquastat located in storage tank.

<u>Air Controls</u>: There will be (2) air control packages, one located in the space heating loop and one located in the intermediate loop. Air Control packages will consist of an air separator, a vent and expansion tank.

Relief and Pressure Switches: Two sets, one set located in the space heating loop and one set located in the intermediate loop.

Relief Valves will be piped to drains, the pressure switches will be wired to solenoid valves, mounted on the supply and return high temperature water pipes.

Pressure Reducing Package: To be connected to the space heating loop and to include a pressure reducing valve and a check valve or backflow preventor. This is to allow for any makeup water to enter into space heating loop as required.

Storage Tank: One 50 gallon glass lined storage tank, insulated and jacketed.

b) Estimated Installed Cost: \$2,300

This includes: 1 - Storage Tank (1)

2 - Module (1)

3 - Solenoid Valves, Isolation Valves & Valves in Module

4 - Air Separator & Expansion Tank (2)

5 - Pumps (3)

6 - Miscellaneous Piping Between Components

2. Hot Water Heating System Module for Multi-Family House (Figure #2)

The heating module will provide space and domestic hot water energy requirements for a multi-family house. This module will monitor and maintain all the space heating and domestic hot water requirements while having the capacity of relieving excessive pressure and shutting down the high temperature, supply and return if a leak is detected within the system.

This module will also provide double wall protection for domestic water.

- a) Components: All the components will be the same as for single family dwelling except for equipment capacities and pipe sizes. Storage tank will be 120 gallons.
- b) Estimated Installed Cost: \$4,000

This includes: 1 - Storage Tank (1)

2 - Module (1)

3 - Solenoid Valves, Isolation Valves and other Valves in Module

4 - Air Separator & Expansion Tank (2)

5 - Pumps (3)

6 - Miscellaneous piping between components

3. Hot Water Heating System Module for Multi-Unit Apartment (Figure #3)

The heating module will provide space and domestic hot water energy requirements for a multi-unit apartment. This module will monitor and maintain all the space heating and domestic hot water requirements while having the capacity of relieving excessive pressure and shutting down the high temperature, supply and return if a leak is detected within the system.

This module will also provide double wall protection for domestic water.

a) Components

Heat Exchangers

This module uses three shell and tube type heat exchangers HE-1, HE-2, HE-3.

The tube side of HE-1 and HE-2 will be rated for 300 psi because the high temperature water flows in series through the tube of HE-1 and HE-2. Shell side of HE-2 is connected to the tube side of HE-3, forming an intermediate loop offering double wall protection to the portable water. HE-3 is a tube bundle located in a 1000 gallon glass lined hot water tank. This capacity plus the hot water storage, gives 1873 gallons of 140°F peak draw capacity.

The same accessory equipment as provided in the single family module.

b) Estimated Installed Cost: \$21,000

This includes: 1 - Heat Exchangers (3)

2 - Pressure Switch (1)

3 = Pump (2)

4 - Air Separator (2)

5 - Storage Tank (1)

6 - Valves

7 - Miscellaneous Piping Between Components

4. Warm Air Heating System for Single Family House (Figure #4)

The heating module will provide space and domestic hot water energy requirements for a single family house. This module will monitor and maintain all the space heating and domestic hot water requirements while having the capacity of relieving excessive pressure and shutting down the high temperature supply and return valves if a leak is detected within the system.

This module will also provide double wall protection for domestic water.

a) Components

Heat Exchangers (2) Counterflow, tube in tube heat exchangers HE-1, HE-2.

High temperature water (290°F at 0°F ambient outside air temperature) flows through the tube side of HE-1 and the heating coil in the warm air furnace. This offers two benefits, one will be the savings in regard to heat loss, as the colder of the fluids is facing the ambient air. The second benefit is added protection in case of a leak in the high temperature, high pressure side, it would enter the shell side rather than flash to steam, causing a dangerous situation. Any leak in the tube side will enter the shell side of the heat exchanger and be detected and relieved by relief valves pipe to drain. It would also cause the shut down of high temperature, high pressure supply and return via pressure switches and solenoid valves. The shell side of heat exchanger number 2, and the tube side of heat exchanger number 3 form an intermediate loop, offering double wall

protection to the domestic water. If there was a high temperature, high pressure leak in exchanger number 2, it would be detected and relieved before it could enter the domestic water supply.

Pumps: (3) Circulators, P-1, P-2 & P-3
P-1 will circulate hot water for space heating requirements and will be operated by a thermostat located in living quarters. P-2 & P-3 will be operated by an aquastat located in storage tank.

<u>Air Controls</u>: There will be (2) air control packages, one located in the space heating loop to the heating coil and one located in the intermediate loop. Air Control packages will consist of an air separator, a vent and expansion tank.

Relief and Pressure Switches: Two sets, one set located in space heating loop to the heating coil and one set located in the intermediate loop.

Relief Valves will be piped to drains, the pressure switches will be wired to solenoid valves, mounted on the supply and return at the high temperature water pipes.

Pressure Reducing Package: To be connected to the space heating loop and to include a pressure reducing valve and a check valve or backflow preventor. This is to introduce any makeup water into the space heating loop as required.

Storage Tank: One 50 gallon glass line storage tank, insulated and jacketed.

b) Estimate Installed Cost: \$2,500

This includes: 1 = Heat Exchangers (2)

2 = Pumps (3)

3 = Pressure Switches (2 sets)

4 - Solenoid Valve, Isolation Valves and all valves in Module

5 - Air Separator & Expansion Tank (2)

6 - Hot Water Heating Coil (1)

7 = Additional Duct Work Required to Install Coil

8 - Miscellaneous Piping Between Components

5. Warm Air Heating Module for Multi-Family House (Figure #4)
The heating module will provide space and domestic hot water energy requirements for multi-family house. The module will monitor and maintain all the space heating and domestic hot water requirements while having the capacity of relieving excessive pressure and shutting down the high temperature, supply and return if a leak is detected within the system.

This module will also provide double wall protection for domestic water.

a) Components

All the components will be the same as for warm air single family dwelling equipment capacities and pipe sizes as well as increased size of heating coil in warm air furnace. Storage tank will be 120 gallons.

b) Estimated Installed Cost: \$5,300

This includes: 1 - Heat Exchangers (2)

2 - Pumps (3)

3 - Pressure Switches (2 sets)

4 - Solenoid Valve, Isolation Valves and all Valves in Module

5 - Air Separator & Expansion Tank (2)

6 - Hot Water Heating Coil (1)

7 - Additional Ductwork required to Install Coil

8 - Miscellaneous Piping Between Components

- D. For comparison purposes the costs of installing or providing for comparable heating and domestic water tanks is included here:
 - a. Installed price for H.W. Boilers:

Single Family (60,000 Bruff)	Gas Fired \$1,100	0il Fired* \$1,800
Multi-Family (160,000 Btuff)	\$1,300	\$2,500

*Includes oil tank

b. Equipment costs for domestic water heaters (gas fired):

50 Gallon - \$150 120 Gallon - \$250 1,000 Gallon - \$2,500

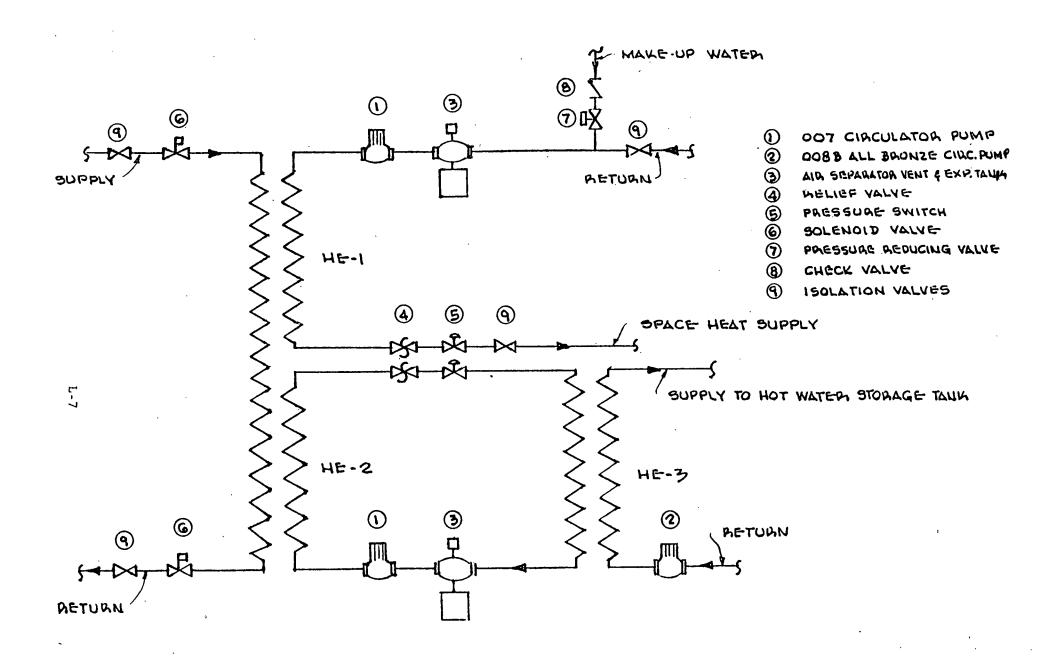


FIGURE 1

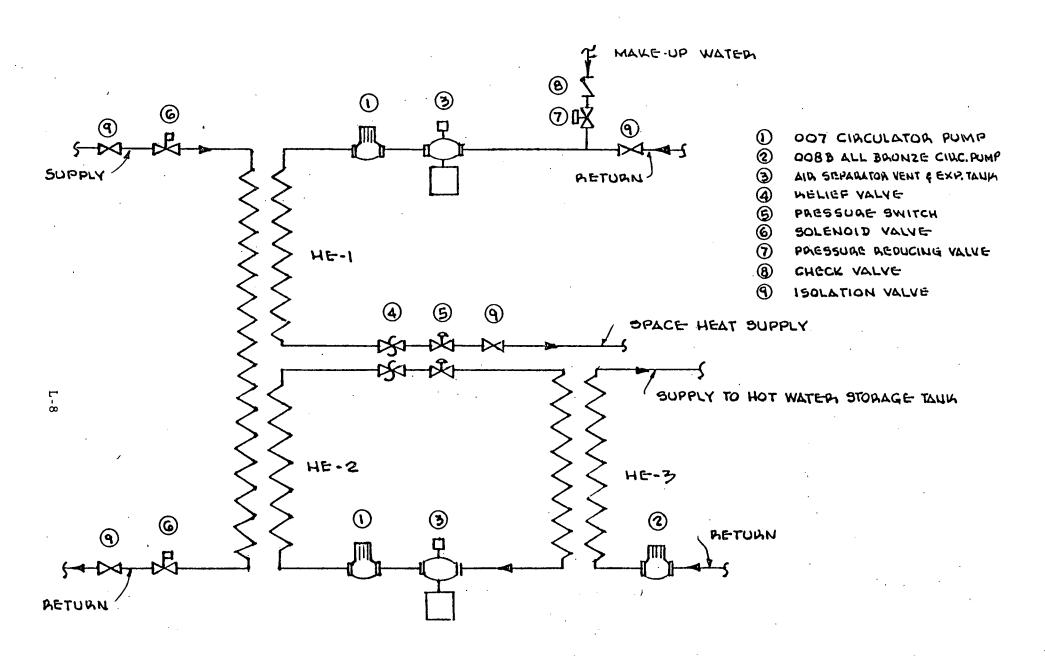


FIGURE 2

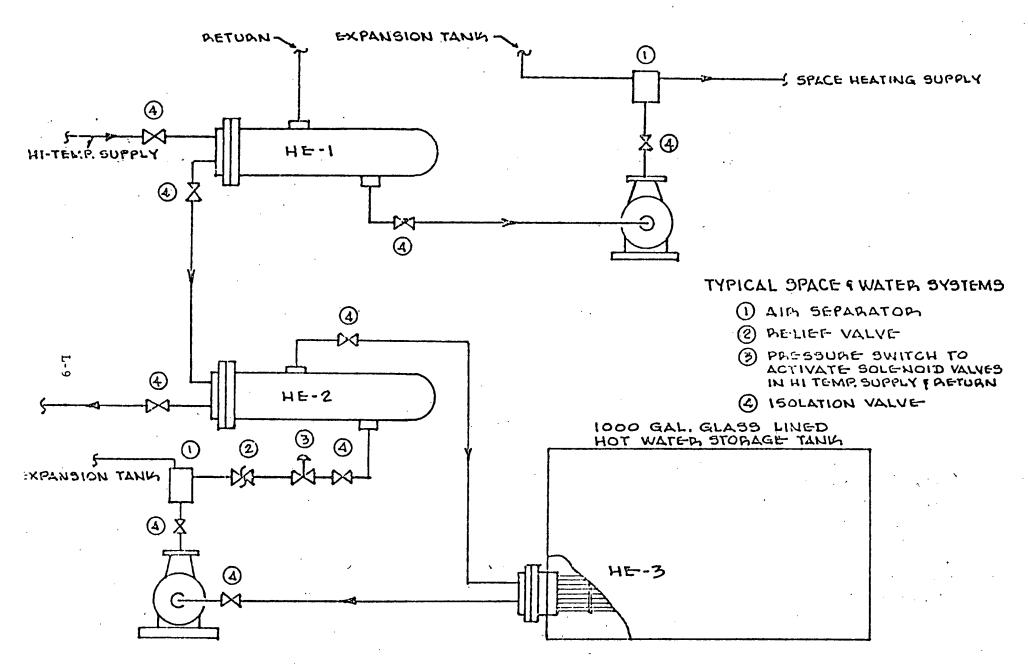


FIGURE 3

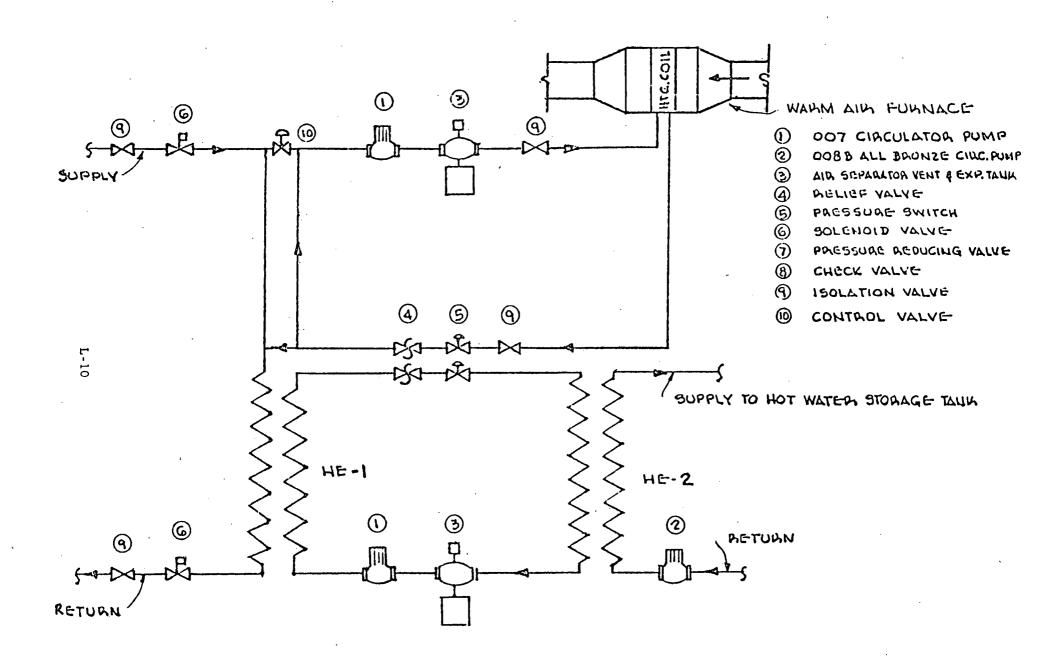


FIGURE 4

APPENDIX M

Maintenance Required

For the Customer System

The customers system begins where the district heating/cooling pipes enter the premises from the distribution system and includes any heat exchangers, forced air plenum heating or cooling coils, domestic hot water storage, controls and heating/cooling supply metering.

The customer system does not include components of the existing heating/cooling systems, except as it may be necessary to interface with them.

Generally, the type of conversion system installed in the customer's premises determines the amount and type of maintenance required.

However, there are some general items which apply to all of the various types of systems installed and by following proper operation and maintenance procedures, breakdown or failure of any component may be costly, can be prevented. We must also consider any inconvenience to the customer and the possible partial or complete shutdown of his system.

Two types of maintenance programs should be followed:

<u>Preventive Maintenance</u> - For prolonged operating life and satisfactory supply to the consumers, this involves cleaning, lubricating, inspections etc.

<u>Corrective Maintenance</u> - Such as system testing, fault isolation, changing of replaceable units and modules, replacement or repair of components and equipment adjustments and alignments.

The following items are typical of the type of procedures to be followed on parts of the system:

- 1. Heat exchangers maintenance and inspection
 - a) Cleaning to remove fouling or deposits
 - b) Removal and replacement of gaskets
- 2. Pumps maintenance and inspection
 - a) Seals should be checked for leaks, and packing replaced as required.
 - b) Bearings should be periodically lubricated
- 3. BTU Meters and water Meters:
 - a) Periodic calibration procedure to determine accuracy of meters, which includes visual check of the water meter and zero point check of the BTU Meter.

The following lists the various conversion and in-house systems which will be encountered in the maintenace program; and the items which should be checked and maintained for each system.

- 1. Steam to hot water heat exchanger for heating and steam to

 hot water exchanger for domestic hot water.
 - a) Hot water storage tank
 - b) Heat exchanger module
 - c) Pumps
 - d) Pressure reducing and relief valves
 - e) Automatic controls
- 2. One pipe steam heating system
 - a) Hot water storage tank
 - b) Heat exchanger module
 - c) Pumps
 - d) Pressure reducing and relief valves
 - e) Automatic controls
 - f) Electric booster heater

3. Two pipe steam heating system

- a) Hot water storage tank
- b) Heat exchanger module
- c) Pumps
- d) Pressure reducing and relief valves
- e) Automatic controls

4. Two pipe hot water heating system

- a) Hot water storage tank
- b) Heat exchanger module
- c) Pumps
- d) Pressure reducing and relief valves
- e) Automatic controls

5. Heating with a gas fired forced hot air furnace

- a) Hot water storage tank
- b) Heat exchanger module
- c) Eilter and hearing coil
- d) Pumps
- e) Pressure reducing and relief valves
- f) Automatic controls

6. A two-pipe dual-temperature system

- a) Hot water storage tank
- b) Heat exchanger module
- c) Pumps
- d) Pressure reducing and relief valves
- e) Automatic controls

APPENDIX N

WATER TREATMENT CONSIDERATIONS

The proposed District Heating System will be operating in the temperature range of 160 F to 290 F at about 450 psig. Heated water will be distributed in a two-pipe system to secondary heat exchangers located at the user's end. The volume of water in the piping systems for the different loops proposed are given below:

- Scheme No. 1 Piping system from the Hudson Station to Jersey City and Hoboken via existing urban streets and piping system to the Hackensack-Meadowlands area via existing and new suburban streets, including secondary distribution piping, 1.3 x 10 gallons. (28,770 GPM Flow Rate)
- Scheme No. 2 Piping system from the Essex Station to Newark via existing urban streets, including secondary distribution piping,

 O.7 x 10⁶ gallons. (13,910 GPM Flow Rate)
- Scheme No. 3- A combination of Scheme No. 1 and Scheme No. 2, with the addition of the Bergen Station to supply the northern portion of the Hackensack-Meadowlands area, and Hoboken, including secondary distribution piping, 3.3 x 10⁶ gallons. (64,310 GPM Flow Rate)

Due to the need of the large quantity of water to initially fill the system, it is proposed that the initial fill be made using city water. Prior to start-up of the system, the water in the district heating system will be treated to remove dissolved oxygen and scale forming substances such as calcium (Ca) and magnesium (Mg).

Two major sources of city water have been considered: Hackensack for Hudson County and Jersey City for Essex County. There are other smaller suppliers which have not been considered at this time. The average quality of the city water considered is given below:

City Water Quality (Average Condition, Concentration in ppm)

•	•							02				
	TDS	TSS	Ca	Mg	Na	HCO3	S04	C1	SiO2	N03	dissolved	Free CO2
Hackensack	136	< 1	27.8	5.3	9	86	24	46	7.3	0.1	13.5	3
Jersey City	7 100	<12	5	4	12	50	15	12	3	0.1	13	3

It should be pointed out that the quality of the city water changes with the weather conditions, especially during the rainy season. The Jersey City Municipal Water Treatment Plant currently has plans to improve the quality of its water by the additions of filtration and coagulation systems.

To remove oxygen dissolved in the district heating water, two different approaches can be used. One is deaeration and the second is oxygen scavenging. To deaerate the water before filling the system is not practical. Since the district heating water piping system is initially filled with air, to fill the system with deaerated water will simply cause the water to be saturated with oxygen again during the filling process. Oxygen can be removed by introducing into the district heating water an oxygen scanvenger.

Due to the high temperature of the district heating water, many of the organic type oxygen scanvengers decompose. One of the most common non-organic materials; hydrazine, will work under the temperature conditions considered. However this material is toxic and is not compatible with copper.

To prevent scale deposit in the system appropriate means must be employed to remove the scale forming substances such as the calcium and magnesium ions (in bicarbonate form). One of the processes of removing Ca and Mg ions is called softening. Softening is done through an ion exchanger which uses a sodium (Na) base resin, a brine solution is used as a regenerant.

There are two disadvantages of using this process. Softened water, if not deaerated, is very corrosive, consequently an oxygen scavenger must be added. Since softened water still retains the bicarbonate, which may decompose into CO₂ to form acid, it may become corrosive at high temperatures. An alternative is to use demineralized water with a rust inhibitor. This approach is very costly on account of the large quantity of water which must be processed.

Based on operational experience of district heating systems in Sweden, it is estimated that the volume of water in the system will need to be replaced once a year because of leakages. Make-up to the system is needed therefore on a continuous basis throughout the year.

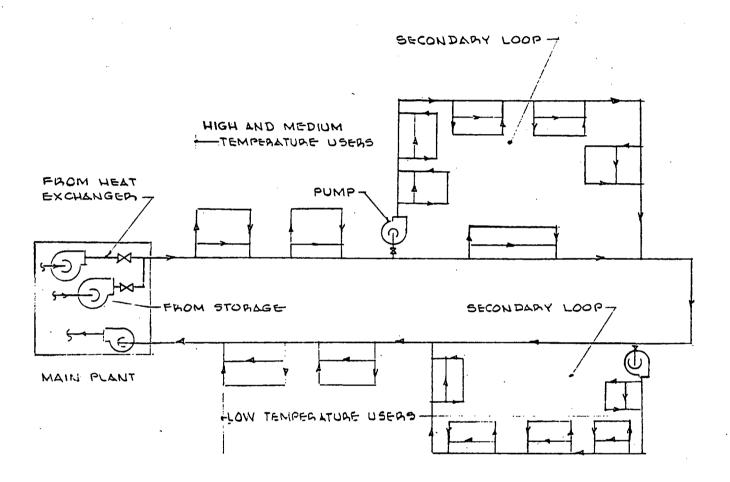
A detailed analysis of the water supply and the economics of the water treating and monitoring systems will be addressed during Phase II of the study.

APPENDIX O

COMMON HEATING AND COOLING DISTRIBUTION SYSTEMS

1. Hot Water System

a. One Pipe Circuit

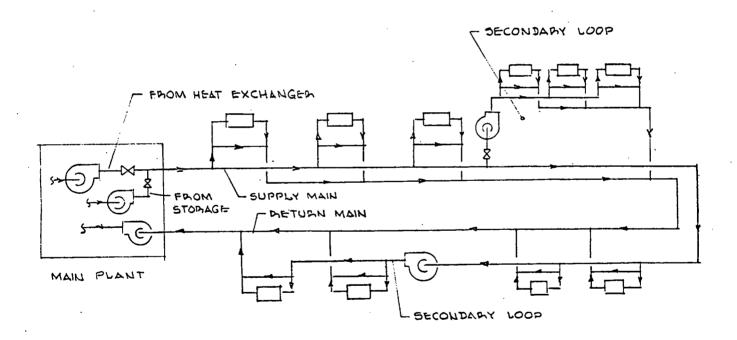


The one pipe system has a single main for supply and return piping. The main does not change size from the first user to the last user, as a result the amount of water which passes through the main is constant. However, the temperature drop from the first user to the last user is substantial, because the return low temperature water from each user is blended with the temperature in the main line. The disadvantage of this system is that the farthest users from the plant with high heating load demand would have to use larger heating units, as the same amount of water always flows thru the main, the sizes of the main pipe will be the same throughout and larger in sizes in comparison with other systems. It is difficult to control the temperature of the main, as the blending return water tempera-

ture to the main varies with the load demand of the users. Hence every user would have his own pumps and expansion tanks for controlling the temperature requirement for his heating load. This system has a disadvantage for very long piping runs, because temperature will drop substantially at the end if there is a large demand before reaching the farthest point.

However, this system is easy to install, the same main pipe size demands less fittings and large quantities can be prefabricated. Since the same quantity of water flows through the mains, it is easy to balance the system. Due to its simplicity, this design can be very useful as a branch or zone when incorporated in an installation of multiple requirements. For example, the nearest users may be industries which generally require high temperature water for processing purposes, and the lower temperature at the farthest end could be used by residential users where temperature demand is low. A pump can be used to supply increased volume of water making it a secondary circuit.

b. Two Pipe Circuit



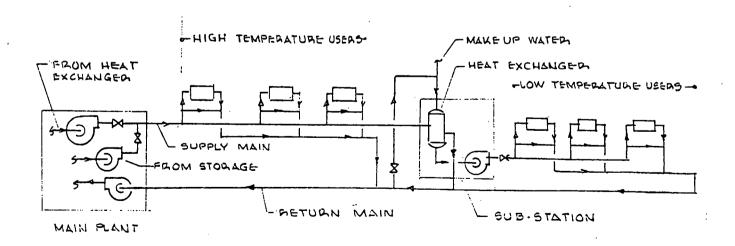
The two pipe system has individual main supply and reverse return piping which can be connected to the end users. The temperature of water in the main remains fairly constant except for thermal temperature drop, due to its longest runs, which is negligible (approximately 1°F/10 miles of run). Due to the fact that the temperature of the main hot water supply remains fairly constant, the demand for larger heating units is not required for the end users. The pipe size of the main supply can be gradually reduced, similarly the return pipe size is gradually increased as more and more return water is collected from the users. As the pressure drops towards the farthest points, a secondary booster pump will be required to increase pressure in the mains.

C. Substation Circuit

To meet the demand of low temperature water (especially for residential dwellers) from a high temperature main, a substation concept may be used. High temperature water from the main passes through a heat exchanger to meet a particular temperature of water and then pumped to the individual low temperature users.

The fairly constant temperature of the mains in this system gives the advantage of different kind of users (industrial, commercial, or residential) from the nearest part of the plant to the farthest part. As there are separate piping lines for supply and return, the individual users have a greater control in using the supplied heat by metering devices, since return water temperature from his unit does not affect the supply main temperature to other users.

Material costs are more than a single pipe circuit because of two separate pipes, however gradually reduced sizes of the mains narrows the difference substantially. The installation cost will not be much different from a single pipe system as the two pipes run side by side on same supports, piers, tunnels or trenches.



2. Steam System

a. One Pipe System

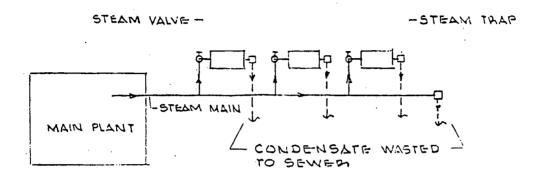


FIGURE 8

This system uses one main supply steam line to the end users, and the condensate is not returned to the plant but is wasted to the sewer. High make-up water requirement makes this system very expensive. The condensate may be recovered from this system by gravity flow. However as the distance becomes greater, the system is not feasible because of deeper depth of trench, excavation or tunne.

b. Two Pipe System with Gravity Return

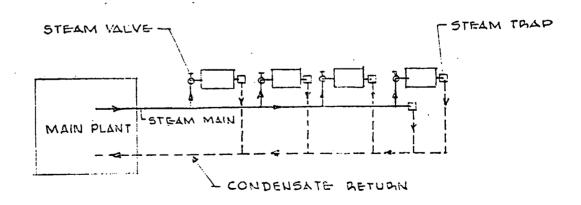


FIGURE 9

This system provides one supply main for supplying steam to the end users and condensate is returned by gravity thru a separate return main by the use of steam traps. The advantage of this system as compared with the one pipe arrangement is that the condensate is recovered and sent back to the main plant, where the heat is recovered.

c. Two Pipe System with Vacuum Return

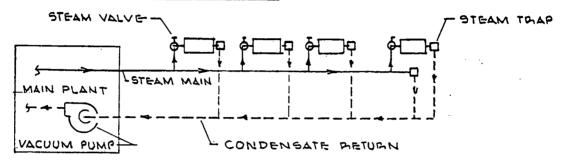


FIGURE 10

This system is same as above except that the condensate is returned to the plant under vacuum.

The Substation concept may be used here in combination with steam and hot water as shown in Figure 11.

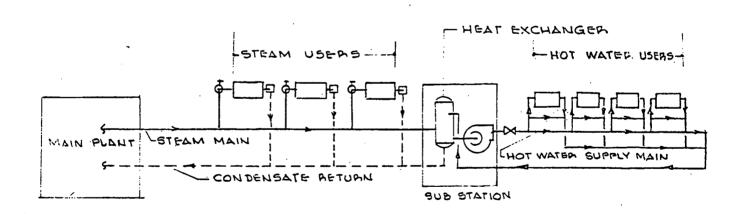


FIGURE 11

In this system steam is supplied to the process steam user by a two pipe system and supplied to a substation where a heat exchanger makes hot water and the hot water is then supplied to the user. Steam condensate and hot water return is then separately returned to the main plant by a two pipe system. The advantage of this system is that the process steam can be supplied to the industrial users located nearby to the plant and hot water can be supplied to the farthest customers thereby avoiding the disadvantages of running miles of steam piping. However, separate condensate return and hot water returns add additional installation costs.

C. Cooling Systems

1. Two Pipe System

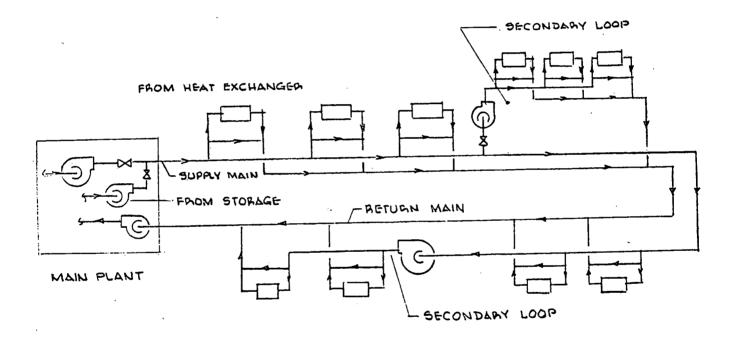


FIGURE 12

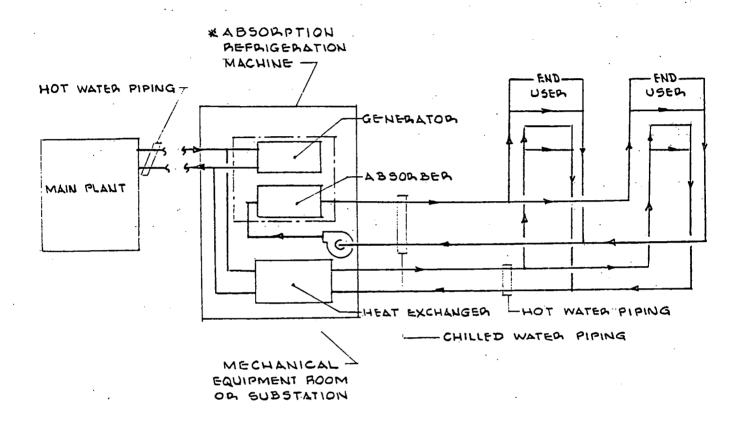
A one pipe circuit is not technically feasible in this case, as the chilled water return from the end users mixing with the mains will raise the temperature in the supply water temperature making it practically useless to the farthest end users.

In a two pipe circuit system, individual supply and return pipes run side by side, connected to the end users. The temperature of the supply is fairly constant except for the drop in temperature due to radiation loss from the pipes which is kept to a minimum. The fairly constant temperature in the supply line gives the end users the advantage of metering the flow only as a measurement of the load requirements. The chilled water plant could be either an electric driven centrifugal type or an absorption type.

It is possible to use the same two pipes for the chilled water, which are used in the winter season to carry hot water, however, if the demand calls for using chilled water in conjunction with hot water, then a four pipe system (two for hot water and two for chilled water) must be adopted. Also using two pipes with seasonal changeover negates the use of district heating hot water for the domestic water system. The thermal carrying capacity of the piping system will be limited to the pipe size which is determined by the hot water piping system.

2. Combined Heating - Cooling System

A type of cooling piping system using electric driven centrifugal or absorption refrigeration machines located in a mechanical equipment room or substation local to the area served - (See Figure 13). The advantage of this system is that the districut heating hot water pipes can be piped to the substation or equipment room and then repiped to the individual buildings or areas through heat exchangers. Therefore both chilled water and heating or domestic hot water is available at all times.



*If electric centrifugal refrigeration machine is used then all hot water piping is used for heating and domestic water.

FIGURE 13

APPENDIX P

OST ESTIMATE OF DISTRICT HEATING SYSTEMS

(In Thousands of Dollars)#

	Scheme No. 1	Scheme No. 2	Scheme No. 3
Heating Capacity, 10 ⁶ BTU/nr	(1,600.)	(772.)	(3,572.)
Station Retrofit Costs			
Bergen Station	- ,	-	18,594.
Essex Station	-	16,221.	16,221.
Hudson Station	33,462.	-	33,462
Transmission Costs	19,954.	11,596.	51,511
Distribution Costs	26,021.	15,469.	57,931.
Customer Conversion Costs	13,043.	5,997.	28,267.
Overhead (29.2% of Capital Cost Excluding AFUDC)*	27,004.	14,391.	60,147.
Allowance For Fund Used During Construction (AFUDC)	2,650	1,285.	5,408

[#] Cost based on present day dollars, no escalation used

^{*} Percent overhead based on PSE&G figures.