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Energy
CONSERVATION

DISTRICT HEATING AND COOLING SYSTEMS FOR COMMUNITIES THROUGH POWER PLANT RETROFIT DISTRIBUTION NETWORK. PHASE 2

Volume I: Detailed Summary

Final Report for the Period March 1, 1980–January 31, 1984

January 31, 1984

Work Performed Under Contract No. AC02-78CS20071

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Newark, New Jersey

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

PHASE 2

FINAL REPORT

FOR THE PERIOD

1 MARCH 1980 - 31 JANUARY 1984

VOLUME I
DETAILED SUMMARY

REPORT DATE: 31 JANUARY 1984

WORK PERFORMED UNDER CONTRACT

DE-AC022-78CS20071

PUBLIC SERVICE ELECTRIC & GAS COMPANY
80 PARK PLAZA
NEWARK, NEW JERSEY 07101

FOREWORD

This is the Final Report of Phase 2 of "District Heating and Cooling Systems for communities through Power Plant Retrofit Distribution Network." It is composed of an Executive Summary and seven volumes:

Executive Summary

Volume I: Detailed Summary

Volume II: Introduction, Load & Service Area Assessment, Institutional Questions, Rates, Financial Considerations

Volume III: Technical Considerations

Volume IV: Cost Estimates, Staged Development Scenarios, Economic Evaluation, Impact on Fuel and the Environment, Alternates to Conventional Heating Systems, Conclusions, Recommendations

Volumes V-VII: Appendices A - C

ACKNOWLEDGEMENTS

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

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Transflux International, Ltd.: M. G. Kurz

Stone & Webster Management Consultants, Inc.: G. S. Levitt, E. Schiaffino

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

PREFACE

This volume is designed to provide a detailed, self-contained summary of the history, methodology and results of the study, and to direct the reader to the particular volume containing further information on any topic. To this end, Volume I contains, in addition to its own Table of Contents, an overall Table of Contents for the entire Final Report (all volumes). Volume I also contains the overall Table of Figures and Table of Tables for the entire report. When Figures or Tables in Volume I are taken from other volumes of the report, their original Figure or Table numbers are retained, to direct the reader to the Volume and Section containing further related information.

Volume I begins with a description of the history of the District Heating Study, the project team and the basic scope of the study. The load and Service Area Assessment are then described and a summary given of the technical highlights of the proposed district heating system. The three types of heat sources (peaking and back-up plants, intermediate plants and retrofitted central power plant) are described, and the concept of staged development on the European model is introduced. A brief description is given of hot water transmission and distribution and of the use of recovered landfill gas as a low-cost fuel for the initial phase of district heating system development.

Operation of various combinations of the three heat sources, at different stages of system development is then described, and month-by-month fuel use for the fully developed system is given. Descriptions are given of user connections (customer interface packages) to convert the district heating system hot water to serve the customer's thermal needs. Both hot water and steam in-house systems are considered.

System development is then described in detail including thermal load growth, thermal source construction and transmission and distribution line construction schedules.

Next, capital and operating cost estimates are presented, including review of transmission and distribution piping capital costs by Swedish and Danish district heating experts with U.S. construction experience.

A financial analysis is then presented for a number of ownership/financing options, and year-by-year cost of heat from district heating is compared with conventional heating (gas furnace in each building) for a number of district heating scenarios. An economic analysis is given showing the 28-year Levelized Annual Minimum Revenue Requirement (LAMRR) for each alternative.

Impacts of district heating on fuel use and on the environment are then reviewed, including results of air quality modeling for NO_x, SO_2 and particulates.

Institutional questions and barriers to district heating implementation are then discussed. A summary of district heating presentations to PSE&G management, USDOE and N.J.BPU is given.

Volume I closes with a summary of conclusions and recommendations.

TABLE OF CONTENTS

Table of Contents (continued)

Topics of other volumes of this report:

DETAILED SUMMARY

INTRODUCTION

PSE&G's involvement in cogeneration and district heating began in the late 1950's with large scale combined steam and power production and steam transmission through a pipeline to a nearby oil refinery. In 1975 the Company conducted an internal study of the potential for district heating using waste heat from its electric generating stations. This was followed by a survey of potential industrial cogeneration sites in New Jersey.

In late 1978 the USDOE-funded Phase 1 (Preliminary Feasibility) Study of District Heating was initiated. All of PSE&G fossil-fueled electric generating stations were screened (Figure 1.1), and three northern New Jersey stations (Hudson, Essex and Bergen), in the areas of highest thermal load density, recommended for further study. It was found that there was more than enough potential thermal load within five miles of each of these stations to utilize the available waste heat.

The Phase 2 (Detailed Feasibility) District Heating Study began in 1980 and concentrated on the Hudson Generating Station because of its proximity to the concentrated Jersey City and Newark load areas and the new developments planned for the Hackensack Meadowlands. Initially, the oil-fired Essex Unit No. 1 (Newark) and Hudson Unit No. 1 (Jersey City) were also considered. However it was soon apparent that district heating based on coal would be more viable, and the coal-fired Hudson Unit No. 2 was used as the study basis of a large, regional district heating system for northeastern New Jersey (Figures 1.2 and 1.3).

The potential for district heating was examined in terms of the total system and two subsystems of overlapping scales:

A. The total system (3.7 x 10^9 BTU/hr peak) based on Hudson Unit No. 2, Kearny Unit No. 12 and local gas-fired heating and cogeneration plants built up in staged development on the European model.

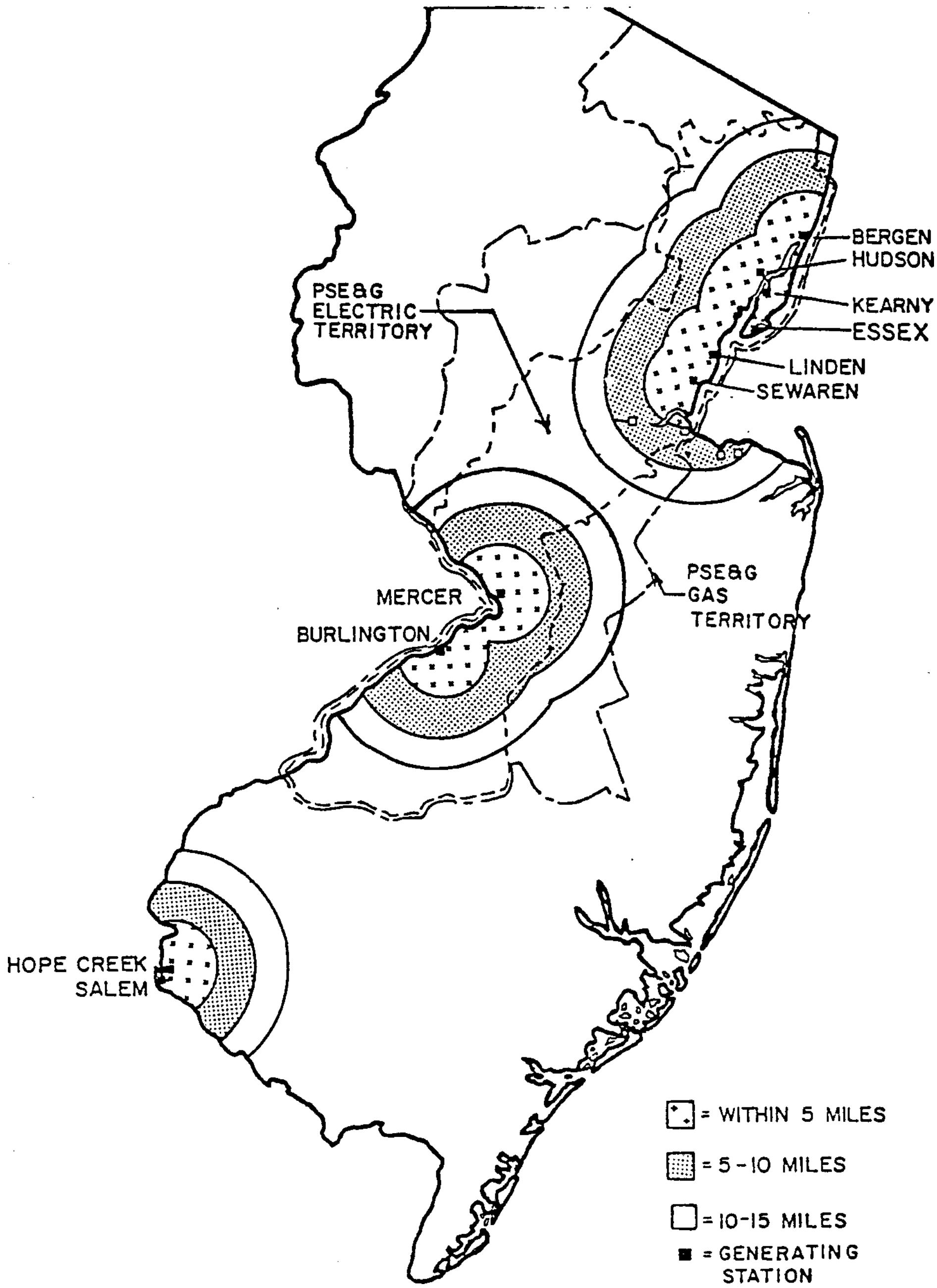

BERGEN
HUDSON
KEARNY
ESSEX
LINDEN
SEWAREN
PSE&G ELECTRIC TERRITORY
PSE&G GAS TERRITORY
MERCER
BURLINGTON
HOPE CREEK
SALEM
= WITHIN 5 MILES
= 5-10 MILES
= 10-15 MILES
= GENERATING STATION

FIG. 1.1

Staged Development and Dispatch Concept

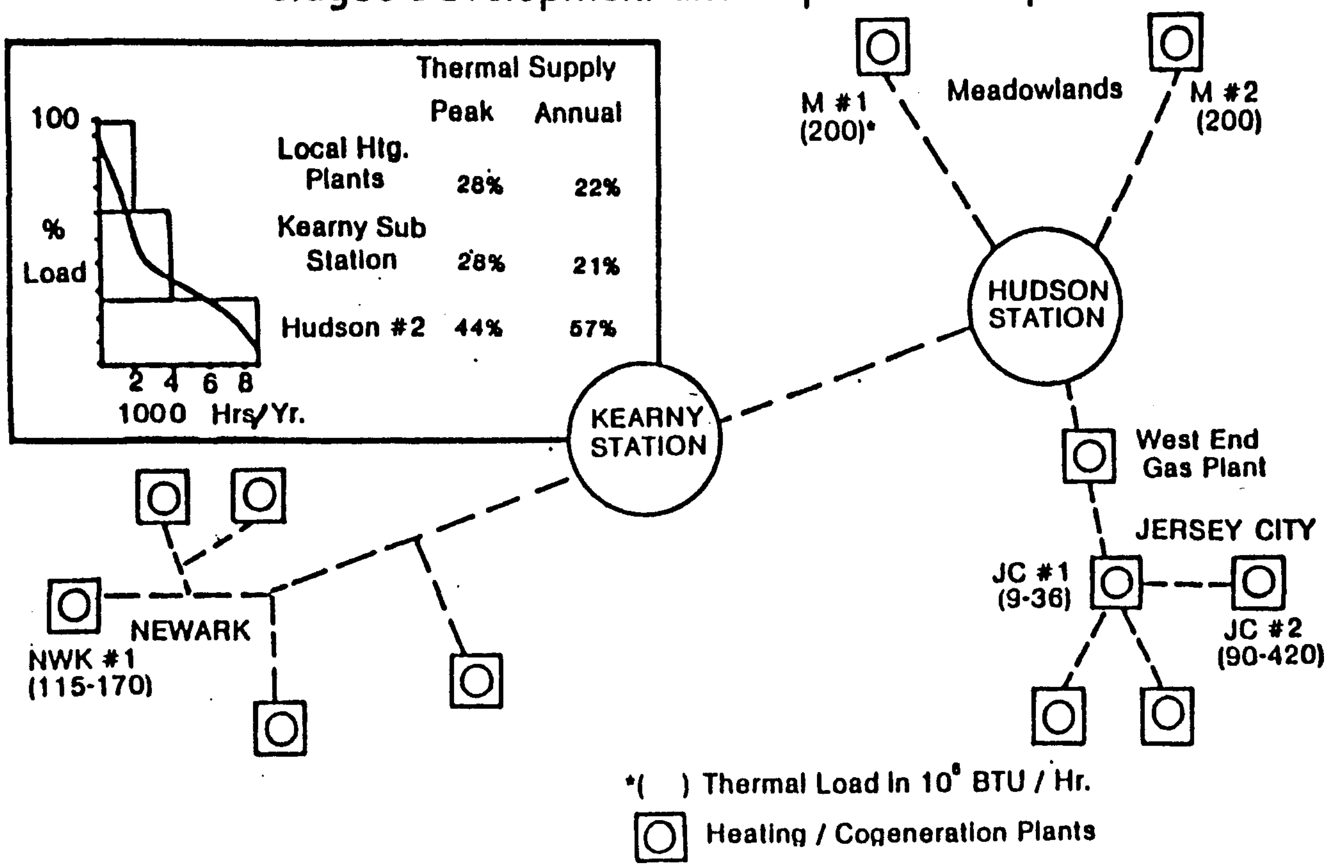


FIG. 1.2

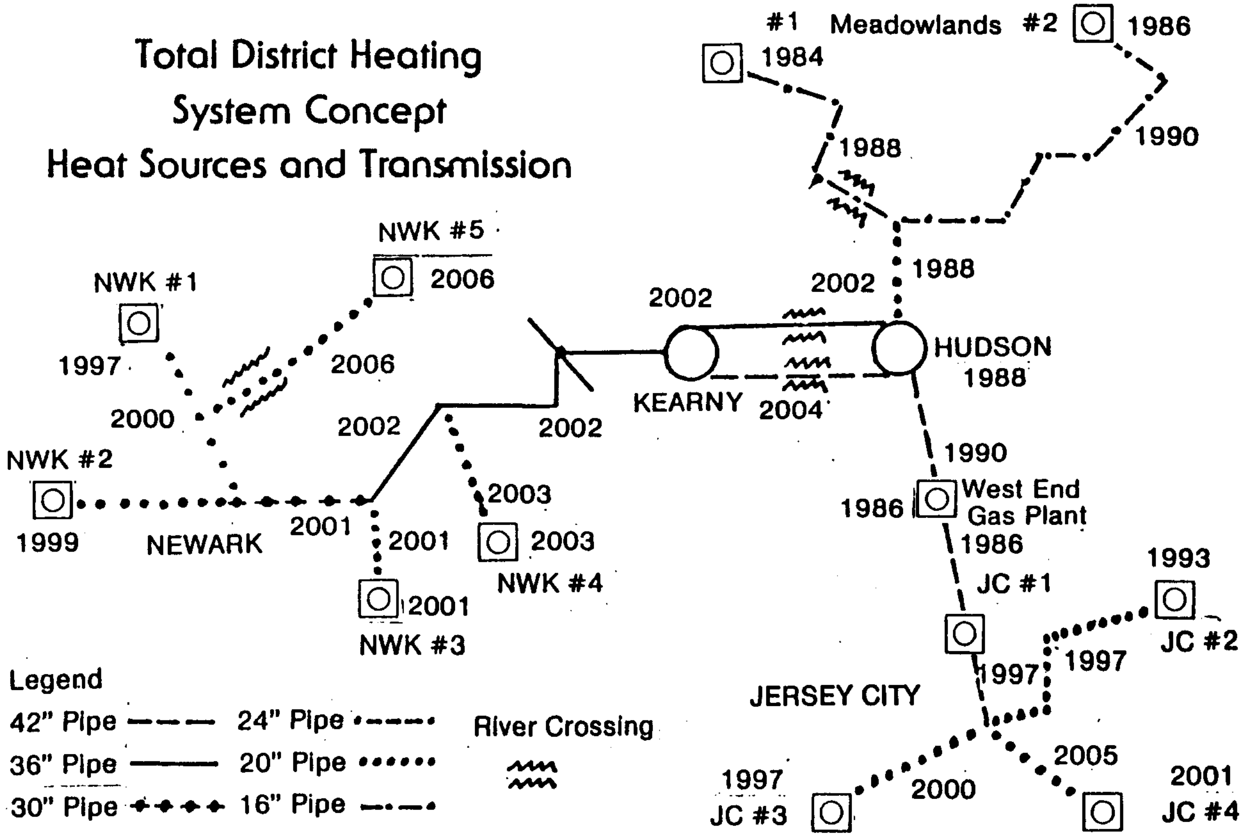

Total District Heating
System Concept
Heat Sources and Transmission
#1 Meadowlands #2
1984
1986
1988
1990
1988
2002
2002
HUDSON
1988
KEARNY
2004
NWK #5
2006
NWK #1
1997
2006
2000
2002
2002
NWK #2
1999
NEWARK
2001
2001
2003
2003
NWK #4
2001
NWK #3
1990
1986
West End
Gas Plant
1986
JC #1
1993
JC #2
1997
1997
JERSEY CITY
1997
JC #3
2000
2005
2001
JC #4
Legend
42" Pipe
24" Pipe
36" Pipe
20" Pipe
30" Pipe
16" Pipe
River Crossing

FIG. 1.3

B. A major district heating site (200 x 10^6 BTU/hr peak) based on a new development or an existing urban housing complex, using landfill gas, natural gas or limited steam extraction from Hudson Unit No. 2.

C. A mini district heating site (on the order of 10 x 10^6 BTU/hr peak) based on "stand-alone" cogeneration facilities serving a small number of apartment buildings, and fueled by waste gas, natural gas, or wastes. These could serve as the initial nuclei for district heating system development while being economically viable even if a larger district heating grid (based on a coal-fired central generating station) were not eventually built. The need for this type of facility emerged late in Phase 2 as capital needs and constraints became apparent. They were thus not studied in detail, but are the subject of on-going PSE&G investigations of district heating options/opportunities for future consideration.

The basis of the economic analysis of district heating was that the utility's electric and gas customers would not be economically burdened by the implementation of district heating, and that any incremental costs due to district heating (e.g. district heating capital and operating costs, replacement electric power, abandonment of unamortized gas mains) would be charged to district heating customers.

The project team assembled for Phase 2 included:

<u>PSE&G:</u>

R&D – Project Management and Coordination
System Planning – Economic and Financial Analysis, Rates
Gas Transmission and Distribution – Piping system design and costs
Engineering and Construction – Review of cost estimates and designs
Customer and Marketing – Load survey
Rates and Load Management – Tariffs
Law, Finance, Environmental Affairs

Subcontractors:

Stone & Webster Engineering Corp.	– Powerplant retrofit, detailed engineering design and cost estimates
Transflux International Ltd.	– Load determination, conceptual design of district heating systems and heating plants
Stone & Webster Management Consultants, Inc.	– Load assessment questionnaire design, analysis of responses
Westinghouse Electric Co.) General Electric Co.)	– Steam turbine retrofit
Coopers & Lybrand Inc.	– Assessment of financing and ownership options
Trenton State College	– Air quality modeling calculations
N.J. Department of Energy	– Fuel and energy use data
Desert Reclamation Industries Inc.	– Aquifer thermal storage consultant

In the course of Phase 2 of this district heating study, meetings, briefings and consultations have been held with the following groups, to inform them about the potential benefits of district heating, and to solicit their input:

PSE&G Senior Management

New Jersey Board of Public Utilities

New Jersey Department of Energy

New Jersey Department of Environmental Protection

New Jersey Department of Labor & Industry Office of Boiler and Pressure Vessel Compliance

Bergen County Utilities Authority (Sewage and MSW authority)

Hackensack Meadowlands Development Commission

Newark Redevelopment and Housing Authority

Summit Plaza (Former "Operation Breakthrough" Total Energy housing Complex)

Hartz Mountain Industries, Inc.) Land developers in the

Bergen County Associates) Hackensack Meadowlands

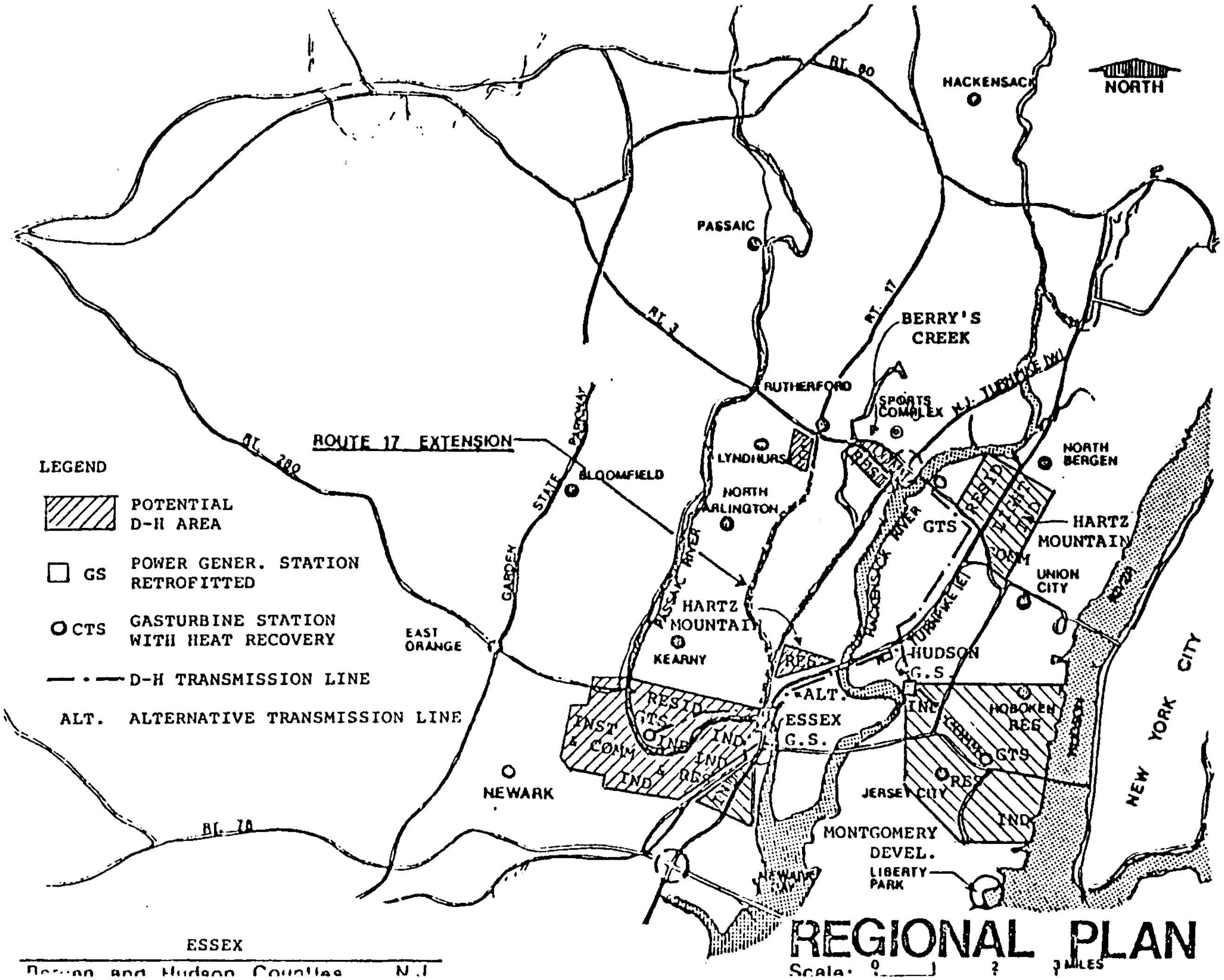
Various potential sources of venture capital for "third-party" energy projects

LOAD AND SERVICE AREA ASSESSMENT

The Phase 1 study identified the high-density population areas within the Company's supply territory. It ended up recommending the concentration of further efforts on the Newark-Jersey City-Hackensack Meadowlands triangle. See Figure 2.1.

The Phase 2 work proceeded in that direction. First a service area assessment was based on industrial/commercial directories and on statistical data. For the Hudson G.S., the Jersey City/Hoboken area and the developing Hackensack Meadowlands area (including Secaucus and parts of Lyndhurst) were evaluated, all within 3-4 miles of the plant. For Essex, the Newark/Harrison area was investigated, also within 3 miles. The results:

	Million BTU/hr.	
Jersey City/Hoboken		
-industrial commercial	135	
-high-rise residential	375	
-low-rise residential	2000	2510



HACKENSACK
NORTH
RT. 80
PASSAIC
RT. 3
RT. 17
BERRY'S CREEK
RUTHERFORD
SPORTS COMPLEX
N.J. TURNPIKE
ROUTE 17 EXTENSION
LYNDHURST
BLOOMFIELD
NORTH ARLINGTON
NORTH BERGEN
HARTZ MOUNTAIN
UNION CITY
GTS
LEGEND
POTENTIAL D-H AREA
GS POWER GENER. STATION RETROFITTED
CTS GASTURBINE STATION WITH HEAT RECOVERY
D-H TRANSMISSION LINE
ALT. ALTERNATIVE TRANSMISSION LINE
GARDEN STATE PARKWAY
RT. 280
EAST ORANGE
HARTZ MOUNTAIN
KEARNY
HUDSON G.S
ALT.
ESSEX G.S.
HOBOKEN
NEW YORK CITY
NEWARK
JERSEY CITY
RT. 78
MONTGOMERY DEVEL.
LIBERTY PARK
ESSEX
REGIONAL PLAN

Fig. 2.1

Meadowlands		
-new developments	370	
-existing industrial/commercial	40	410
Sub-total		2920
-Kearny area new development	270	
Newark/Harrison		
-industrial/commercial	900	
-high-rise residential	100	
-low-rise residential	2400	3670
TOTAL		6490

These figures do not account for additional potential users as

- heating of public buildings
- heat for process use

The capability of the Hudson No. 2 unit is more than sufficient to provide heat for the total potential market in the Jersey City–Hoboken–Hackensack Meadowlands area within its 10 year development. It is also capable of providing 62% of the potential heat use in both areas combined, including heat derived from intermediate gasturbine plants and from peaking heater plants.

The regional plan (Figure 2.1) shows not only the supply area which was found promising, but also the transmission mains and the approximate locations of logical intermediate stage gasturbine stations with heat recovery. The fully developed size of these stations at this point can be estimated to be:

Newark - if supplied by Essex	40 MW
- if supplied by Hudson	100 MW
Jersey City	60 MW
Meadowlands	20 MW

It was found later that for the area in question a combustion turbine unit in place at Kearny, with a capacity close to the aggregate capacity of the above-listed individual units, presents an attractive alternative.

A number of small boiler plants will be connected to these gasturbine facilities. Their total installed capacity could be roughly four times the gasturbine plant capacity in megawatt heat equivalent.

Additional data have been collected also by a number of direct survey methods. Questionnaires (see Exhibit 1) had been sent to 280 selected potential customers to find what kind and how much fuel is consumed and in what final form the heat is transmitted. The results show a split of approximately 45% gas and 55% oil of different types is fired by these enterprises. Nearly 45% of the non-residential customers have steam systems and 70% of these operate at or below 15 psig send-out pressure. The share of steam systems in the overall customer pool is an important consideration because it can materially affect the sizing and operation of an HTW system.

Another survey of 41 industrial plants in Newark and Jersey City established heating and cooling loads and fuel usage. The plants surveyed have an hourly peak fuel consumption of approximately 600 x 10^6BTU/hr at 17 locations in Newark and approximately 130 x 10^6BTU/hr at 24 locations in Jersey City. The plants so surveyed include such high fuel use activities as food processing, chemicals, glass and textiles.

HEATING, COOLING, AND DISTRICT HEATING QUESTIONNAIRE

Name of firm ______________________ Questionnaire # ______________________
Address ______________________ Date ______________________
______________________ Person interviewed ______________________
______________________ Interviewer ______________________

CUSTOMER CLASS

(A) Residential ☐ (C) Commercial ☐
(B) Multiuse ☐ (D) Industrial ☐

Gas customer account #(s) ______________ Gas rate schedule(s) ______________
Electric customer account # ______________ Electric rate schedule ______________

1. Customer Information — Code # 1 ☐☐☐☐☐☐☐☐☐☐☐ 11

Manufacturing (M) — Product manufactured ______________
Apartments (A) — No. of dwelling units ______________
Office (F)
Warehouse (W)
Retail establishment (R)
Other (O), including multiuse, specify ______________ 12 ☐
Total building floor area (1,000 sq. ft.) ______________ 13 ☐☐☐☐☐ 17
Heated floor area (1,000 sq. ft.) ______________ 18 ☐☐☐☐☐ 22
Daily occupancy (hours) ______________ 23 ☐☐ 24
Weekly (hours) _______ 10-40(A) 41-80(B) 81-120(C) 121-168(D) ______________ 25 ☐
Number of boiler and cooling plant operators ______________ 26 ☐☐☐ 28

2. Fuel Consumption for the Twelve Months Ending December 1980

	Amount	Annual Bill ($1,000)	Used For*
Natural gas (1,000 therms)	29 ☐☐☐☐ 32	33 ☐☐☐☐ 36	☐ 37
Fuel oil (1,000 gal.) #2	38 ☐☐☐☐ 41	42 ☐☐☐☐ 45	☐ 46
#4 or #5	47 ☐☐☐☐ 50	51 ☐☐☐☐ 54	☐ 55
#6	56 ☐☐☐☐ 59	60 ☐☐☐☐ 63	☐ 64
Electricity (1,000 kwh)	65 ☐☐☐☐ 70	71 ☐☐☐☐ 74	☐ 75

Other fuel type ______________ Consumption ______________ Unit ______________

* H = Space heating P = Process W = Domestic water heating G = General (specify % of each type of use) 80 ☐1

Has this consumption changed over the previous 12 months?

Yes ☐ No ☐ Percent change _____ %

Reason for change ____

____

Comments: ____

____

____

____

EXISTING EQUIPMENT

3. Heating Equipment — Code # ☐☐☐☐☐☐☐☐☐☐☐ (1–11)

How is the heat supplied to the rooms?
- Steam (S) ________ ☐ 12
- Hot water (W) ________ ☐ 13
- Other (O), specify ________ ☐ 14

How is the heat produced?

	Type	Output MMBtu/hr
Steam boiler (S) ________	☐ 15	16 ☐☐ 17
Hot water boiler (W) ________	☐ 18	19 ☐☐ 20
Direct-heated hot air furnace (A) ________	☐ 21	22 ☐☐ 23
Electric (E) ________	☐ 24	25 ☐☐ 26

Age of equipment - (A) 1-10 years (B) 10-20 years (C) over 20 years ________ ☐ 27

If steam, is system operated at 15 psig or below? Yes (Y) No (N) ________ ☐ 28

If yes, level of operation in psig ________ 29 ☐☐ 30

Comments: ________

____

4. Cooling Equipment

Type of use (check all applicable)

Comfort ☐ Computer ☐ Process ☐ Refrigeration ☐

Total cooling tonnage ________ 31 ☐☐☐☐ 34

Total absorption tonnage ________ 35 ☐☐☐☐ 38

Average age of absorption equipment in years ________ 39 ☐☐ 40

Comments: (specify refrigeration and process tonnage and temperature)

____

____

5. Process Steam or Hot Water

If steam pressure is at 15 psig or below, supply annual usage in million lb. ________ 41 ☐☐☐ 43

If hot water, supply the following:

Temperature (°F) ________ 44 ☐☐☐ 46

Flow rate during operating hours (gal./hr.) ________ 47 ☐☐☐☐ 50

Is water recycled? ____ Yes (Y) ____ No (N) ________ 51 ☐

If yes: Percent of recycling ________ 52 ☐☐ 53

Temperature of recycled water ________ 54 ☐☐☐ 56

Type of Operation ____ Seasonal (S) ____ Year Round (R) ________ ☐ 57

Annual average operating hours ________ 58 ☐☐☐☐ 61

Type of steam end use, describe: ________

____

6. Domestic Water Heating

Type of distribution system ____ Central (C) ____ Individual (I) ________ 62 ☐

Boiler type: Direct fired (F)________ Steam from other systems (S)
Hot water from other systems (W) ____ Electric (E) ________ ☐ 63

Size of total storage capacity (in 100 gal.) ________ 64 ☐☐☐ 66

Water temperature ________ 67 ☐☐☐ 69

Annual use (1,000 gal.) ________ 70 ☐☐☐☐☐ 74

Maximum hourly use (gal.) ________ 75 ☐☐☐☐☐ 79

Comments: ________

____

FUTURE PLANS

7a. Short Term Code # 1 ☐☐☐☐☐☐☐☐☐☐ 11

Based on current operation and knowledge, are there any firm plans for change of equipment or amount of fuel use in the next six months to one year? ________ Yes (Y) ________ No (N) ________ ☐ 12

Is all or part of the change operational? Yes (Y) ________ No (N) ________ ☐ 13

If yes, describe and give reasons for the change:

____

____

Does this represent an increase (I) or decrease (D) in fuel use? ________ ☐ 14

percent of change ________ 15☐☐ 16

If change in equipment is anticipated, please describe below.

Type Heating, Cooling, Process (H) (C) (P)	Equipment Description	New Equipment Estimated Cost ($1,000)	Addition (A) Removal (R)	Annual Fuel or Energy Use	Units*	Type*
17☐	________	18☐☐☐☐ 21	22☐	23☐☐☐☐☐ 27	28☐	29☐
30☐	________	31☐☐☐☐ 34	35☐	36☐☐☐☐☐ 40	41☐	42☐
43☐	________	44☐☐☐☐ 47	48☐	49☐☐☐☐☐ 53	54☐	55☐

*Units
T = thousands of therms
G = thousands of gallons
K = thousands of kwh

*Type of Fuel
N = Natural gas
O = Oil
E = Electricity

Comments: ____

____

7b. Long Term

On a long-term basis, what increase (decrease) do you expect in the next two to five years?

	Amount	Units (P-F)
Building Floor Space % Growth (P) or 1,000's of sq. ft. (F) ________	56☐☐☐☐ 59	☐ 60
Increase (I) ________ Decrease (D) ________		☐ 61

Do you anticipate any changes in the heating, cooling, or process equipment?

Yes (Y) ________ No (N) ________ ☐ 62

If yes, describe below

Type (Heating, Cooling, Process)	Equipment Added (Removed)	Approximate Annual Energy Requirements (Specify Units)	Cost of Equipment ($1,000)	Year of Change
________	________	________	________	________
________	________	________	________	________

8. What is the payback period or return on investment required for fuel and energy related investments

________ Years 63☐☐ 64 ________ % 65☐☐ 66

9. Are you able and willing to eliminate the boiler operator position?

Yes (Y) ________ No (N) ________ Don't Know (D) ________ 67☐

10. Can you provide your daily or annual thermal energy consumption curves for your building?

Yes ________ No ________

Information attached ________ Will follow ________ [3] 80

Other Comments: ____

____

11. Do you now, or will you in the future, generate electricity?

Yes ________ No ________

If yes, describe equipment used.

	Maximum Hourly Kw	Annual Mwh
Engine	________	________
Gas turbine	________	________
Steam turbine	________	________

12. Estimate your annual usage of energy for the next ten years (or annual growth rate (decline) in energy usage)

____

13. <u>For Campus Type Projects Only</u>

Number of buildings ________________

Heat distribution media-steam ______ psig, hot water supply ____ | return ____ °F/°F

Heat user pressure, temperature
in buildings – steam __________ psig, hot water ____ | ____ °F/°F

Distribution piping -	Total length __________ ft.
	Max. dia. ____________ in.
In-house connection -	Direct ☐ ______ indirect, with heat extractor ☐
Domestic hot water -	Central ☐ individual building ☐
Average age of system -	Central plant ______ yr.
	Distribution ______ yr.
	In-house systems _______ yr.

An additional effort was made to identify and assess the impact of new developments. The Hackensack Meadowlands is one of the areas being developed. There are four major developments planned in Jersey City and one in Kearny. The Newark area has no firm major plans. The Housing Authorities of both Jersey City and of Newark have urgent needs in renewing plant and heating systems of their existing housing stock. In Jersey City there are several major new developments in their initial stages.

TECHNICAL CONSIDERATIONS

The Phase 2 (Detailed Feasibility) District Heating Study concentrated on the Hudson General Station because of its proximity to the concentrated Jersey City and Newark load areas and the new developments planned for the Hackensack Meadowlands. The coal-fired Hudson Unit No. 2 was used as the study basis of a large, regional district heating system for northeastern New Jersey.

To keep capital investment in step with revenues, the staged development of district heating on the European model was adopted. Local heating/cogeneration plants in dispersed areas showing high thermal-load concentrations would be built initially. They would be interconnected first with each other; later with a heating/ cogeneration plant of larger magnitude, the 196 MWe Kearny No. 12 combustion turbine complex; and/or with the 600 MWe Hudson Unit No. 2.

The potential for district heating was examined in terms of the total system and two subsystems of overlapping scales:

A. The total system (3.7×10^9BTU/hr peak) based on Hudson Unit No. 2, Kearny Unit No. 12 and local gas-fired heating and cogeneration plants built up in staged development on the European model.

B. A major district heating site (200×10^6BTU/hr peak) based on a new development or an existing urban housing complex, using landfill gas, natural gas or limited steam extraction from Hudson Unit No. 2.

C. A mini district heating site (on the order of 10 x 10^6BTU/hr peak) based on "stand-alone" cogeneration facilities serving a small number of apartment buildings, and fueled by waste gas, natural gas, or wastes.

The following exhibits, as an introduction to the technical details presented, summarize the highlights of the Phase 2 study.

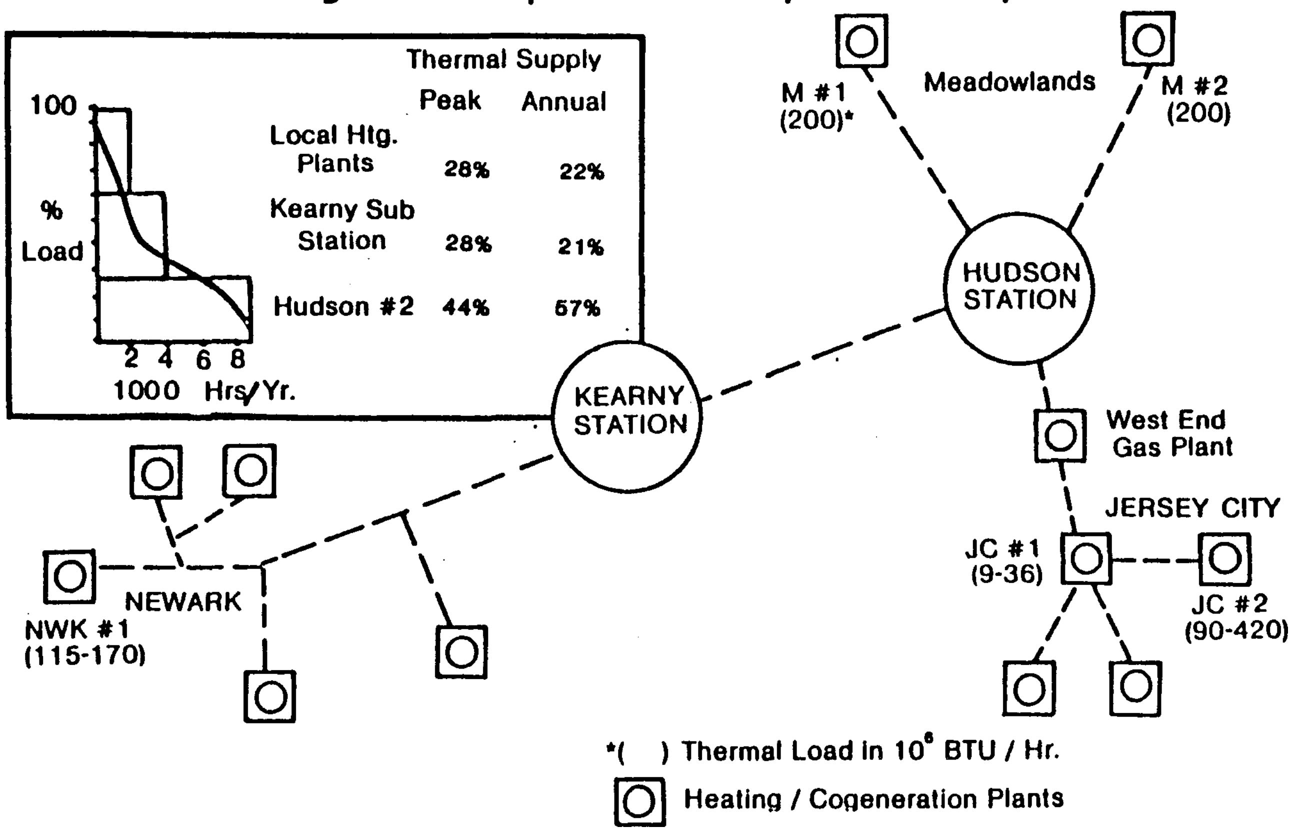
From the perspective of energy efficiency and use of low cost fuel, the staged development of district heating offers the greatest advantages after all the interconnections with the main thermal source (e.g. power plant) are completed. To facilitate the transition from one stage to another, the development of dispersed district heating/cogeneration sites need to be coordinated. The specifications of the thermal sendout from each site are to fit into an overall plan so it can be eventually interconnected properly into a district heating grid. The investigations completed addressed this aspect, as well as the individual plant design problems in a detailed and conservative manner in line with standard utility practice.

PEAKING AND BACK-UP PLANTS
(Initial Development Phase of a Staged System)

The district heating development plan identified potential service areas. Within those, customers will materialize on a random and one to few-at-a-time basis. Particularly new construction has to be supplied as its schedule dictates. The method to meet these objectives in an economical way is to provide heat from a nearby and relatively low first cost installation. The "HTW heater plant" is such a facility.

The second, at least as important function of these plans is to provide back-up heat supply capability to the system at a low first cost. The location of these plants in the midst of major load concentrations provides stand-by capability not only for loss of generating capacity but also for loss of transmission lines and/or pumps.

Staged Development and Dispatch Concept



DH SYSTEM TECHNICAL HIGHLIGHTS

SYSTEM AND SUBSYSTEMS	Thermal Capacity Btu/hr* (Peak)	Equivalent Heating Load # Typical Dwellings
A Total DH System	$3,700 \times 10^6$**	185,000
B Major DH Site	200×10^6	10,000
C Mini DH Site	10×10^6	500

THERMAL SOURCES

A - Hudson 2 Steam Unit - 600 MW_e (electric capacity without DH) Coal Fired
Peak DH Output - $1,600 \times 10^6$ Btu/hr (86 MW_e derating by DH use)

- Kearny 12 Gas Turbines (GT) - 196 MW_e Oil/Gas Fired
Peak DH Output - $1,100 \times 10^6$ Btu/hr

B - Package Boilers - 50×10^6 Btu/hr Unit Gas Fired
Peak DH Output - 200×10^6 Btu/hr with 25% back-up

C - Cogeneration Units -(1.2×10^6 Btu/hr + 316 KW_e) /Unit
Types - Diesel, IC Engine, Combustion Turbine
Peak DH Output - 1.2×10^6 Btu/hr/Unit base load
10×10^6 Btu/hr peak thermal load (Multi-Unit)

*3.4×10^6 Btu/hr = $1MW_{th}$
**Annual load: 8.8×10^{12} Btu

THERMAL EXTRACTION

A - Hudson 2 - Steam extraction at IP/LP Crossover (80 psia)*
- Hot Water Sendout: 223°F, Return: 165°F (Peak Load)

Kearny 12 - Heat recovery from exhaust gases
- Hot Water Sendout: 261°F

B - Package Boilers - Hot Water Sendout: 293°F

C - Cogeneration Units - Hot Water Sendout: 290°F (Nominal)

THERMAL CONVEYANCE

Transmission piping: 16" - 42" diameter; 118,600' length
Carbon Steel/Polyurethane/Polyethylene

Distribution piping: 1 1/2" - 12" diameter; 984,000' length
Carbon Steel (primary) and PVC (Secondary)/Foam glass or Polyurethane/Polyethylene

Hydraulic pressure in grid: 70 - 230 psig

DH Flow Rate: 58,700 gpm

*Expanded to 30 psia and 12 psia through turbines for 2-stage heating.

DH SYSTEM TECHNICAL HIGHLIGHTS - (Continued)

CUSTOMER'S SITE*

Hot Water: Space Heating and domestic uses
20,000 Btu/hr per typical dwelling
ΔT_{lm} (DH loop - User's loop) = 56°F

Cooling: 1.5 tons of refrigeration per typical dwelling
35 x 10^3 Btu/hr at 230 - 290°F for absorption cooling

Steam: 8.5 psig steam from 243°F DH water
Higher steam grades with on-site heat pump

*Typical Dwelling Assumptions
Heating: Outside T = 0°F, inside T = 70°F, 5200 Heating Degree Days
Cooling: Outside T = 77°F Wet Bulb, Inside T = 75°F, 1100 Cooling Degree Days
94°F Dry Bulb
Domestic Hot Water: 140°F year round

The number and size of these plants were defined on the basis of the total heat supplied in the future. Twenty-eight percent of total system output, that is 3.7 x 10^9 x .28 = 1.036 x 10^9BTU/hr, was the total capacity of all plants. The supply area to be covered by any one of the plants is about one square mile and the total area within the proposed boundaries is about 11 square miles. On this basis, 11 of the heater plants will be required. The average minimum capacity requirement of 94 million BTU/hr has been increased to 100 million for areas of lower and to 120 million for areas of higher load concentrations.

The stand-by capability of the system will also be provided in the form of fired hot water heaters. The required total maximum back-up is to replace the output of Hudson No. 2 unit extraction providing up to 1600 million BTU/hr. Therefore each heater plant installed capacity will be double the output calculated above, or 2400 million BTU/hr total installed capacity.

The average plant size thus proposed is then

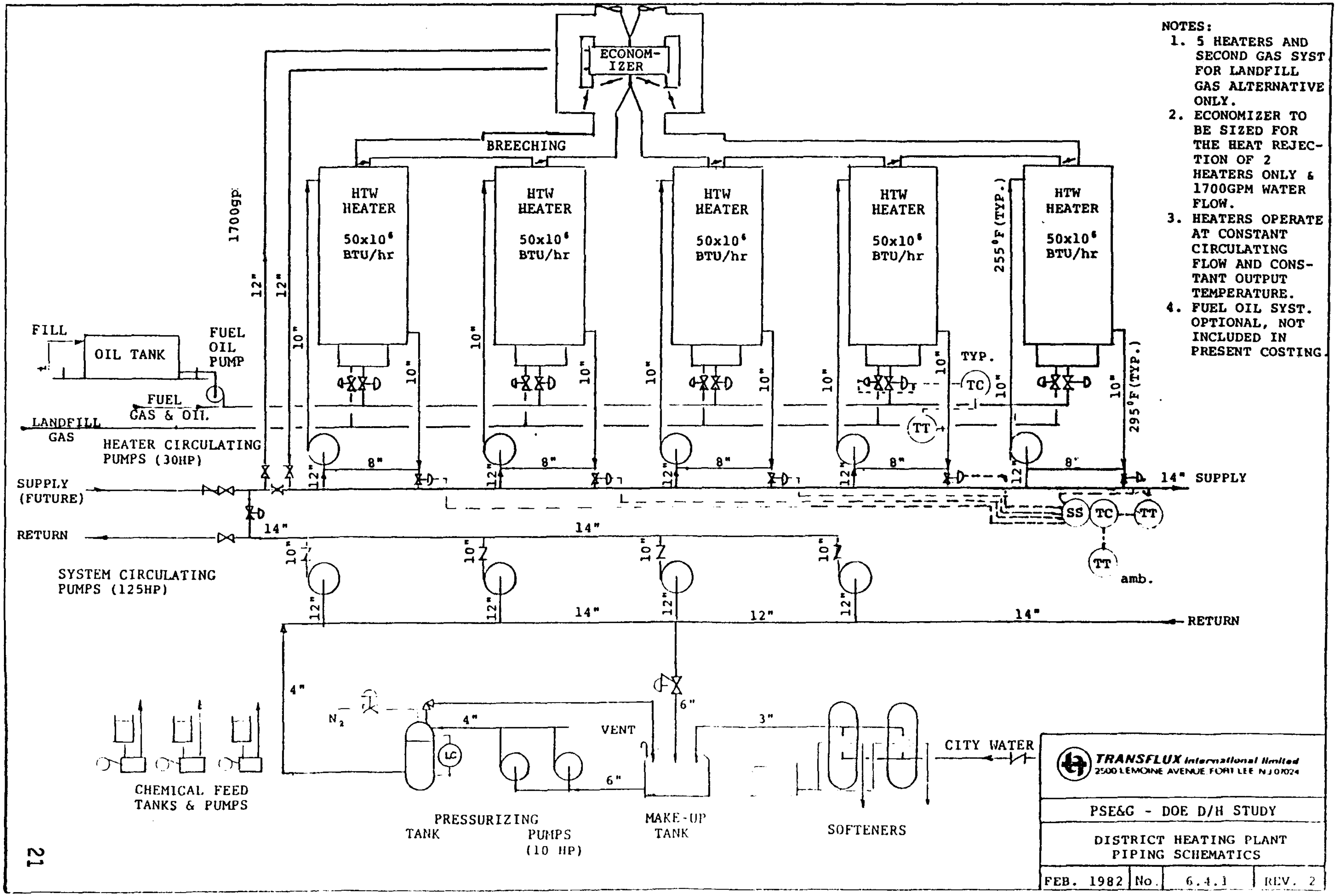
5 plants of 240 million BTU/hr (Newark)
and 6 plants of 200 million BTU/hr (other)

total, normal heat output capacity.

No plant will be built with less than two units installed initially. One of these will be stand-by.

Drawing 6.4.1 shows schematically the equipment and piping of a typical plant.

Each high temperature water heater has its own circulating pump. It is sized to circulate at a flow of water in excess of that circulated in the district heating system. The units are controlled to maintain a constant set outlet temperature of about 307°F. The fuel input is controlled by that temperature. The units are natural gas fuel fired watertube packaged units with their own forced draft fan,



NOTES:
1. 5 HEATERS AND SECOND GAS SYST FOR LANDFILL GAS ALTERNATIVE ONLY.
2. ECONOMIZER TO BE SIZED FOR THE HEAT REJECTION OF 2 HEATERS ONLY & 1700GPM WATER FLOW.
3. HEATERS OPERATE AT CONSTANT CIRCULATING FLOW AND CONSTANT OUTPUT TEMPERATURE.
4. FUEL OIL SYST. OPTIONAL, NOT INCLUDED IN PRESENT COSTING.
ECONOMIZER
BREECHING
HTW HEATER 50x10⁶ BTU/hr
1700gp
255°F (TYP.)
295°F (TYP.)
TYP.
TC
TT
SS
amb.
FILL
OIL TANK
FUEL OIL PUMP
FUEL GAS & OIL
LANDFILL GAS
HEATER CIRCULATING PUMPS (30HP)
SUPPLY (FUTURE)
RETURN
14" SUPPLY
SYSTEM CIRCULATING PUMPS (125HP)
RETURN
CHEMICAL FEED TANKS & PUMPS
N2
VENT
CITY WATER
PRESSURIZING TANK
PUMPS (10 HP)
MAKE-UP TANK
SOFTENERS
TRANSFLUX International limited
2500 LEMOINE AVENUE FORT LEE NJ 07024
PSE&G - DOE D/H STUDY
DISTRICT HEATING PLANT PIPING SCHEMATICS
FEB. 1982
No. 6.4.1
REV. 2

ignition and combustion controls and safeties mounted on individual panels associated with each unit.

A control valve in each heater circuit mixes the flow from the district heating system to that of the heater in accordance with the supply temperature required momentarily by the users. This temperature is controlled by the ambient temperature.

Drawing 6.4.2 shows the layout of the plant.

The plant is located in an 80 x 100 ft., approximately 20 ft. high single story building or space.

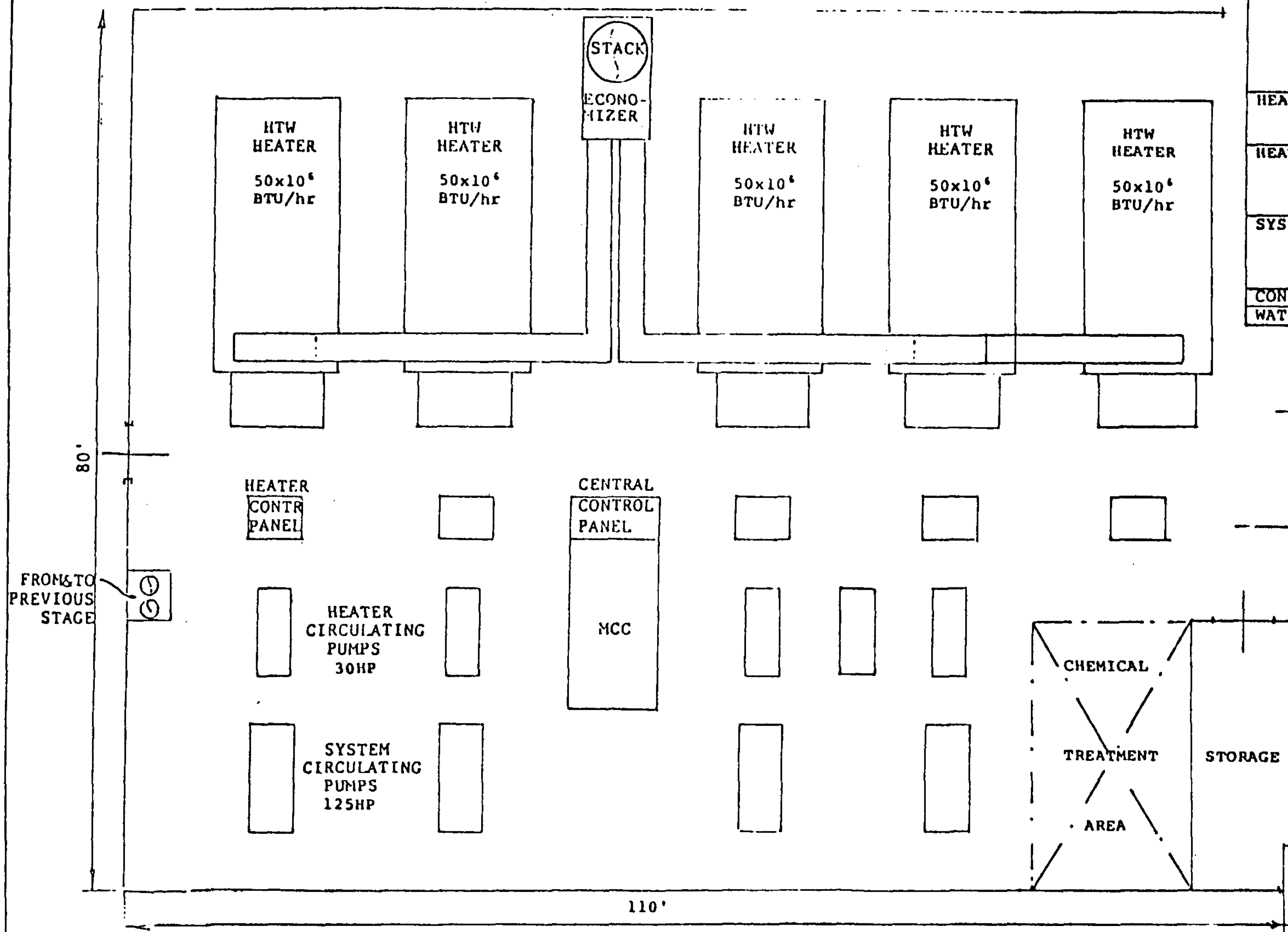
The tabulation on the referred drawing shows the required equipment sizes in the different potential supply areas.

These plants will be built in two or three steps. The first step includes at least two units and the treatment plant. Further units can be added one by one or the other two also in one step. Building construction should be completed in the first step. The prefabricated building cost probably does not warrant a second building phase.

The two-unit plant can be completed within a year. Where speed is necessary, the availability of heaters and pumps will define the shortest possible construction time.

The required total installed power supply capacity is 800 kW for the smaller and 950 kW for the larger plants plus some 20 kW for utilities and yard lighting.

The electrical load when the heater plant is in operation and when the users have reached the total capacity of the heater is as follows:



	MEADOWLAND	JERSEY CITY	NEWARK
HEATERS-TOTAL	200	200	240
-UNIT	50	50	60
10^6 BTU/HR	50	50	60
HEATER CIRC.	1300	1300	1300
PUMP - GPM	1300	1300	1300
- ΔP	30	30	30
- HP	35	35	35
SYSTEM CIRC.			
PUMP - GPM	1100	1100	1100
- ΔP	150	150	150
- HP	125	125	150
CONN. LOAD MW	.8	.8	.95
WAT. TREAT'T-GPM	50	50	60

NOTES:

1. 5 units for landfill gas operation only.
2. 4 units in conjunction with Hudson G.S. retrofit. Length of bldg. to be 100'.

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PSE&G - DOE D/H STUDY

DISTRICT HEATING PLANT LAYOUT

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	heaters operating		
	1	2	4
heater circ. pump	35	70	140
F.D. fan	30	60	120
system circ. pump	375	375	375
make-up	10	10	10
contr. & light	20	20	20
	470 HP	535 HP	665 HP
or approx.	350 kW	400 kW	500 kW

INTERMEDIATE STAGE PLANTS(S) (GASTURBINE)

Random load development met originally by "heater plants" reaches a point in time when further extension of those plants is not practical and/or economical. At this point of the D–H system growth a gasturbine plant with heatrecovery facilities will provide cogeneration of heat and electric power and therefore a cheaper source of heat than the heater plants. Since it is a less expensive source of heat, it will take over the supply of base heat load while the heater plants will supply peaks and act as stand–by.

The large multi–turbine units at Essex and Kearny were targeted for this purpose. Essex units #10 and #11 and Kearny unit #12 are Pratt & Whitney, so–called "Twin–Pac" combustion turbine generators. Each of two 22MW ISO combustion turbines drive a common 50MVA generator and four pairs of them form a unit. Their combined rating is 170–196MW. The units at Essex have dual fuel capability––gas or oil–– while the Kearny unit is gas fired only. There are slight differences in the models used. The Model C turbine at Kearny has a higher efficiency than the Model A at Essex and also a better reliability record. Partly for this reason, but mainly because of its location, the Kearny No. 12 unit has been included in the final development scheme of the D–H system.

The unit ISO rating is 8 x 22 MW = 176 MW, but it is capable of generating 196 MW in the winter, when most of its use as part of the D–H system is concentrated Its heat rate is 13500 BTU/kWh at rated conditions. With the attachment of a heat–recovery section, imposing about 6" W.G. pressure drop, plus duct losses, the heat rate will increase and the total output decrease somewhat. The calculated recoverable heat from the unit at full load was established as 1100 x 10^6BTU/hr.

Figure 6.3.2 shows the proposed layout based on Twin–Pac (Pratt & Whitney) units.

The unit, as is, is a basically outdoor installation with the components in their customary service enclosures. The heat recovery heat exchangers will stand elevated above the electrical rooms. Freeze protection has to be provided in the form of electric heaters and small circulators.

The main controls and supervisory equipment along with the circulating pumps are located in a prefabricated building with minimal heating for freeze protection. The present location is in the middle of a large, free yard area, some distance away from the main plant and other equipment.

The existing exhaust ducts and silencers will be left in place and serve as by–pass. The damper layout allows normal operation without heatrecovery, or maintenance, of one unit while the other is operating.

Figure 6.3.3 shows the proposed piping schematics of the plant.

The plant is piped to two 36" returns. One from the Newark, the other from the Jersey City area. Similarly two supply lines leave connecting to these areas. At the final stage of system development, as the Hudson plant is retrofitted for D–H, an additional 36" line combined with the line serving previously as the Jersey City

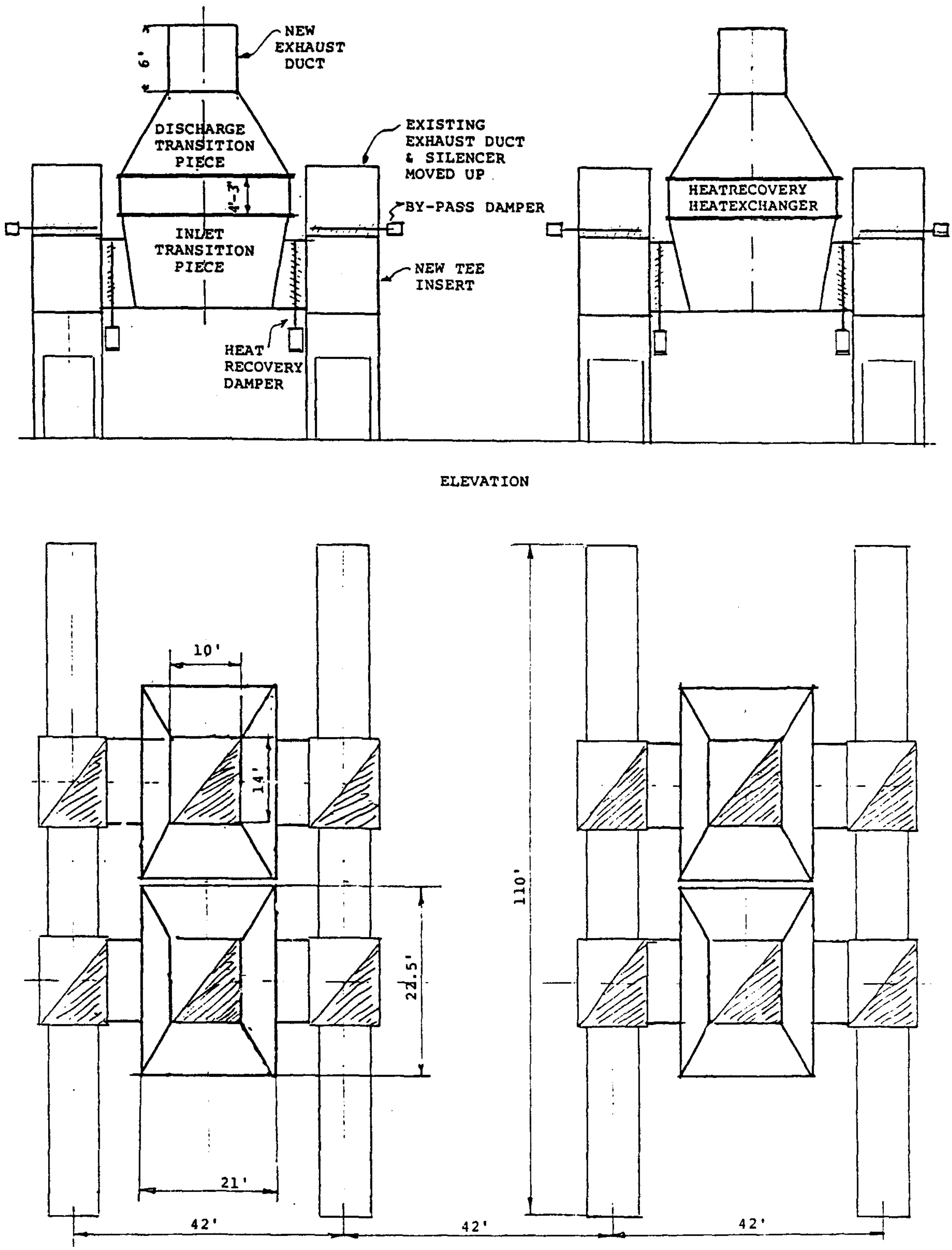

FIG. 6.3.2

No scale

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PSE&G-DOE D-H STUDY

KEARNY #12 COMBUSTION
TURBINE RETROFIT
LAY-OUT

NOV. 81	NO.		REV. 0

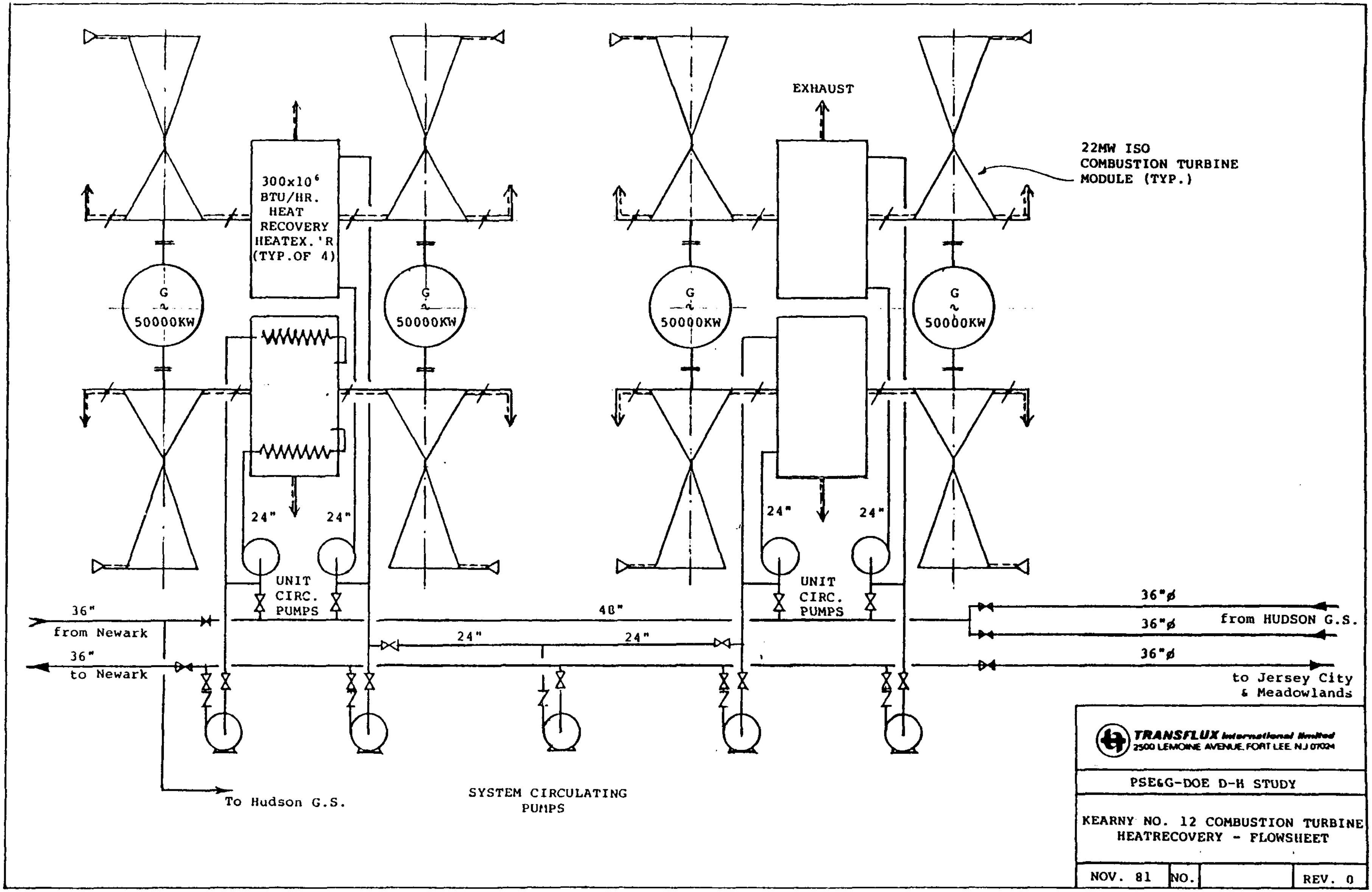

300x10⁶
BTU/HR.
HEAT
RECOVERY
HEATEX.'R
(TYP.OF 4)
EXHAUST
22MW ISO
COMBUSTION TURBINE
MODULE (TYP.)
G
50000KW
24"
UNIT
CIRC.
PUMPS
36"
from Newark
36"
to Newark
48"
36"ø
from HUDSON G.S.
to Jersey City
& Meadowlands
To Hudson G.S.
SYSTEM CIRCULATING
PUMPS
TRANSFLUX International limited
2500 LEMOINE AVENUE, FORT LEE, NJ 07024
PSE&G-DOE D-H STUDY
KEARNY NO. 12 COMBUSTION TURBINE
HEATRECOVERY - FLOWSHEET
NOV. 81
NO.
REV. 0

FIG. 6.3.3

return will bring the total flow to this plant but there will be no change in the supply lines. Should Hudson come on line, partially or fully retrofitted before this unit is incorporated into the system, the two lines may be replaced by a single 42" dia. connection. At that point the return from Newark by-passes this plant as it is directed straight towards Hudson.

The unit circulating pumps are sized to match the heat exchangers and each handles one-quarter of the total flow. A fifth pump acts as a stand-by. The pump head is to match the pressure drop of a heat exchanger. The system circulating pumps are sized to provide for that of the piping (supply and return) between this plant and the farthest of the heater plants it connects to.

The selected gasturbines are in position, so manufacture and installation of the heatrecovery units and pumps will set the time requirement for construction.

Presently those are available on a 26–30 week basis and another 8–12 weeks is needed for their installation. Therefore this facility can be constructed within a year from the placement of equipment orders.

HUDSON GENERATING STATION RETROFIT

The retrofit concept is based on extracting steam from turbine cross-overs to heat district heating water. Back-pressure turbines are used to reduce the pressure of the extracted steam to the required heater pressure. This approach minimizes electrical capacity losses of the units during district heating operation and avoids major retrofitting of the existing turbines. The retrofitted units retain the ability to operate near their peak electrical generating capacity when there is no district heating load.

The study started with conceptual engineering and cost estimate for retrofitting Hudson Units 1 and 2 and Essex Unit 1 to provide district heating water heating capability at the two stations. The technical feasibility of extracting steam from the turbine cross-overs was investigated by Westinghouse Electric Corporation and

General Electric Company, the turbine suppliers for the Hudson and the Essex units respectively, through study contracts awarded by PSE&G. The study of heat cycle modifications, development of conceptual design, and cost estimating of the plant retrofits were undertaken by Stone & Webster Engineering Corporation. No attempt has been made in optimization or to work out engineering details.

The results of the studies show that the retrofit concept described in this report is technically feasible, and that there is sufficient space available at both the Hudson and the Essex Stations to accommodate the added equipment and piping within reasonable distance from the existing units. The study also shows that the described retrofit scheme with new back-pressure turbine-generators is the preferred choice over an alternate scheme with no back-pressure turbines.

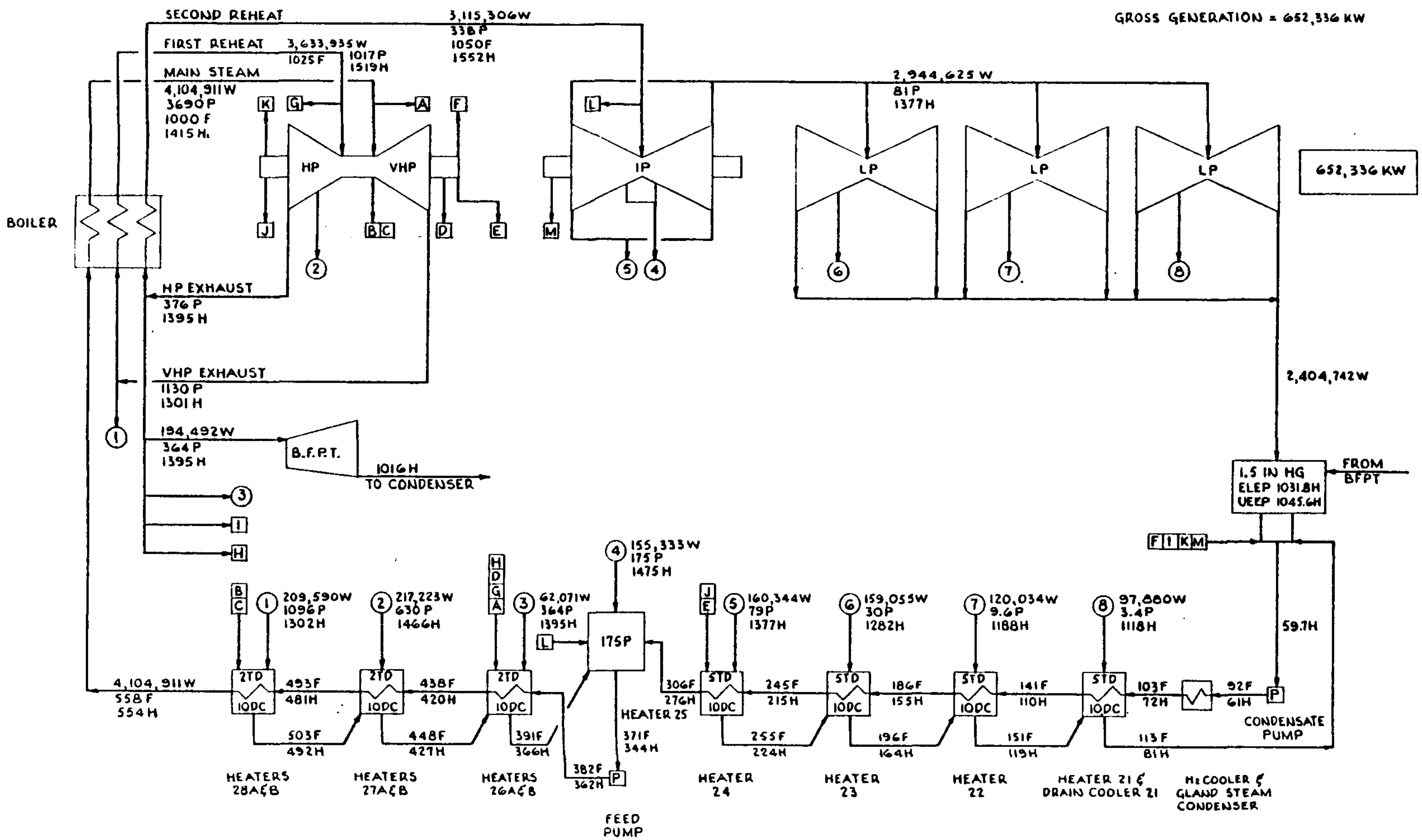
During the early stage of the Phase 2 Study, Hudson Unit 1 was removed from consideration by PSE&G because of the difficulty of routing steam and condensate pipings through Unit 2 to the new water heating plant, to be located east of Unit 2. Some time later, Essex Unit 1 was also removed from the study by PSE&G. The following pertain only to Hudson Unit 2.

Hudson Unit 2 is a coal fired unit. It was placed in service in 1968. The unit has a random-compound six-flow turbine built by Westinghouse Electric Corporation. The turbine nameplate rating is 620 MW. This rating includes power developed in the feed pump turbines. Rated steam conditions at the main turbine are 3500 psig and 1000°F, with reheat to 1025°F and 1050°F. Steam to this turbine is supply by a once-through supercritical-pressure steam generator. The maximum guaranteed turbine throttle flow is 3,704,643 pounds per hour at the rated steam conditions. With valves-wide-open and five-percent over-pressure, the turbine could pass a flow of 4,105,000 pounds per hour. Two half-size boiler feed pumps are driven by auxiliary turbines, powered by steam taken from the high-pressure turbine exhaust. Two half-size motor driven boiler feed booster pumps are also provided. The condenser has two separate welded steel shells. Each shell receives its cooling water from its respective circulating water pump. There are no cross connections between the circulating water pumps and the shells, nor are there connections between the shells except the common connection to the LP turbine exhaust hoods. Two new vacuum pumps have been installed recently. The vacuum pumps have sufficient capacity to maintain the condenser pressure at 0.6 Inch Hg. absolute during low load. A full flow condensate polisher is provided upstream of the secondary condensate pump suction. The polisher has four mixed-bed units, one of which serves as a standby. The heat cycle has eight stages of feedwater heating. There are four low pressure heaters and an external drain cooler upstream of the deaerator. There are three pairs of high pressure heaters in two parallel trains downstream of the boiler feed pumps.

Figure 6.2.4 shows the heat balance of the unit operating at maximum throttle flow with no steam extraction from the cross-overs. The gross generation in the figure is 652 MW. The maximum test output of Hudson Unit 2 was 651.4 MW gross. Presently the capacity of the unit is limited at 625 MW gross and 600 MW net due to the limitation on particulate emissions imposed by the state operating permit.

Hudson Unit 2 does not come down on load except during weekends, and two hours each night to deslag the boiler. During these periods, the unit operates at the minimum load of 300 MW. In the future when new pulverizers will be installed and additional nuclear generating capacity will be available in the PSE&G system, the minimum load for Hudson Unit 2 will be reduced to 150 MW.

The recommended retrofit scheme for Hudson Unit 2 involves the modification of the existing turbine cross-overs with the installation of two butterfly pressure control valves and the connection of two extraction steam lines to the cross-over pipes upstream of the valves. See Figure 6.2.1. The steam lines will supply steam from the cross-overs to two new back-pressure turbine-generators. Steam exhaust from the turbines is condensed in district heating water heaters which provide two stages of heating of the district heating water. Drains from the heaters are cooled in an external drain cooler before returning to the condenser. New heater drain pumps are provided to pump the heater drains from the district heating water heaters. A new feedwater heater train, to be installed in parallel to the existing low-pressure feedwater heaters, will share the feedwater heating load during district heating operation.



LEAKAGES	
A. 41,049W	H. 18,371W
B. 102,769W	I. 3,024W
C. 43,339W	J. 4,258W
D. 62,318W	K. 1,718W
E. 4201W	L. 15,347W
F. 1710W	M. 2,570W
G. 17,472W	

KEY

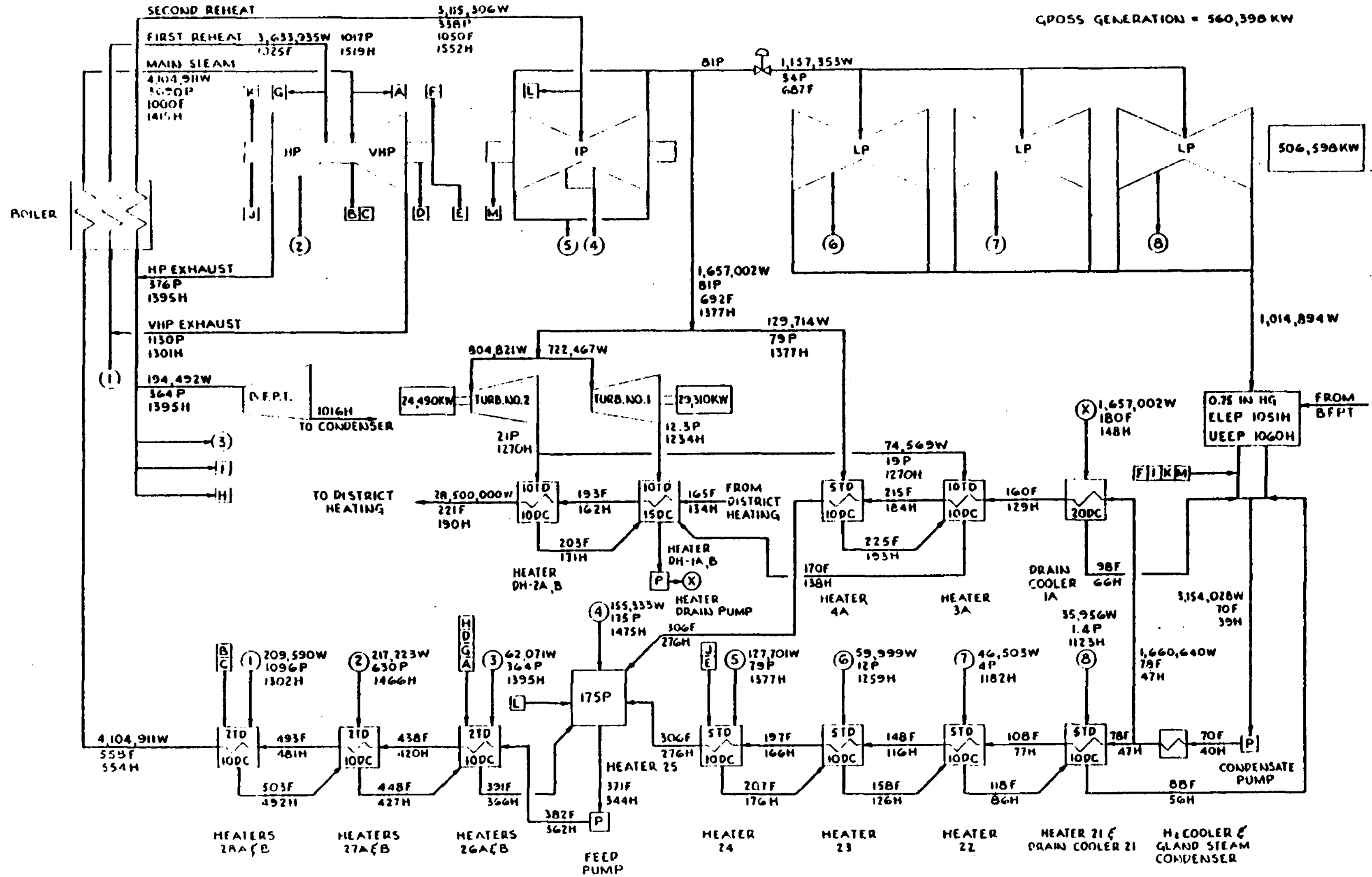
W – LB/HR
P – PSIA
F – °F
H – BTU/LB

FIG. 6.2.4

HUDSON GENERATING STATION UNIT 2
HEAT BALANCE AT MAX. THROTTLE FLOW
NO DISTRICT HEATING

STONE & WEBSTER ENGINEERING CORP.

DWG. NO. 13222.01 - HB - H2-1



LEAKAGES

A. 41,019 W	H. 18,371 W
B. 102,769 W	I. 3,024 W
C. 43,339 W	J. 4,258 W
D. 62,318 W	K. 1,718 W
E. 4701 W	L. 15,347 W
F. 1710 W	M. 2,570 W
G. 17,472 W	

KEY

W - LB/HR
P - PSIA
F - °F
H - BTU/LB

FIG. 6.2.1

HUDSON GENERATING STATION UNIT 2
HEAT BALANCE AT MAX. THROTTLE FLOW & MAXIMUM DISTRICT HEATING LOAD

STONE & WEBSTER ENGINEERING CORP.

DWG NO 13222.01 HB 112-2

A water heating plant will be provided to house the new equipment, which includes the back-pressure turbine-generators, heaters, pumps, switch gears, motor control centers, control room, and the water treatment system. This building measures approximately 206 feet long by 165 feet wide. It will be located between the No. 1 and the No. 2 fuel oil tanks, directly east of the turbine laydown area.

The study shows that 1.65 million pounds steam per hour can be extracted from the Hudson Unit 2 turbine cross-overs. With the above steam flow, approximately 28.5 million pounds water per hour (59,600 GPM) can be heated from a return temperature of 165°F to the supply temperature of 221°F. To obtain this water temperature, the maximum steam pressure needed at the water heaters is only 21 psia (using a terminal temperature difference of 10°F). Since the steam pressure at the turbine cross-overs is much higher than this pressure, back-pressure turbines are used in the retrofit scheme to generate additional power and to reduce the steam pressure. See Figures 6.2.2 and 6.2.3. During operation of the unit with maximum throttle flow and maximum steam extraction for water heating, the reduction in generation is approximately 92MW. During operation of the unit with maximum throttle flow and no district heating load, the loss in generation, due to pressure drop through the butterfly valves, is about 275 KW. The resulting heat rate penalty is about 5 BTU/kW-Hr.

On each of the extraction steam lines, a motor-operated shut-off valve and an air-operated non-return valve are provided. During operation with no steam extraction from the cross-overs, the butterfly valves will be fully open; both the motor-operated shut-off valves and the air-operated non-return valves will be closed. During operation when steam is extracted from the cross-overs, the butterfly valves will be partially closed; the motor operated shut-off valves and the air operated non-return valves will be fully open to pass the extracted steam flow.

In a fully developed district heating system, the water heating plant at the Hudson Station will have a capacity factor of about 40%. This capacity factor corresponds to approximately 3,500 hours of full load operation per year. During

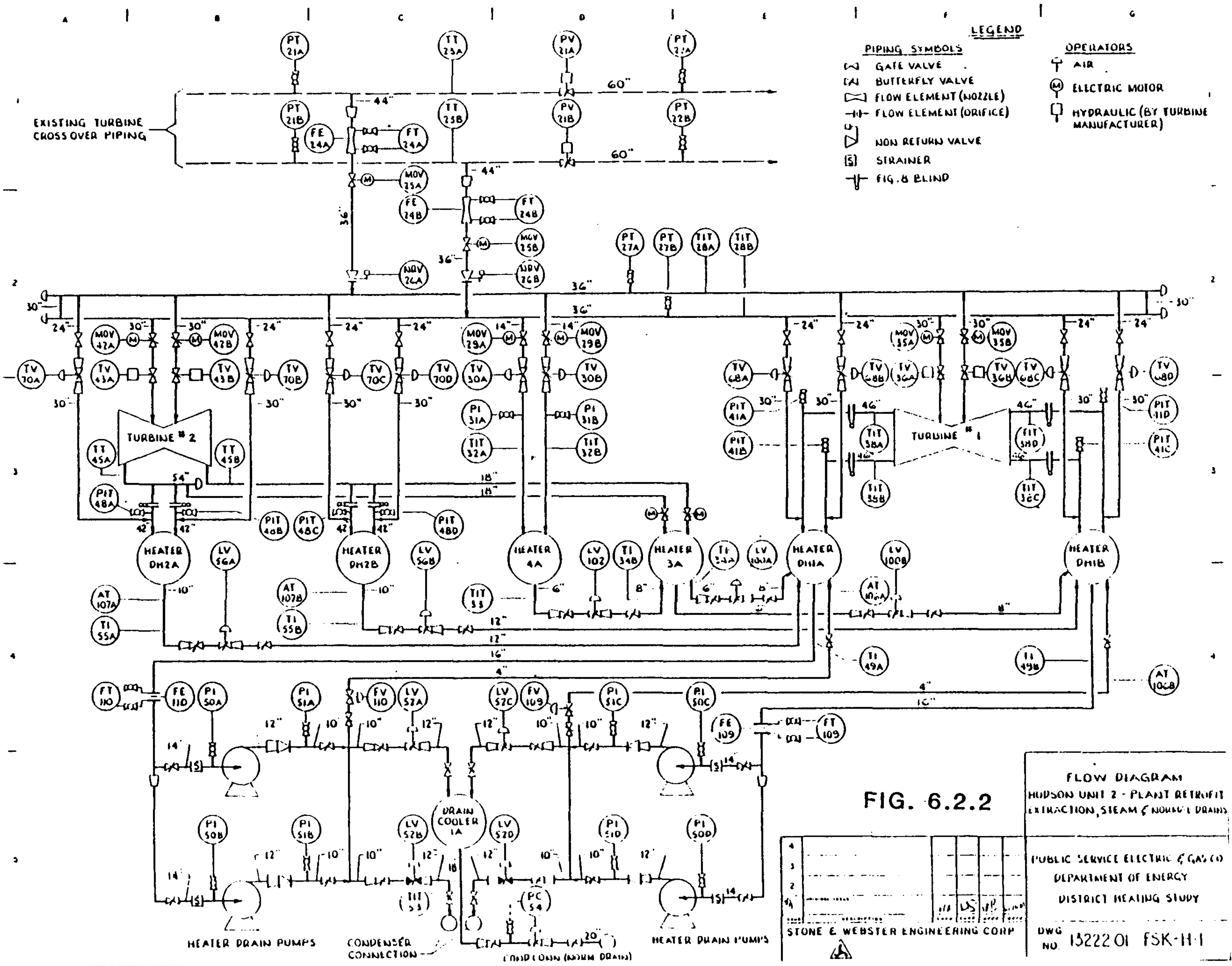
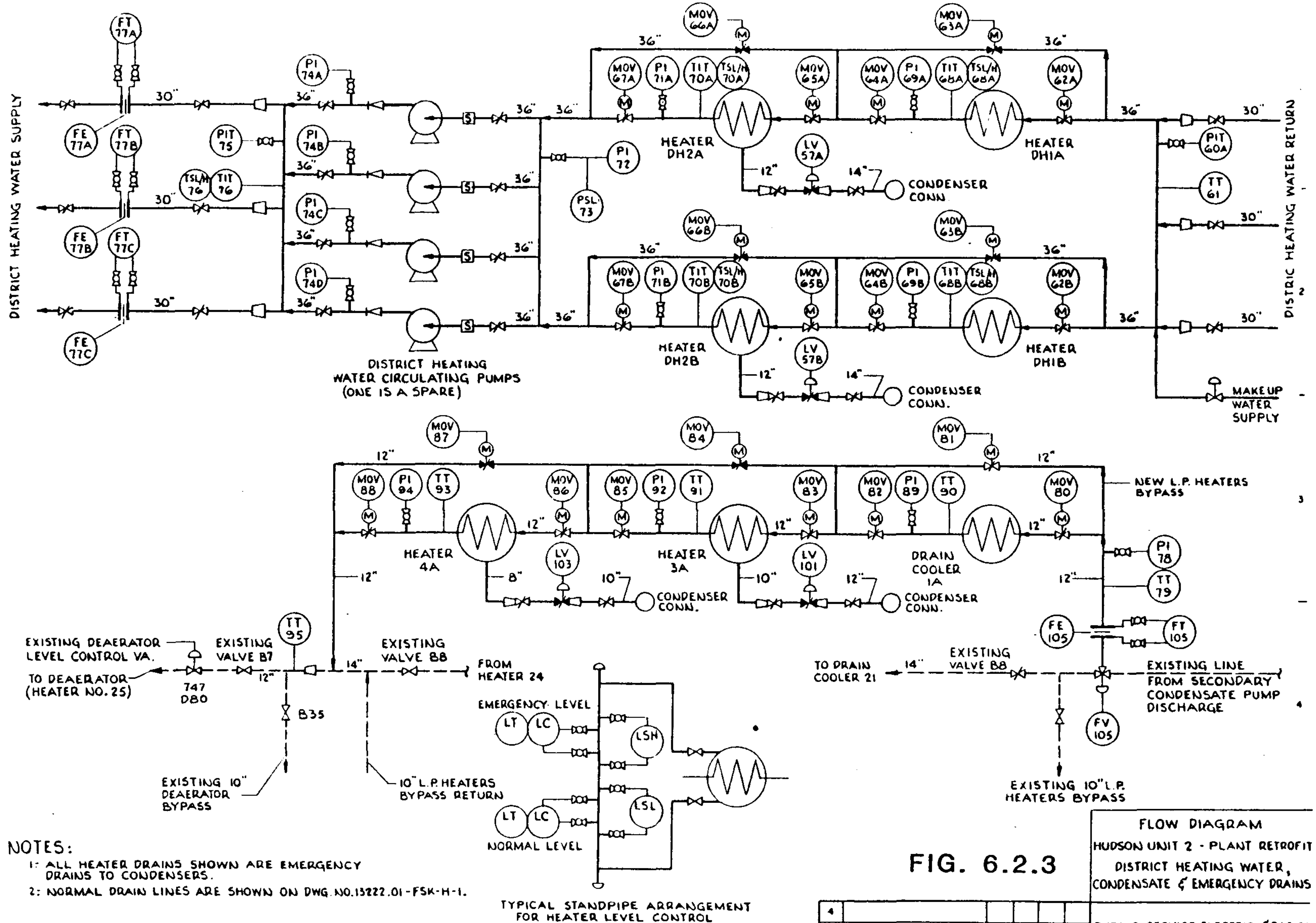

LEGEND
PIPING SYMBOLS
GATE VALVE
BUTTERFLY VALVE
FLOW ELEMENT (NOZZLE)
FLOW ELEMENT (ORIFICE)
NON RETURN VALVE
STRAINER
FIG. 8 BLIND
OPERATORS
AIR
ELECTRIC MOTOR
HYDRAULIC (BY TURBINE MANUFACTURER)
EXISTING TURBINE CROSS OVER PIPING
TURBINE # 2
TURBINE # 1
HEATER DH2A
HEATER DH2B
HEATER 4A
HEATER 3A
HEATER DH1A
HEATER DH1B
DRAIN COOLER 1A
HEATER DRAIN PUMPS
CONDENSER CONNECTION
FLOW DIAGRAM
HUDSON UNIT 2 - PLANT RETROFIT
EXTRACTION, STEAM & NORMAL DRAINS
PUBLIC SERVICE ELECTRIC & GAS CO
DEPARTMENT OF ENERGY
DISTRICT HEATING STUDY
STONE & WEBSTER ENGINEERING CORP
DWG NO. 13222.01 FSK-H-1

FIG. 6.2.2



NOTES:

1: ALL HEATER DRAINS SHOWN ARE EMERGENCY DRAINS TO CONDENSERS.
2: NORMAL DRAIN LINES ARE SHOWN ON DWG. NO. 13222.01-FSK-H-1.

FIG. 6.2.3

FLOW DIAGRAM
HUDSON UNIT 2 - PLANT RETROFIT
DISTRICT HEATING WATER, CONDENSATE & EMERGENCY DRAINS

PUBLIC SERVICE ELECTRIC & GAS CO
DEPARTMENT OF ENERGY
DISTRICT HEATING STUDY

ISSUE	DESCRIPTION	CHKD	COOR	APPR	DATE
4					
3					
2					
[illegible]	ORIGINAL ISSUE	GTK	DB	AB	[illegible]

STONE & WEBSTER ENGINEERING CORP.

DWG. NO. 13222.01-FSK-H-2

the periods of full load operation, the district heating water flow, the extraction steam flow, and the district heating water temperature rise will all remain constant. At lower load, both the district heating water flow and the water temperature rise will be reduced. During periods of very low heating load, Turbine No. 2, which supplies steam to the second stage Heaters DH2A and DH2B, will be shut down, leaving Turbine No. 1 running.

The Westinghouse study shows that the butterfly valves on the cross-overs will have a pressure drop of about 0.3 psi when the unit is operating at maximum throttle flow and rated steam conditions, with no steam extraction from the cross-overs. The loss in generation due to this pressure drop is less than 0.05 percent, or about 275 kW. The resulting heat rate penalty is about 5 BTU/kW-hr. With maximum throttle flow and maximum extraction from the cross-overs, the pressure drop through the butterfly valves is approximately 49 psi and the reduction in generation is about 92 MW. The reduction in generation during district heating operation will vary with the amount of steam extracted and the IP exhaust pressure. Figure 6.2.14 shows the relationship between boiler output and generation of the retrofitted unit at different percent district heating loads. In this figure, the generation is the total electrical output of the unit, including the back-pressure turbine-generators, prior to deducting the plant auxiliary power requirements.

The two new generators to be driven by the back-pressure turbines will be hydrogen cooled, rated 45,000 KVA and 37,500 KVA respectively, 0.8 PF, 13.8 KV, 3600 RPM, 3-Phase, 60 Hertz. Each generator will be grounded through its own neutral grounding transformer and resistor. Figure 6.2.5 shows the one line diagram for the new equipment.

In order to minimize short circuit duty on the 13.8 KV equipment, two separate 13.8 KV Switchgear Buses will be provided, one for each generator. Each bus will consist of 2000A generator circuit breaker, 1200A feeder breaker to station power transformer for the district heating auxiliary loads, and 2000A main circuit breaker through which generator output will be connected through the main transformer to the 26 KV Station Switchyard (not shown on the drawings). Additional switchgear

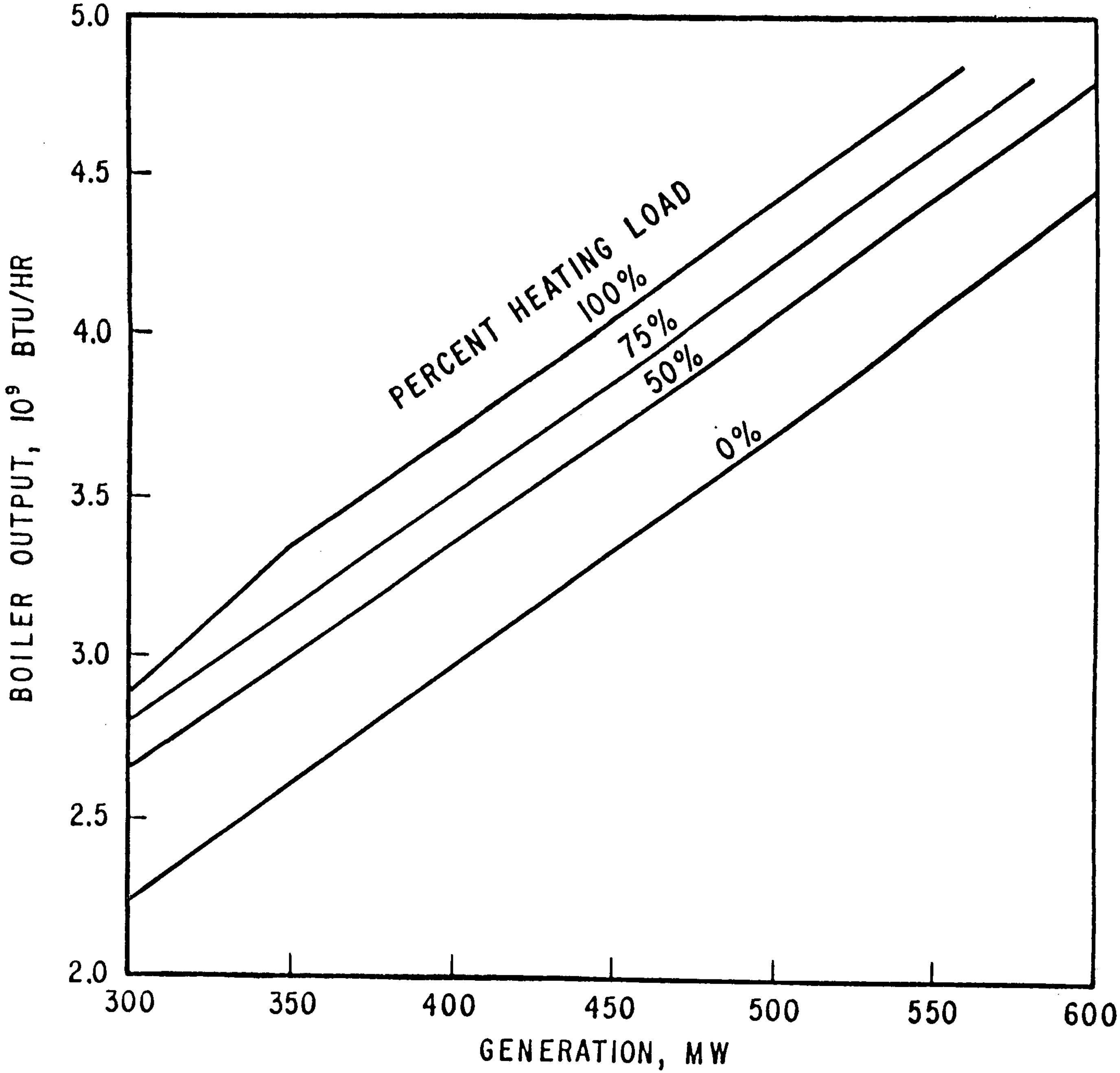
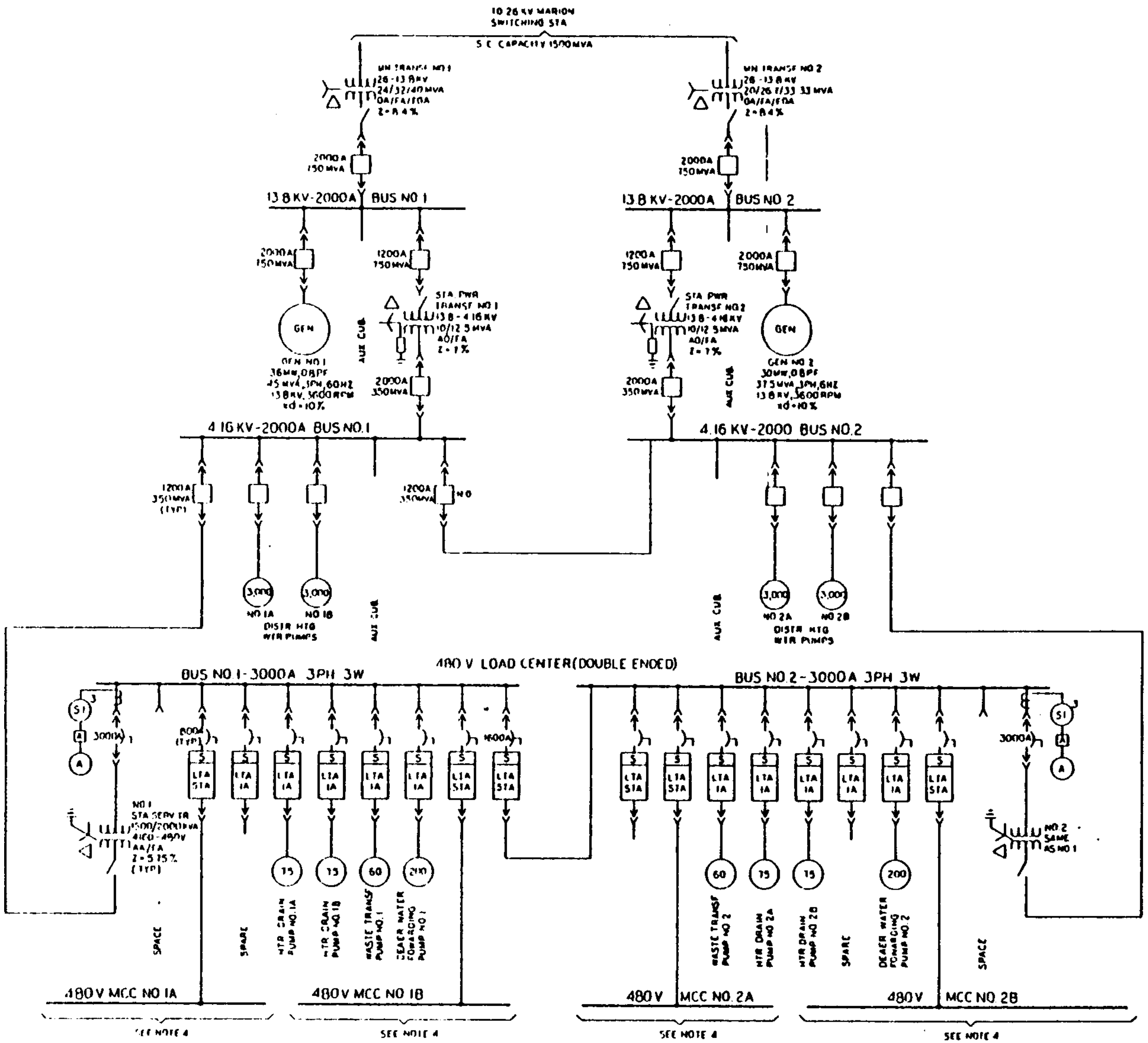


FIG. 6.2.14
BOILER OUTPUT VS.GENERATION



REFERENCES:

ELECTRICAL SYMBOLS S&W STD-ME-10-1 THRU STD-ME-10-8

NOTES:

1. PROTECTION, RELAYING, METERING, SYNCHRONIZING AND CONTROLS ARE NOT SHOWN.
2. ALL 800AF CIRCUIT BREAKERS ON 480V LOAD CENTER SHALL BE OF 42,000 AMPERE INTERRUPTING AND SHORT-TIME CAPABILITY AT 480V, SIMILAR TO G E TYPE AKR-30H.
3. 13.8KV BUS TO BE BRACED FOR 800 MVA.
4. EACH MOTOR CONTROL CENTER WILL HAVE THE FOLLOWING EQUIPMENT:

COMBINATION STARTERS, CIRCUIT BKR. TYPE:
FVNR NEMA SIZE 3 – 3
SIZE 2 – 2
SIZE 1 – 5
FVR NEMA SIZE 2 – 3
SIZE 1 – 5

CIRCUIT BREAKERS:
225 AF – 1
100 AF – 3

SPACES FOR FUTURE USE:
FVNR NEMA SIZE 1 – 2
CKT BKR 100 AF – 2

FIG. 6.2.5

STONE & WEBSTER ENGINEERING CORPORATION

ONE LINE DIAGRAM
HUDSON UNIT 2 – PLANT RETROFIT

PUBLIC SERVICE ELECTRIC & GAS CO
DEPARTMENT OF ENERGY
DISTRICT HEATING STUDY

ORIGINAL ISSUE

DRAWN M J MANULIO

13222.01 ESK-H-1 1

cubicles will be provided to house generator protective relays, main transformer protection, metering, and synchronizing controls.

Main transformers will be outdoor, OA/FA/FOA type, 26 KV WYE–13.8 KV Delta, 3–Phase, 60 Hertz, 200 KV BIL. Rating for Generator No. 1 Main transformer will be 24/32/40 MVA and 20/26.7/33.34 MVA for Generator No. 2.

The district heating loads and required auxiliary loads will be supplied through two station power transformers to two 4.16 KV buses. Each transformer will be rated 13.8 KV–4.16 KV, 10/12.5 MVA, OA/FA, 3–Phase, 60 Hertz, each of sufficient capacity for the total auxiliary load.

Each transformer will be supplied from separate 13.8 KV bus, and will be connected to its own 4.16 KV bus. The normally open, 1200A air circuit breaker will be provided, to tie the two 4.16 KV buses in case one station power transformer should be out of service.

Start–up power will be supplied from the 26 KV switchyard, through main transformers to the station power transformers.

Load center will supply large 480 V loads including motors 60 HP and larger, and motor control centers (two per each 480 V bus section).

Four motor control centers will be provided, consisting of starters and air circuit breakers to supply smaller motors (50 HP and less), motor operated valves, lighting and power transformers and welding receptacles.

The following monitoring and control functions are provided.

1. Extraction steam pressure control with flow limiting constraint (main control room).

2. Flow rate, pressure and temperature of steam extracted from each cross–over (main control room).

3. Back–pressure turbine–generators No. 1 and No. 2 integrated control and supervisory system (main control room).

4. Pressure and temperature of exhaust steam from each back–pressure turbine (main control room).

5. Inlet and outlet temperatures of district heating water to each heater.

6. Total flow of district heating water through the system.

7. Pressures and temperatures of supply and return district heating water.

8. High and low temperature (sliding) alarms for water at the outlet of each heater.

9. Control, monitoring, and protection of district heating water circulating pumps.

10. Control, monitoring, and protection of heater drain pumps.

11. Level control of water in the heater shell with split level drain flow controllers and low level/high level alarms.

12. Control of the L–P heater by–pass flow.

13. Monitoring and control of electrical equipment in the district heating water heating plant and ties to the switchyard.

14. Monitoring and control of auxiliary systems, such as instrument air, HVAC, and fire protection systems.

15. Monitoring of water quality in the drain line of each heater.

The only equipment to be located inside the existing turbine building consists of steam and condensate piping, drain lines, and the associated valves. The two extraction steam lines from the cross–overs will be located partly outdoors. Figures 6.2.6 and 6.2.7 show the equipment arrangement inside this building.

The water heating plant consists of two levels. The back–pressure turbine–generators and the electrical equipment are located on the upper level, or the operating level. A control room is also located on this level. The heaters, pumps, and the water treating equipment are located on the lower level. The building is equipped with an overhead bridge crane with a 50–ton main hook and a 10–ton auxiliary hook. The roof of the upper level is at an elevation 75.5 feet above grade. The roof of the lower level is at an elevation 32.5 feet above grade. The building is constructed of a steel frame with insulated corrugated metallic sidings and poured concrete roof slabs with built–up roofing. The foundation of the building will be placed on piles. An underground pipe tunnel is provided to accommodate the pipings between the water heating plant and the existing turbine building, as shown in Figure 6.2.8.

TRANSMISSION AND DISTRIBUTION

The piping for the distribution of heat generated at the various stages of the D–H system is a two–pipe, closed, circulating water system. There are two equal size pipes required to supply and to return the water and therefore all calculations are based on a pair of pipes, generally laid side–by–side. Length of pipe is given as the length of trench and always refers to two pipes. So are heat loss and pump work requirements.

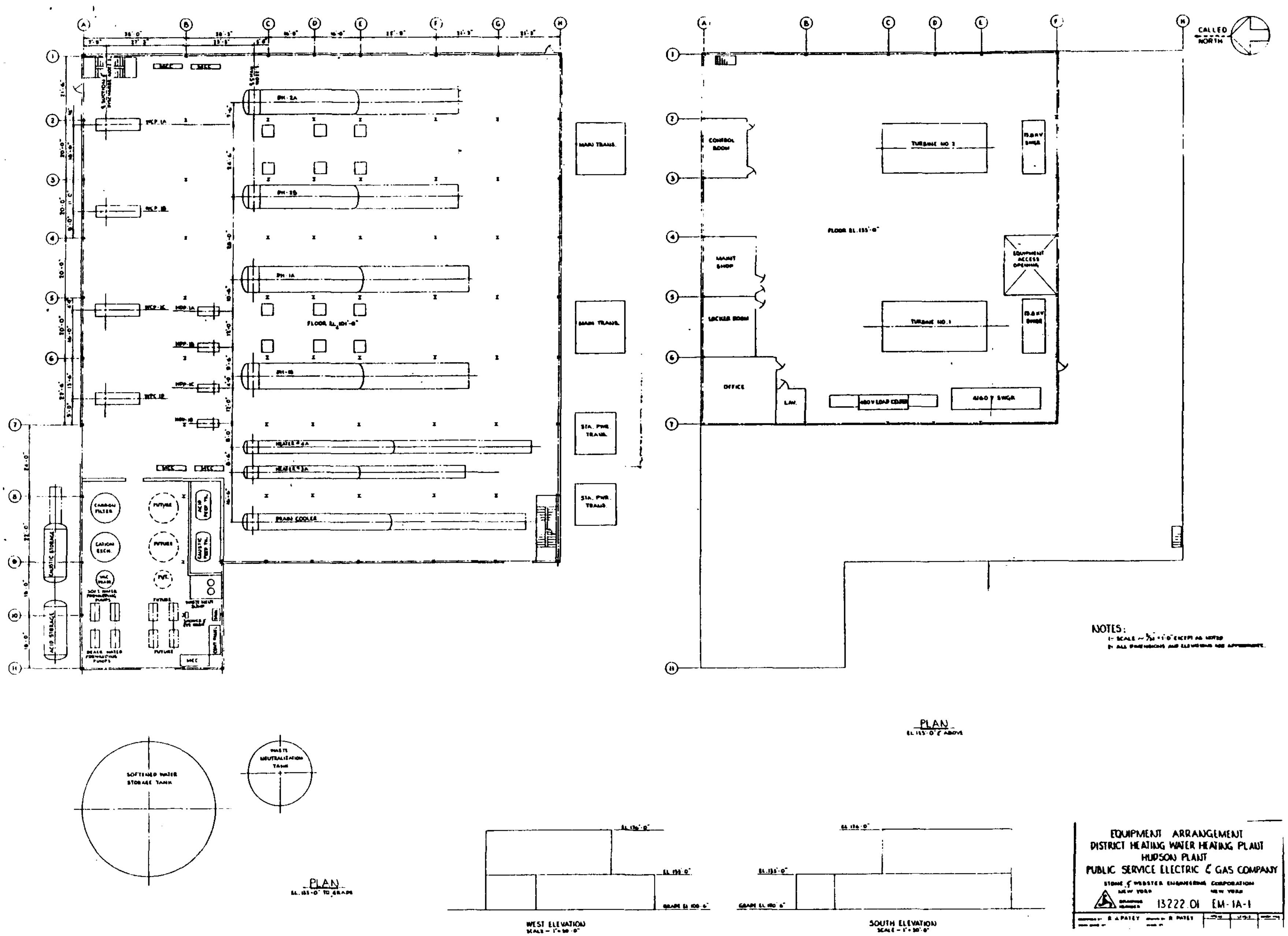
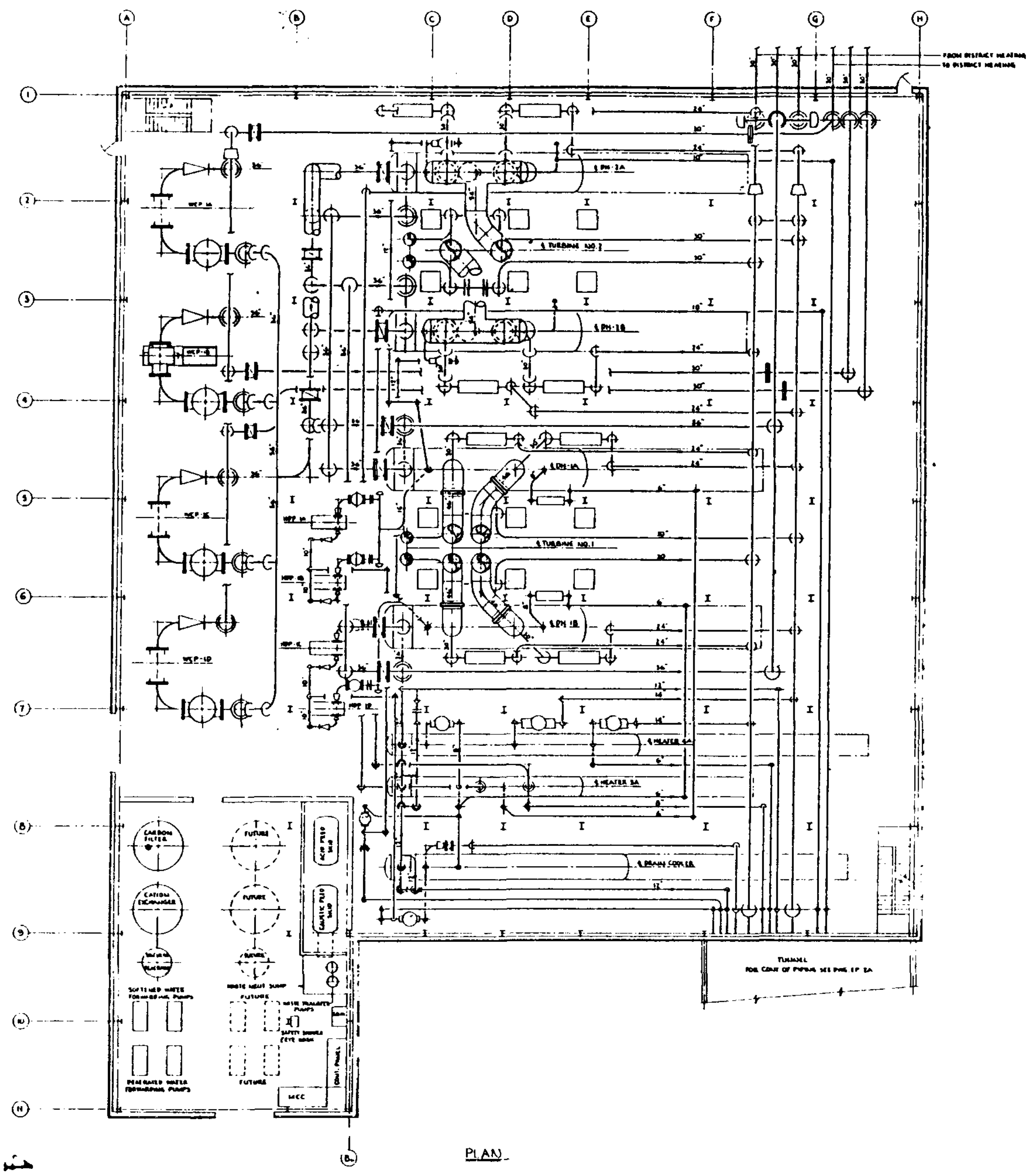

CALLED NORTH
CONTROL ROOM
MAINT SHOP
LOCKER ROOM
OFFICE
LAV.
TURBINE NO 2
TURBINE NO. 1
EQUIPMENT ACCESS OPENING
MAIN TRANS.
STA. PWR. TRANS.
CARBON FILTER
CATION EXCH.
FUTURE
CAUSTIC STORAGE
ACID STORAGE
DRAIN COOLER
SOFTENED WATER STORAGE TANK
WASTE NEUTRALIZATION TANK
PLAN
PLAN
NOTES:
WEST ELEVATION
SOUTH ELEVATION
EQUIPMENT ARRANGEMENT
DISTRICT HEATING WATER HEATING PLANT
HUDSON PLANT
PUBLIC SERVICE ELECTRIC & GAS COMPANY
STONE & WEBSTER ENGINEERING CORPORATION
NEW YORK
13222.01 EM-1A-1

FIG. 6.2.6



NOTES:
1. SCALE – 3/16" = 1'-0"

CONCEPTUAL PIPING ARRANGEMENT
DISTRICT HEATING WATER HEATING PLANT
HUDSON PLANT
PUBLIC SERVICE ELECTRIC & GAS COMPANY
STONE & WEBSTER ENGINEERING CORPORATION
NEW YORK NEW YORK
13222 01 - EP - IA - 1

FIG. 6.2.7

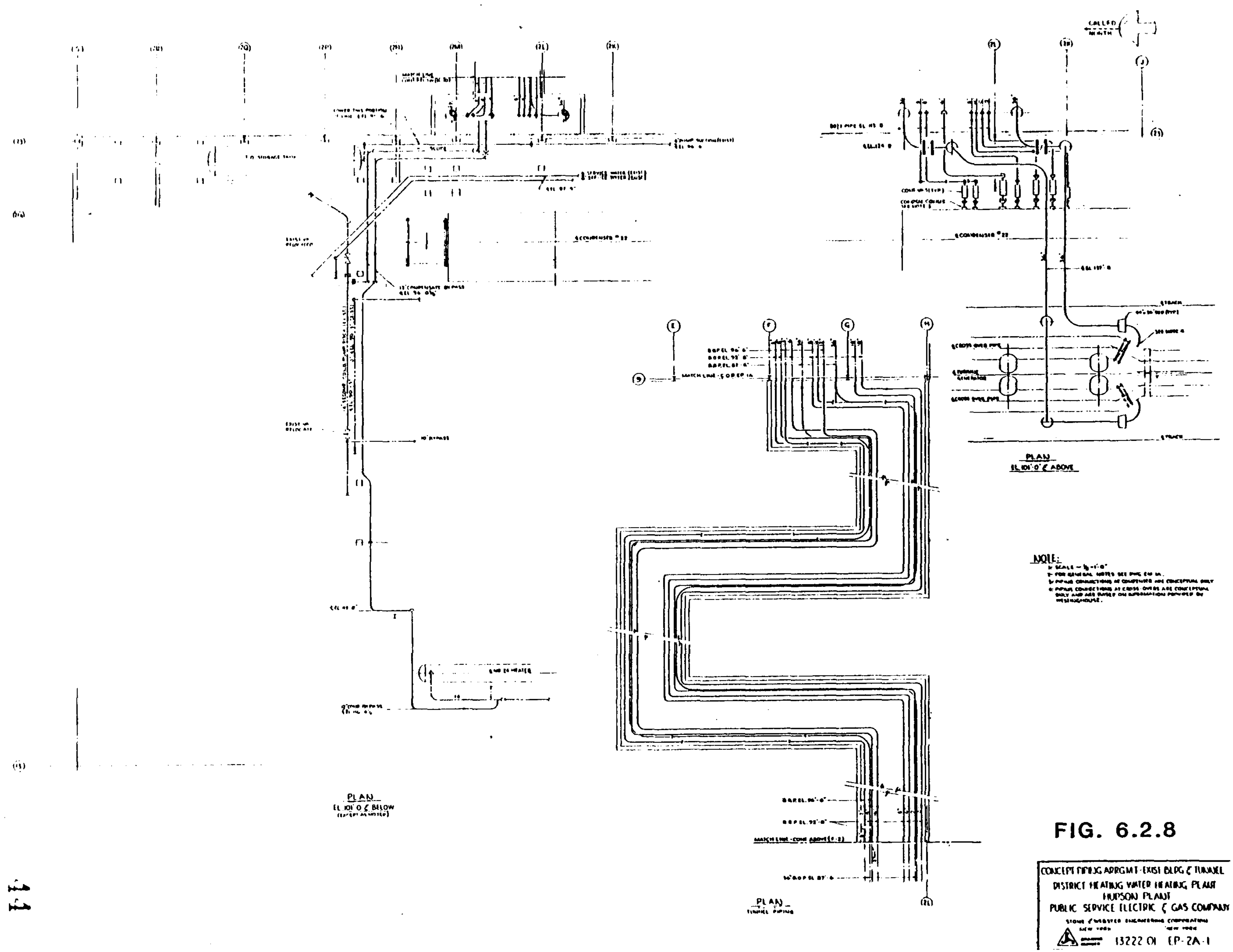

PLAN
EL 101'-0" & BELOW
PLAN
TUNNEL PIPING
PLAN
EL 101'-0" & ABOVE
NOTE:
CONCEPT PIPING ARRGMT - EXIST BLDG & TUNNEL
DISTRICT HEATING WATER HEATING PLANT
HUDSON PLANT
PUBLIC SERVICE ELECTRIC & GAS COMPANY
13222 01 EP-2A-1

FIG. 6.2.8

The selection of economically justified pipe sizes is crucial to the economy of the system. Investment in piping is about 60–75% of the total capital outlay. Operating costs, as pumping power and heat loss, also have a major impact on the cost of heat. Approximate cost estimates were made to assist in optimizing these design details. More precise cost estimates were used in the assessment of economic viability and are presented in the Economic Analysis section of this report.

The investment in piping has a carrying charge of 12.5%. This assumes a 33 year booklife for the investment. It is also assumed that the investment will become productive within the year of its installation. The electrical energy cost is conventionally accounted for at its replacement cost. The average annual replacement cost of electric power in 1981 was given as $69 per MWh.

The cost of heat for the valuation of heat losses will also be calculated on the basis of incremental power cost.

The cost of piping installations is the most significant item of the total investment. It is also the hardest to estimate correctly since purchased items represent a relatively small fraction of the total cost. Site work is the major element and it varies widely with the congestion of services and traffic, with the soil conditions and with the restoration work necessary. The experience of the Gas Department is very relevant and the figures used are based on their calculations.

Material cost estimates were obtained from a number of prefabricated insulated piping fabricators, and those for steel core pipe with polyurethane insulation and FRP outercoating were used up to 8" diameter and concrete culvert prices above that. The transmission lines between the Hudson G.S. and the three major sites and those between the two sites at the Meadowlands were laid out using existing right–of–ways crossing uninhabited areas. The resultant figures are shown in graphic form on Figure 6.5.2. As a comparison, cost figures calculated by Stone and Webster in Phase I and those calculated by Burns and Roe as part of DOE project 79/7672 –

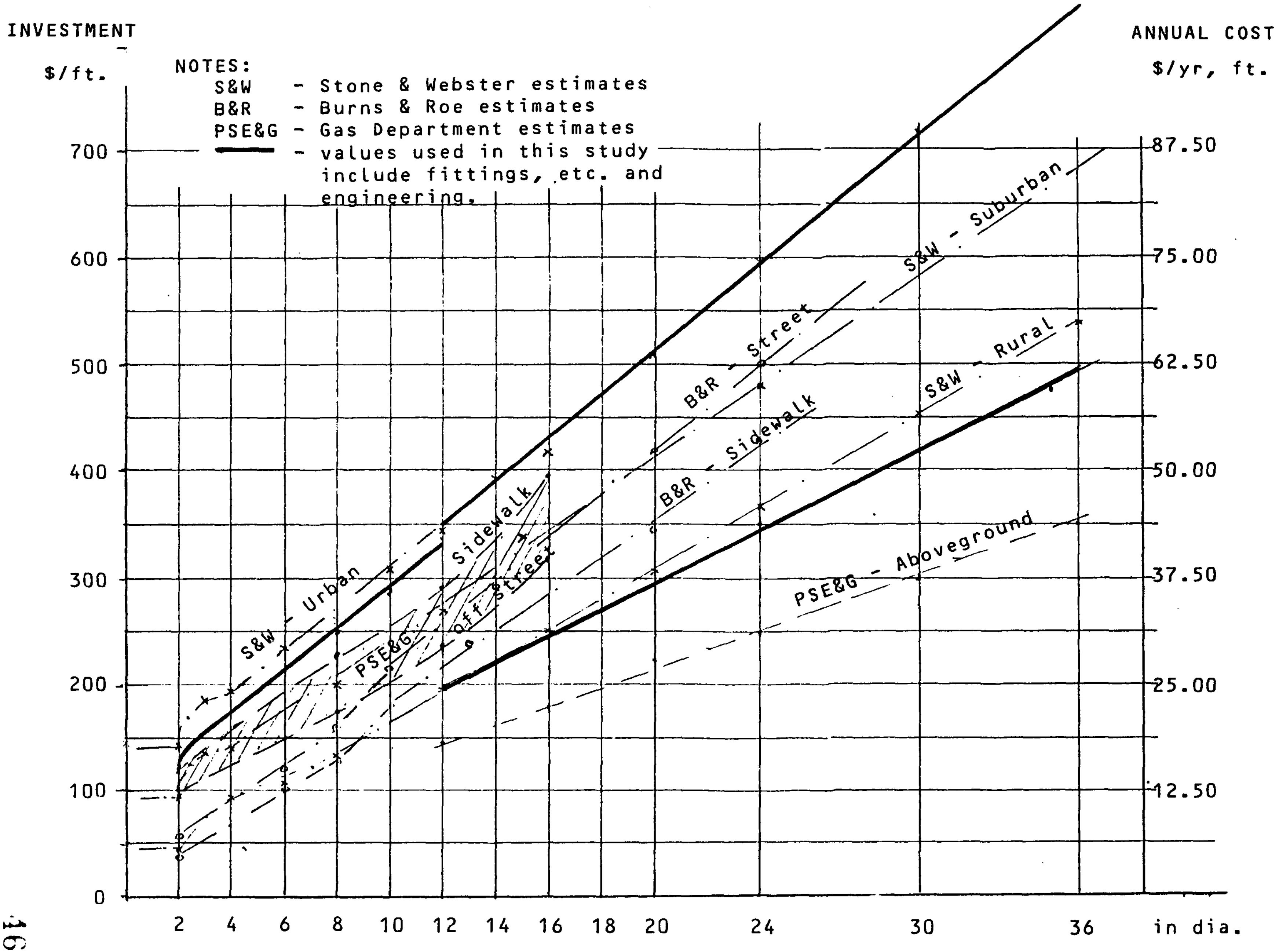


FIG. 6.5.2
INSTALLED PIPING COSTS
AND COMPARISON WITH OTHER ESTIMATES

I. Oliker, "Assessment of existing and prospective piping technology for district heating applications" are also plotted. It clearly shows that there is reasonable agreement among these sources.

The right-hand ordinate of the plot shows the annual cost of installation based on 12.5% capital recovery cost.

The extensive heat distribution network has considerable heat losses. The system operates at variable temperatures throughout the year. The determination of the average supply and return line temperatures was the first step in calculating the losses. Based on these temperatures and on the annual operating hours at each temperature, Figure 6.5.3 shows the heat losses.

Similarly pumping costs were developed based on full design flow for the winter and half of design flow rates during the summer. The costs are shown on Figure 6.5.1.

The proper pipe size for a given load is the one which costs least when all cost components--investment, pumping and heat loss--are considered together. These were compiled as shown on Figure 6.5.4.

All heat loads under 7 million BTU/hr will have 2" connections. No distribution line in the streets will be less than 3" dia.

As it was mentioned, heat loss values and cost can vary considerably with deteriorating soil conditions, The heat loss cost effect, relative to capital charges and pumping cost is however so small that even doubling it will not materially affect the economical pipe size selection.

The distribution piping for the existing city environment had to be estimated on a statistical basis. It was assumed, based on previously developed data, that within a square mile 300 x 10^6BTU/hr and 360 x 10^6BTU/hr space heating

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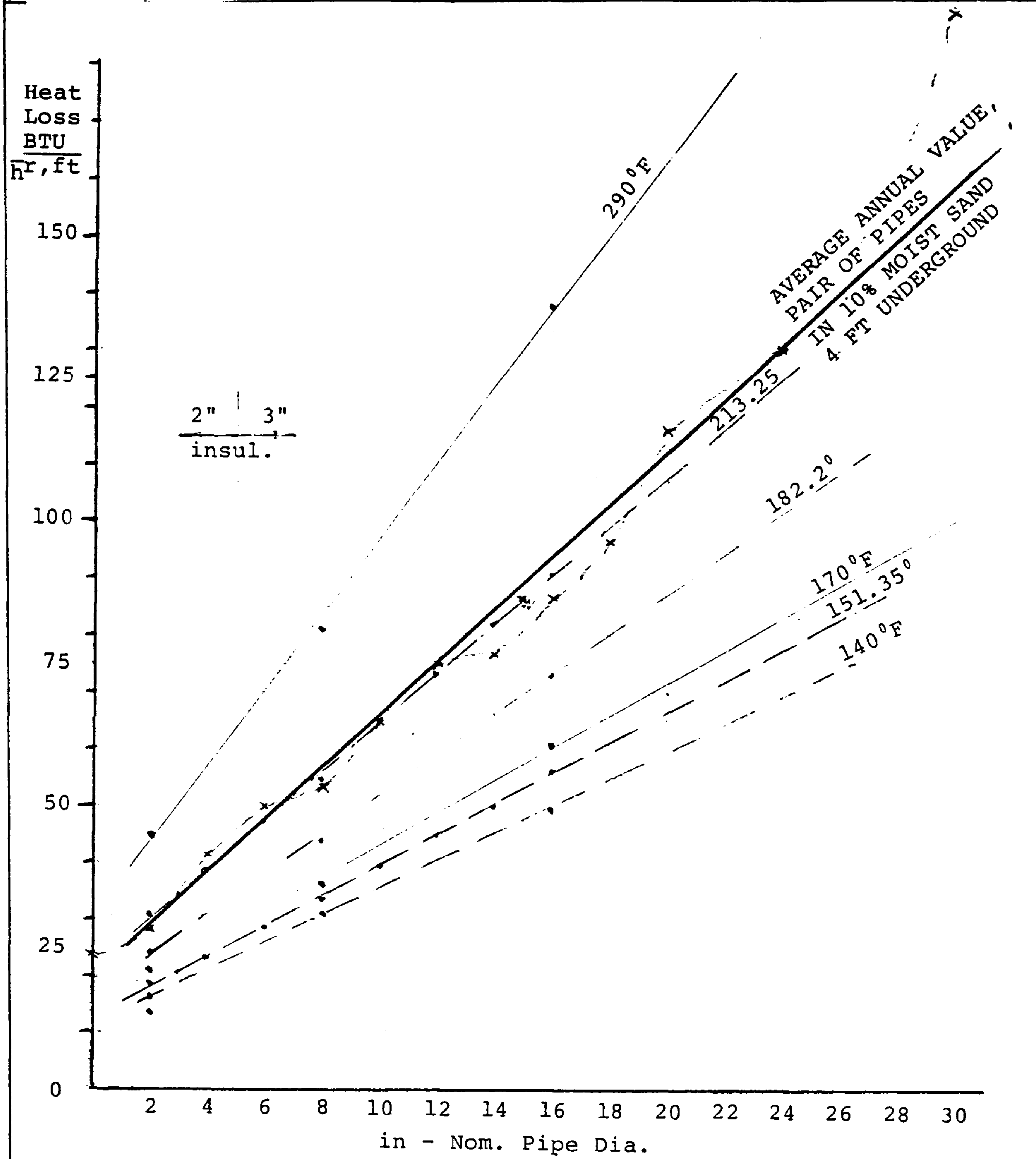


FIG. 6.5.3

SPECIFIC HEAT LOSS OF BURIED PREFAB. PIPE

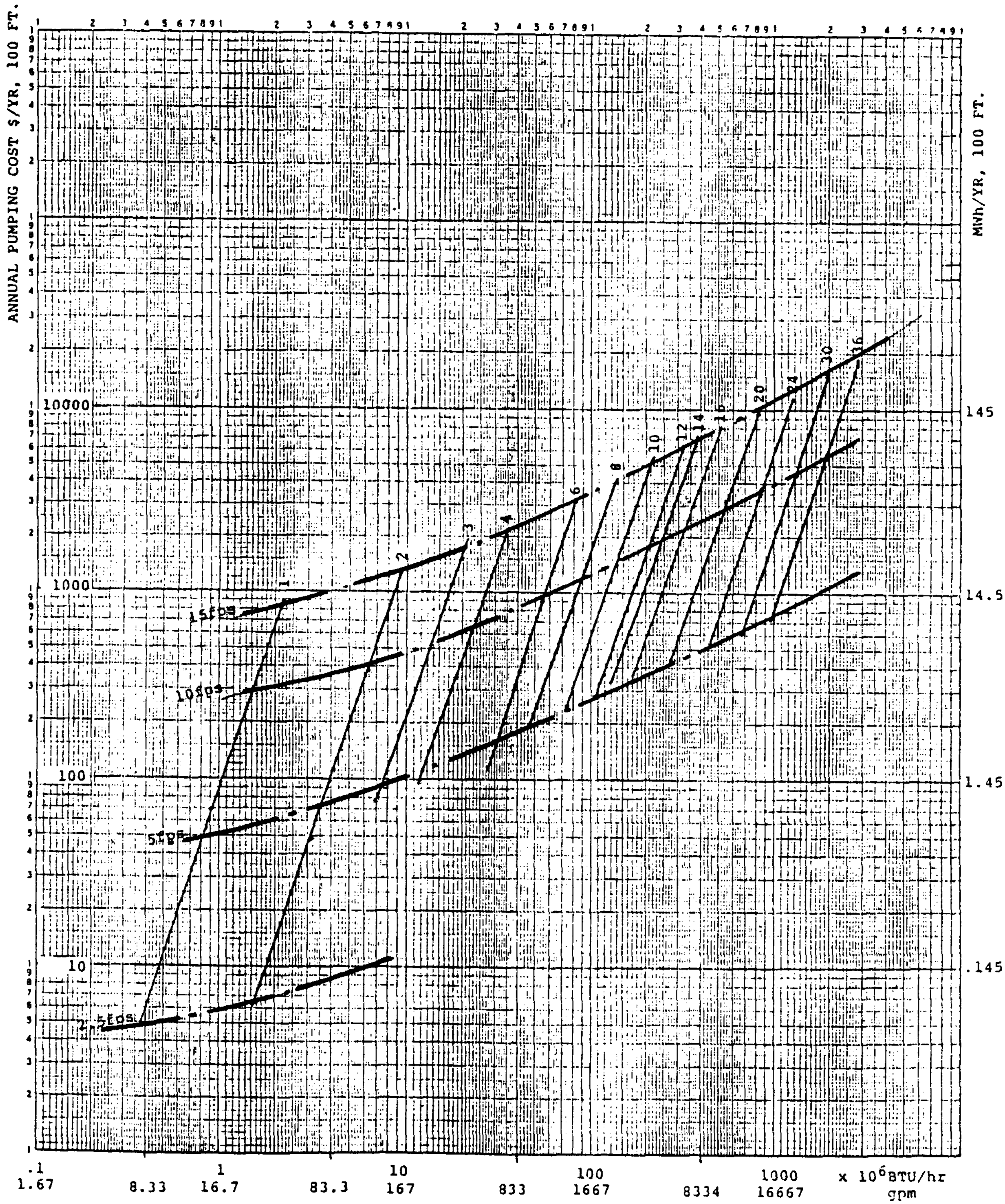
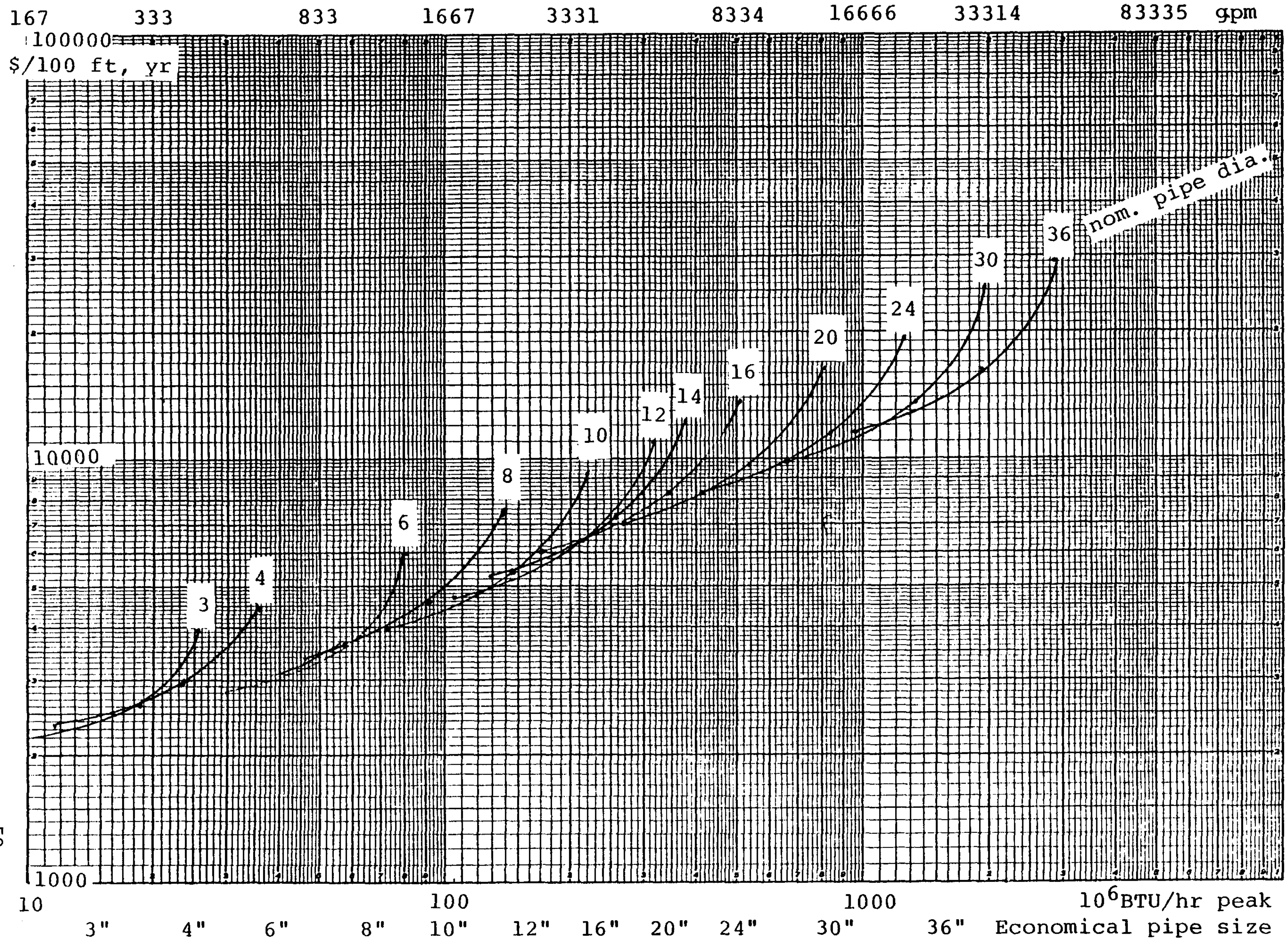


FIG. 6.5.1

ANNUAL PUMPING COST

FIG. 6.5.4
ANNUAL COST OF 100 FT OF PIPING
AND ECONOMICAL PIPE SIZE DETERMINATION



peak load will be connectable, where the two figures refer to Jersey City and to Newark respectively. This meets the send-out capability of a peaking heater plant assumed to be located at a central location, as for example, is shown on Fig. 6.5.5.

The area has approximately 200 city blocks. A city block averages 200' x 400' and about 45% of the total area is public domain, as streets, parks, etc.

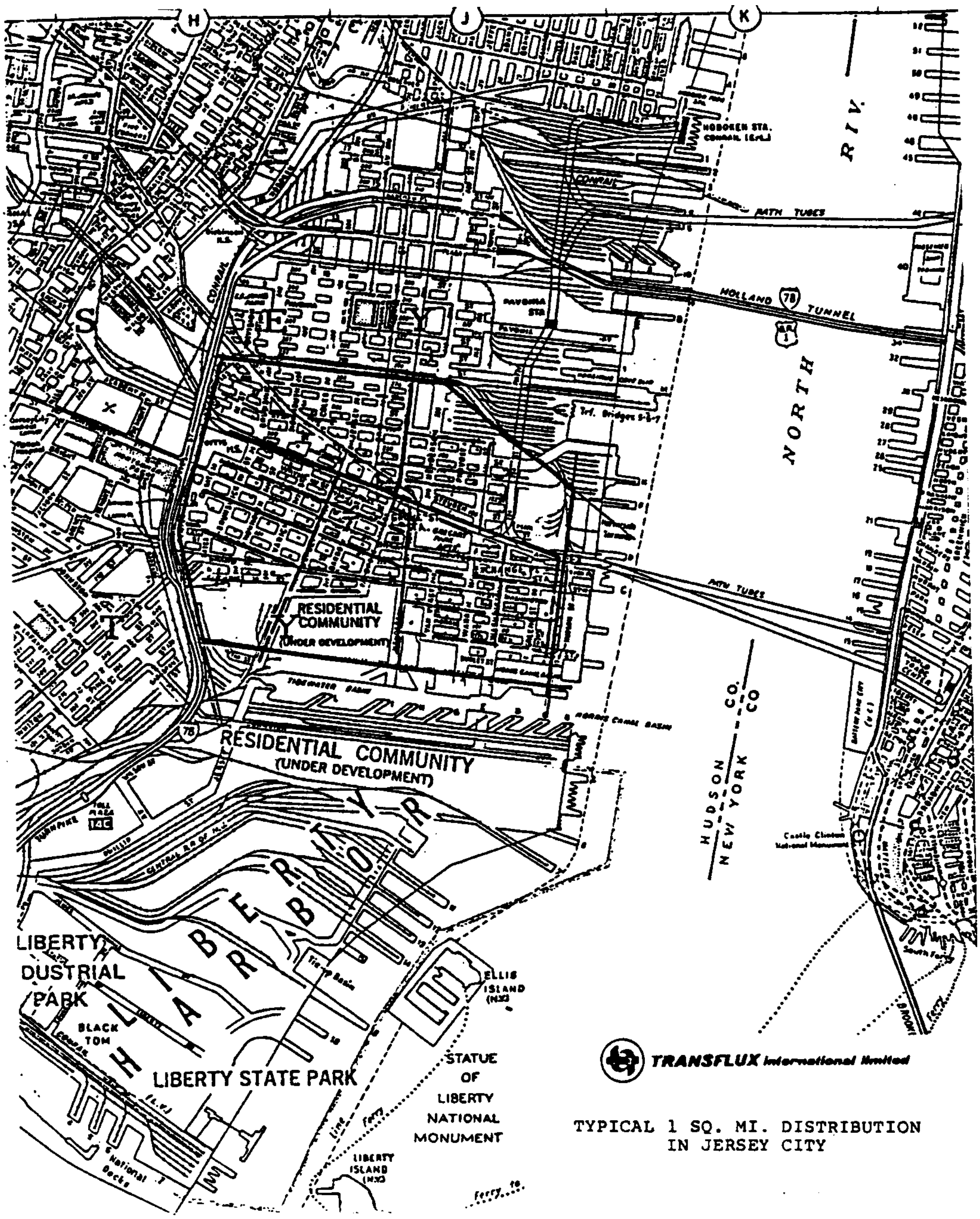
A building one can call a major user has an average of 100 apartments and an estimated peak space heating load of 2 x 10^6BTU/hr. The same load is presented by an office building of about 100–120,000 sq. ft. Small family row houses of 3–4 units estimated @ 34,000 BTU/hr per apartment represent 100–136,000 BTU/hr peak load each. These are typically 20 ft. wide and 50 ft. deep, so there are 25–30 of these on a typical city block, adding up to a total load of 3 to 4.5 million BTU/hr per block.

It is assumed that by the end of an 8–10 year development of district heating in any of these areas there will be connected

380 major users	@ 3x10^6BTU/hr	240x10^6BTU/hr
and 85 blocks of row houses	@ 1.4x10^6BTU/hr	119x10^6BTU/hr
		359x10^6BTU/hr

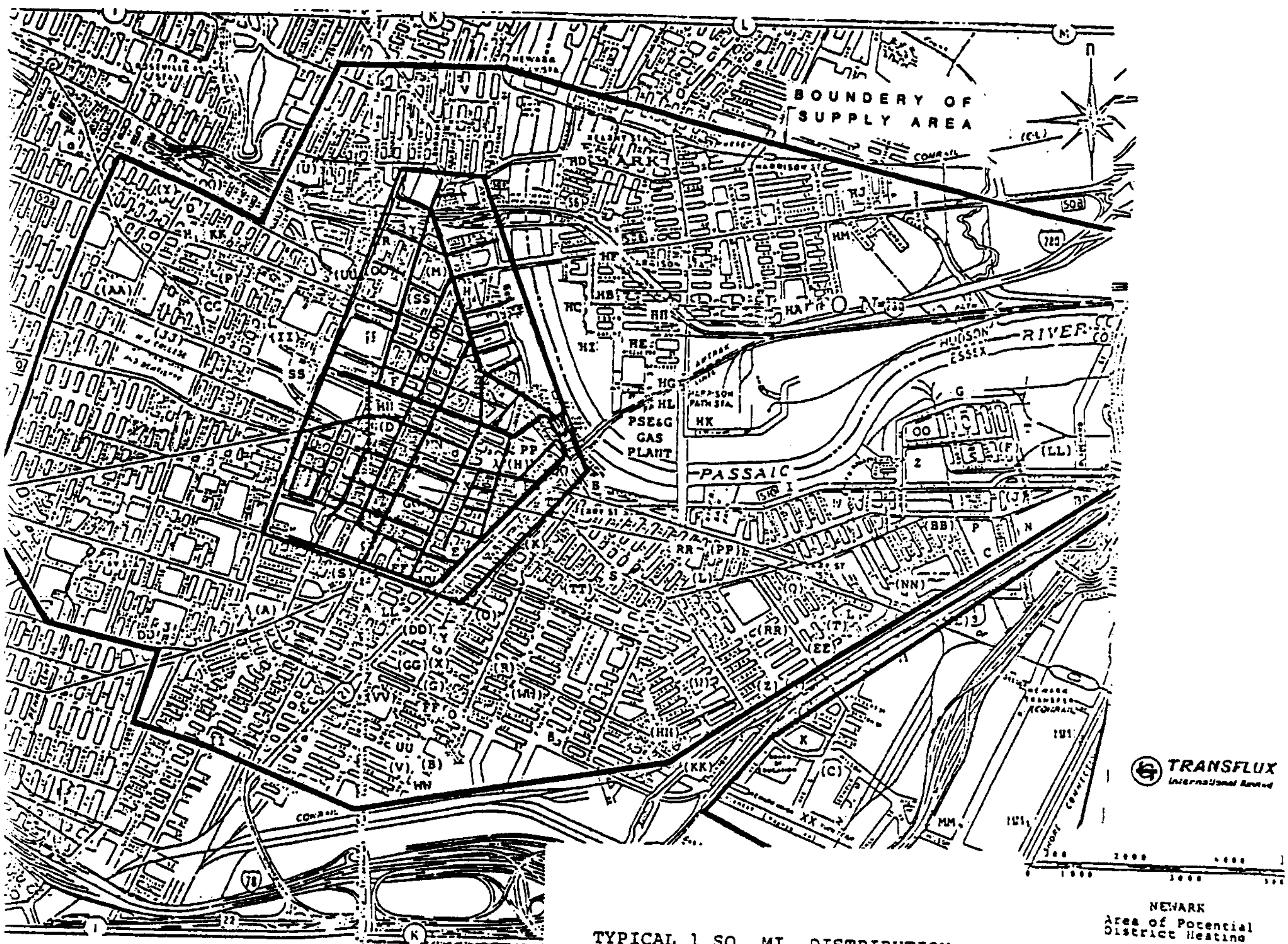
In Newark (Fig. 6.5.7) and 65 major users with 75 blocks in Jersey City (Fig. 6.5.5), for a peak of 300x10^6BTU/hr. This means providing heating to 160 and 140 blocks of buildings out of over 200 city blocks within a square mile. It also means assumption of providing heat to most large complexes and to about 40% of the row houses.

The distribution mains leave the heaterplant in three or four directions dependent on its position within the supply territory. These lines are 12" or 10"



RESIDENTIAL COMMUNITY
(UNDER DEVELOPMENT)
RESIDENTIAL COMMUNITY
(UNDER DEVELOPMENT)
LIBERTY STATE PARK
STATUE OF LIBERTY NATIONAL MONUMENT
HOBOKEN STA.
PATH TUBES
HOLLAND TUNNEL
NORTH RIV.
HUDSON CO.
NEW YORK CO.
BLACK TOM
ELLIS ISLAND
LIBERTY ISLAND
TRANSFLUX International limited
TYPICAL 1 SQ. MI. DISTRIBUTION
IN JERSEY CITY

FIG. 6.5.5



TYPICAL 1 SQ. MI. DISTRIBUTION
IN NEWARK

FIG. 6.5.7

dia. respectively. Each quadrant is looped by 4" distribution lines connecting to the two mains bordering the quadrant. All load centers up to 5 million BTU load will have a house connection of 2" diameter. This same size pipe will also connect to the block supply centers.

Piping to a block of multi-family row houses is shown on Figure 6.5.8. The heatexchanger and pump unit is located in its own housing at the middle of the block. Distribution from here is at the secondary side. Circulating power is also provided by the conversion unit. The lines connecting to a single building are 1" size or 1-1/2" size for two adjoining buildings.

The total average distribution piping system for a square mile of high density city neighborhood then requires the following distribution piping (average):

on-street piping:	10" dia.	5900 ft.
	8" dia.	5900 ft.
	4" dia.	79000 ft.
	2" dia.	26300 ft.
off-street piping:	2" dia.	30000 ft.
	1-1/2" dia.	25500 ft.
	1" dia.	25500 ft.

The on-street piping is made of steel, while the low temperature off-street piping is of plastic or copper. The off-street piping can also be run aboveground if conditions permit in concrete or other protective cover.

The off-street piping is secondary distribution. As such it can be made part of the distribution system or it can be considered as part of the conversion package and let its installation and cost be borne by the customer. These possibilities will be dealt with in Section 9.

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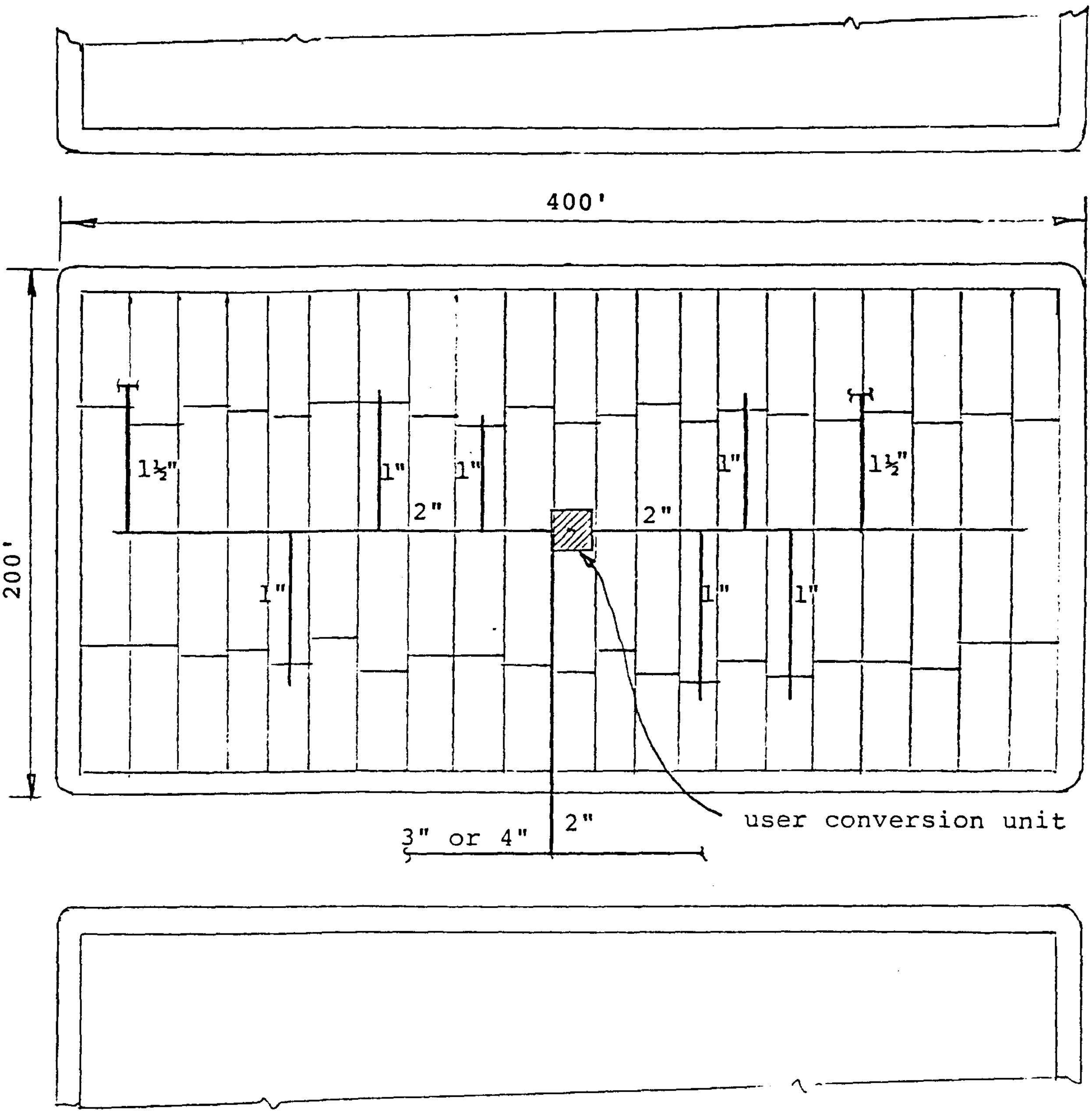


FIG. 6.5.8

TYPICAL BLOCK OF MULTI-FAMILY ROW HOUSES - D-H PIPING

Transmission piping generally is no different from the distribution piping, except for its larger size and for the environment it may be located in. The size range for the project is 18" to 42" in diameter. Because of their position in the three stage series heating system, no transmission line will operate over 260°F temperature, while most of the time considerably lower. Their construction will vary dependent upon their location whether underground or aboveground.

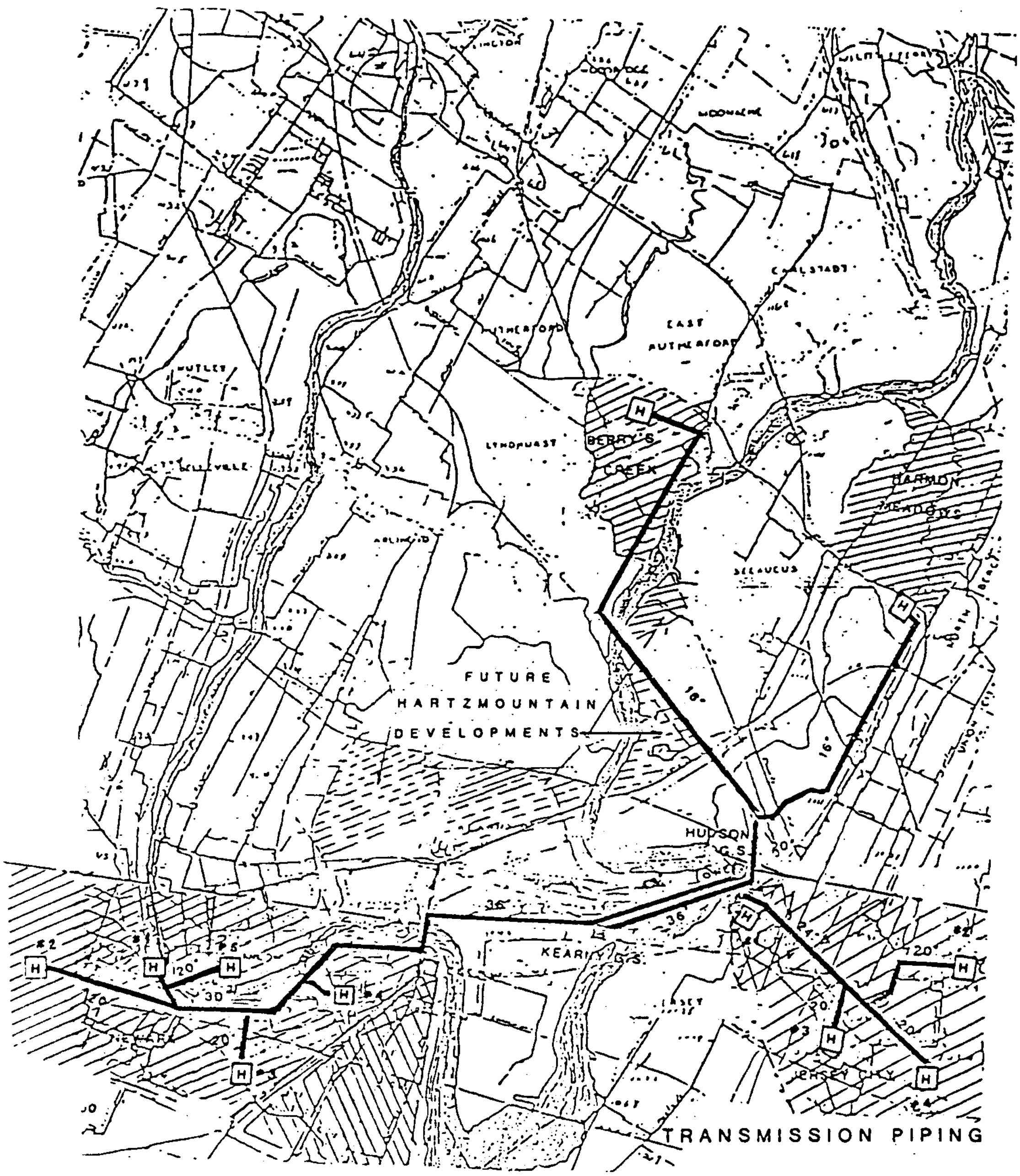
The routing of the transmission lines will, where possible, follow existing PSE&G right-of-ways (ROW) owned or leased by the electrical or gas services.

Remote operated sectionalizing valves for faster repairs will be inserted at every mile on runs with no branches and just downstream of every branch. This way isolation of any pipe failure will assure the minimal effect on the total system. It will also speed the repair work by minimizing line drainage and filling times.

The transmission piping layout shown on Figure 7.3 indicates the overall piping layout for both the Hudson and Kearny Stations. The transmission mains, shown heavy, are actually two (2) lines, supply and return. The common 36" lines and 42" lines between the stations are provided to allow for either plant to supply the total connected district heating system capacity.

Four (4) river crossings are indicated on the layout. All of these crossings will be under the river bottom, except as noted.

Location	Pipe Size	Length
1. Harrison	2-20"	600'
2. Essex	2-36"	1000'
3. Kearny-Hudson	1-42"	1000'
	2-36"	In existing tunnel, 650' horizontal 200' vertical
4. Berry's Creek	2-16"	600'



SCALE: 1" = 6000'

FIG. 7.3

The piping requirements shown below reflect the referred layout.

Pipe Size	Length	Pricing Type
42"	10,800'	Right-of-Way
36"	16,900'	Right-of-Way
36"	2,500'	Urban
36"	7,500'	Suburban
30"	2,500'	Urban
24"	3,000'	Right-of-Way
24"	8,500'	Urban
20"	2,900'	Right-of-Way
20"	27,000'	Urban
16"	37,000'	Right-of-Way

The hot water is supplied by a system of closed, circulating transmission and distribution pipes. As the system is developed in stages, so is the pumping capacity needed to move the water around.

A hot water system requires that the pressure at any point will not fall to a value below the saturation pressure corresponding to the maximum temperature generated. This temperature was defined previously as 293°F. The corresponding saturation pressure is 60.5 psia. A cover pressure of 70 psig (84.7 psia) will be maintained to allow ample margin for control fluctuations (–14 psi) and for temperature excursions (up to 316°F). It is to be recognized that this pressure will prevail over the whole system, when no pumps are operating. In order to maintain that static pressure, the make–up capability has to meet the flow requirements due to leakages and volume changes of the fluid due to cooling. Most of the system volume is that of the distribution lines. Also the cooling effect of those lines is many times that of the transmission lines. It follows logically that the make–up facility should be as close to the distribution as practical. The closest points are the heater plants in the proposed develpment. This is where the make–up introduction is, and so is the pressurization point for simplicity of control. The means of controlling pressure is feeding water in when the pressure decays and let off water when it increases (e.g. heat-up period). The usual point of pressurization is the suction of a system circulating pump, where a constant pressure can be maintained independent of flow rate.

Based on those premises, Figure 6.5.11 shows the pressure diagram of the proposed system. Its three intermeshing circulating loops are so developed that each successive loop operates without any change when an upstream loop was lost. Consequently each loop is a fully operational system even before the upstream systems exist.

It is shown that the maximum pressure within the system is reached at the Kearny circulating pump discharge and it is 230 psig. This is a pressure somewhat higher than allowed for 150 lb. rated flanges (200 psig @ 250°F and 190 psig @ 300°F), but only the discharge side valves of that plant are affected that way. The rest of the system is well within the 150 lb. flange rating requirements.

The hot water transmission and distribution system laid out for the distribution of 3.7 billion BTU/hr will have a total estimated volume of 600,000 cu. ft. Each individual one sq. mi. system will contain 13–15,000 cu. ft. of water in piping, heaters, heatexchangers, etc.

The volumetric variation from cold (50°F) to maximum supply temperature and from cold to maximum return water temperature is 8.3% and 3% respectively. The average change, since supply and return volumes are equal, is 5.65% during initial heat-up. Daily changes in operation are usually limited to 25–30°F variation and the coincident volume change is about 1%.

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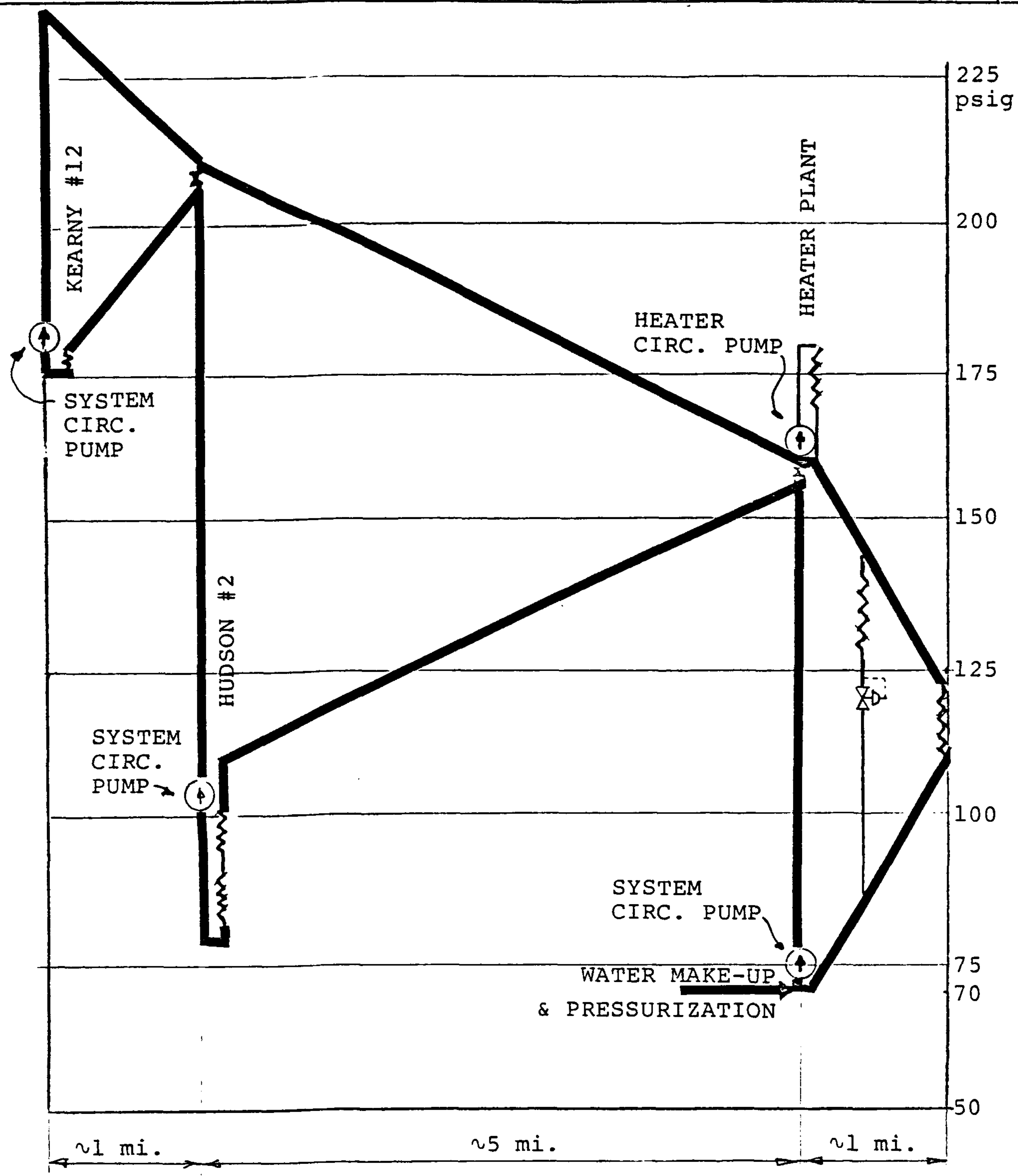

FIG. 6.5.11

SYSTEM PRESSURE DIAGRAM

LANDFILL GAS PRODUCTION

In 1979, PSE&G initiated its first methane extraction project from a landfill in Cinamminson, N.J. to provide a source of fuel for a nearby industrial customer. After a cleaning process to remove some of the impurities comprised mainly of carbon dioxide and water vapor, the methane gas extracted in this manner has a heating value of approximately 500BTU/ft^3, about half that of natural gas. The Company is also pursuing several other potentially viable landfill gas projects in its service territory.

To utilize the landfill gas, separate transmission piping to deliver the gas to the utilization points and modifications of customers' boilers are needed to burn the lower BTU gas. For district heating applications, the adoption of a concept of installing several large boilers at centralized locations with the capability of burning either landfill or natural gas could more effectively use landfill gas.

Landfill gas is expected to reduce the overall fuel cost of supplying thermal energy in comparison with natural gas. However, the dependability and expected life of a landfill gas source may be less certain.

Figure 6.8.3 shows the location of several major landfills in relation to the Berry's Creek and Harmon Meadows district heating regions under consideration.

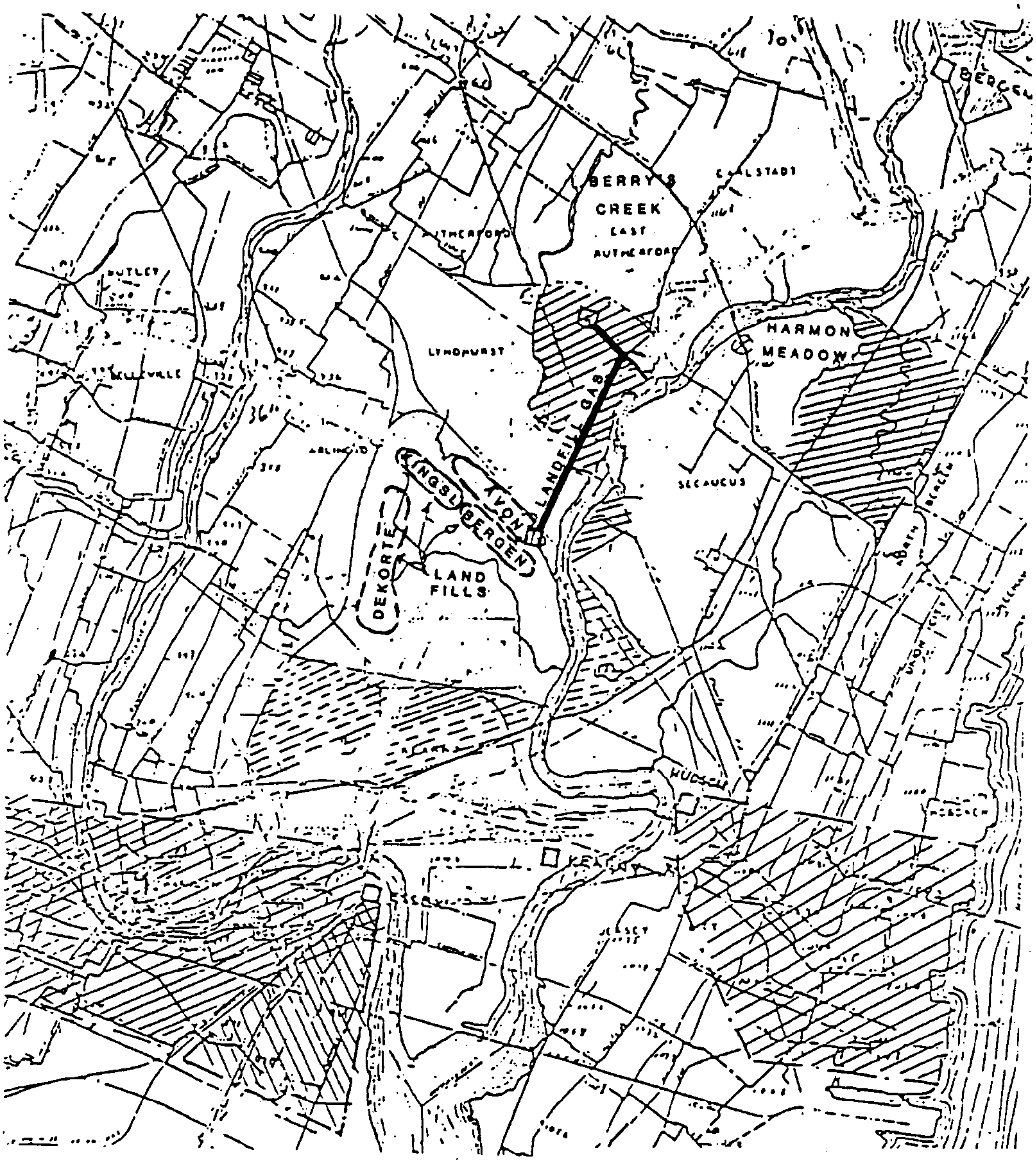
BERRY'S
CREEK
HARMON
MEADOW
LANDFILL GAS
AVON
BERGEN
DEKORTE
LAND
FILLS

FIG. 6.8.3

Each of the landfills was assumed to be capable of full production for a period of 10 years. After 10 years, theory predicts an exponential fall-off of methane production, resulting in the need to slow the extraction rate. Since there are no landfill gas systems currently in operation for more than 10 years, this theory remains to be proven. For study purposes and to simplify the calculations, the landfill capability was reduced to 50% of its full value for the eleventh through twentieth year. It was assumed that there would be no gas extraction after twenty years. No salvage value was assumed for the landfill facilities, althrough it is likely that the transmission piping would have a lifetime that exceeds that of the landfill. The methane production rates assumed for this study are estimates based on landfill age and other data provided by the operators of the landfill.

A more extensive program of testing would be required prior to any decision on development of a landfill.

A typical landfill gas extraction facility consists of a number of wells connected to a centralized compressor used to create a vacuum and extract the methane. The extracted gas passes through a clean-up process and is then delivered by a transmission system to the boiler plant sites.

For Berry's Creek and Harmon Meadows, landfill gas was assumed to supply approximately 2/3 of their combined peak thermal load. This level of supply was judged optimal from an economic viewpoint.

Complete development of all the existing major landfills in the area were assumed for the full system. Even with this extensive development, landfill gas can only supply a small percentage of the peak load of a system as large as this.

SYSTEM OPERATIONS

The complexity of the system and the time span of 25 years for its completion create differing operating scenarios at differing stages. While most of the aspects had been covered in the previous paragraphs, an overview may clarify some of the aspects not shown before.

Heater Plants Alone

Gas fired hot water generators located at the perceived load center of an area will operate on automatic controls and with remote supervision. So will the circulating pumps of the units and of the system. Day-to-day and scheduled maintenance will be performed by roving crews of craftsmen.

The firing of landfill gas, where made available, will always be in preference of the stand-by natural gas. The same burner train will be able to handle both as long as the supply pressures are adjusted for the difference in heating values, so as to compensate for it by varying flow rates.

The distribution, in the form of hot water, will operate at this stage at a basically constant temperature, variable flow rate system. Sliding temperature does not, while sliding flow rate does provide operating savings, when the heat supply is not cogenerative. The flow rate reduction is limited by distribution system balance. When that point is reached then the supply temperature starts to reduce also to meet very low load requirements.

One side effect of the constant temperature send-out is that the system can readily accept old low pressure steam users at the early stages of development. An understanding has to be established however that the steam system needs to be replaced by a hot–water system in a few years' time, as the system grows and/or as it becomes cogenerative. System growth is limited by a steam user, because the utilizable temperature differential is reduced to 60°F at the minimum return temperature of 230°F to be expected from those users. The limitation in the cogenerative model becomes that of economics. High return temperatures prevent the use of a low pressure steam exhaust and reduce the power produced, if not entirely eliminate power production because of the physical limitations of a given turbine. Those limitations do not apply to a combustion turbine driven cogenerative machine, and only partially so to a diesel driven one.

The plant operations are completed by the treatment of the make–up water and by the pressurization of the system. The make–up water, provided by the city water supply system, is planned to enter a resin treatment facility and is stored in a tank. A level controlled pressurization tank dumps water in the same tank on the heat–up cycle. The pressurization pump feeds water in from the tank on the cool–down cycle and to replace leakage losses. It also maintains a set cover pressure on the system to prevent the flashing of hot water.

There is always at least one stand–by heater unit in any one of the plants. These relatively small heaters are capble of coming on–line in less than half an hour without undue strain. Consequently the stand–by unit will not be fired normally and the fly–wheel effect of the considerable heat stored in the distribution system will be called upon to gap the time span created by the stand–by unit start-up. This philosphy is maintained over the later stages of development, since with the increase of transmission systems the fly–wheel effect increases also.

Heater Plants Plus Partial Retrofit of Hudson #2 Unit

It was conceived that a situation may develop when one of the heater plants is called upon to supply a larger load at an early stage of overall system development than its future share in the total load demands. At that point in time two possible actions are feasible. A temporary heater can be installed to bridge the time until other parts of the system grow sufficiently to justify retrofitting either the Kearny or the Hudson G.S. for D–H. This would perpetuate the relatively expensive central heater plant operation.

The other, much more fuel efficient, approach is the partial retrofit of the Hudson #2 unit. This retrofit, which is a relatively simple bleed at the two crossover lines, can supply approximately 200×10^6BTU/hr without controls other than pressure reducing stations to maintain HTW temperasture. The installation of heat–exchanger(s), circulating pumps and transmission line to the affected heater plant are the needed installations. The operation of these elements is totally automatic and self contained.

Start–up of a circulator makes the supply temperature controller call for steam. This opens the control valve in the bleed line and maintains a steam flow which may or may not satisfy the set temperature. It will not meet the control value, if the called–for flow is above the set limits of the bleed line. In this case the heater plant comes on automatically because its supply temperature controller is not satisfied either. Should the turbine shut down momentarily, it does not change this control sequence. It only brings more heaters on as the deviation from controlled temperature increases. Should the turbine outage be sustained, an operator will have to shut off the Hudson plant circulators and remotely open the by–pass valve at the heater plant(s) to direct the return water back at this point instead of circulating it through the transmission line.

There is no pressurization and make–up system required at the Hudson plant. These systems at the heater plants are to be made sufficient to cover the additional small leakage losses due to the transmission line and heaters added. The treatment facility included with the design of the Hudson G.S. retrofit is applicable only if a non–staged system construction scheme was adopted.

The study run by the manufacturer of the turbine, the Westinghouse Corp., established the maximum allowable bleed flow at full throttle flow and also the power generation lost due to that bleed (approx. 18 MW). The paper written by Messrs. Kan and Silvestri on the retrofit (see Appendix B) states that the steam generator can take 5% more flow at 5% higher throttle pressure. It has never been operated at those conditions. Actually, environmental restraints on the steam generator kept the unit operation below rated conditions. It seems possible that the losses encountered by the partial retrofit may be compensated by increased throttle flow, if the environmental restraint can be lifted. That involves a full investigation and impact presentation, beyond the boundaries of this study.

An additional feature of this retrofit is that Hudson Unit #1 has a tie–line of similar capacity to No. 2 unit which can be used as the back–up to this service. So no stand–by heaters are needed in the heater plant for this capacity.

Heater Plants and Combustion Turbine Plant

The operation of these two elements combined is no different from the one described in the previous paragraph. There are only a few exceptions to this statement.

First of all the Kearny #12 unit is made up of of four pairs of combustion turbines. Each pair is going to feed a heatrecovery heatexchanger of about 300×10^6BTU/hr capacity. The gas stream enters at about 900°F at full load and it is cooled to 250–300°F. Consequently there are no limitations on the supply side water temperature within the selected 295–170°F operating range of the HTW system. This in turn means that this unit combined with heater plants, can supply high temperatures year–round at varying flows without thermodynamic penalty. In practice this allows a time extension of supplying steam systems at no other operating losses, but an increase in heat losses on the system and higher pumping power use.

Each of the up to four heatrecovery HX's have their own circlators. They work parallel with the system circulators. This way a constant flow is maintained across the heatexchangers. The temperature leaving is a function of turbine load. At full load it is of a value higher than 295°F. The required leaving water temperature in the HTW system is maintained by mixing the system return water with varying amounts of water leaving the heatexchangers. At peak load all the return water may be flowing through the heatexchanger before leaving as supply water. This will occur only when this stage alone is called upon by the controls to supply 295°F water to the distribution system, without any heaters operating. Any other time the leaving water temperature is less. The fired heaters at the local plant(s) work in series with the heatexchangers.

Electric power production is independent of heating load in one direction only. More power can always be generated than that required by the heating system dictated momentary heatrecovery requirements. Conversely the turbines cannot be on electrical dispatch when the system incremental rate would dictate less output (or no output) from these units. To satisfy the heat requirements will necessitate its operation in lieu of a more cost efficient unit. An incremental cost penalty is incurred at these times and it is carried as a cost component of supplying heat. The installation of heat recovery also reduces the full load output of the units. This reduction amounts to approximately 5% of rated capacity or 3–4 MW, but due to the peaking nature of the plant no penalty was considered as a heating cost. In the winter, at the peak of the heating system, these units operate at a higher than ISO rated output anyway.

Low heating load conditions are also controlled by dampers. All or part of the flue gas flow can by–pass the heatexchangers and exhaust directly to atmosphere. Also any number of the four exchangers can be selected to operate at any given time. This alone provides a step control in 25% of full load increments.

All the operations are controlled by temperature and are automatic. The gas turbines are remote operated and supervised as they are. The only additions needed are the damper controls. Pump controllers and temperature controllers are the only devices needed to operate the HTW side.

Heater Plants and Hudson No. 2 Unit Phase II & III Retrofit

The 600 MW, supercritical, double reheat, coal fired No. 2 steam turbine-generator unit can provide 1600×10^6 BTU/hr heat, at full load, extracted from the two 64" dia. crossover lines between the IP and LP cylinders. This was established by the manufacturer. Extracting this flow reduces the output of the unit by close to 150 MW. The full load pressure at the crossovers is considerably higher than the HTW system leaving temperatures dictate. It was concluded that the insertion of back pressure turbine-generators for the utilization of the available pressure differential is an economically justified proposition. The same justification was found for two-stage heating. So two turbines, each handling half the flow, expand the steam to two different and sliding pressures feeding the two heaters connected in series on the HTW side. The turbine back pressure is controlled by the temperature set of the water leaving the heatexchanger (condenser). Outdoor temperature, with some system related modifications, controls the set point. Should the set point be satisfied by the lower stage unit (low load), the other unit stays idle. The two turbine-generators, at full load, recapture ca. 65 MW of the generation lost for a residual loss of approximately 85 MW.

The two stage approach also allows the graduation of construction. One unit with its heatexchanger and pumps can be erected when more than 200 million BTU/hr load is imposed on the plant. It will operate alone up to the time the plant load reaches 800 million BTU/hr. This corresponds roughly to a connected system peak of 1500 million BTU/hr. The difference is supplied by the heater plants in series with the heatexchangers.

Water from the users returns directly to the heatexchangers at about 167°F maximum. It is heated to a maximum of 237°F before leaving the plant and finally to 290°F+ by the heater plants, when the load so requires. At design peak load the system utilizes a 120°F temperature differential and provides for the system heat losses by actually operating at an approx. 128°F differential (5°F loss on the supply and 3°F loss on the return line at full load). At lower than peak loads the supply temperature is considerably lower than the design value, while the return temperature is also diminishing, but at a lesser rate. The temperature differential is however always proportional to the load as long as constant circulating flow is maintained. At very low loads that is not cost efficient, so the operation in the summer reverts to halving the flow and raising the temperature differential.

The constant flow, sliding temperature operation is the major advantage of a water system compared to a steam distribution system. What is sacrificed is the ability to provide heat at the required temperature level for steam users. There is a possibility to do so by installing heat pumps at these locations, but it is technically marginal with the equipment commercially available. Therefore its economy had not been established either.

The capability of the Hudson #2 unit to provide the design extraction flow is tied to the operation of the unit at not less than 85% load. This means that at times, as during a winter night, the unit will be forced to operate at higher loads than electric power incremental cost rates would dictate. This cost penalty will have to be absorbed by the D–H system. At times when electric power dispatch would call for the full output of the unit and heat is to be provided at the same time, the up to 85 MW lost capacity will have to be made up by some other plant on the system. If there is an incremental cost to do so, it also will be debited to the heat supply side of the ledger.

There are historically considerable intervals each year when the Hudson #2 unit is not available. For eight weeks each year there is a planned maintenance outage, which doubles to 16 weeks every five years for the regular major overhaul of the turbines. Several weeks of unplanned outages need to be added and catered to. The planned outage work will be normally performed during the low heating load periods of March and ALpril. The major planned outage however needs to encroach on the heating season––February to May––because the PSE&G power system peaks in the summer. During these times the heating system would revert to the heater plants including the stand–by heater units in these plants, with the exception of a 190000 lb/hr capacity crossover from Unit #1 at Hudson. This line can be utilized as a stand–by source during those outages of Unit #2.

Heater Plants, Combustion Turbine Plant Plus Hudson No. 2 Unit Retrofit

This combination of plants represents the full development of the 3700 million BTU/hr peak capacity heating system. The three types of plants operate in series on the HTW side, the Hudson #2 unit carrying the base load including the system losses. The peak loads and the entering and leaving water temperatures at each step are as follows.

Plant	Peak output 10^6BTU/hr	entering peak water temp. °F	leaving peak water temp. °F
Hudson #2	1600	167	223
Kearny #12	1100	223	259
Total of 11 heater plants	1000	259	295
(installed)	(2300)		

It is a repetition of the foregoing to say that each plant has its circulators, spared, to move the water to the next plant and the heater plant circulators move the water through the distribution system. Water returning from the users by–passes the upper stages in the chain and enters the plant carrying the base load at that point in time.

The operation and control of the three stage system is no different from the one described for the two stage one, with one stage added to the series chain in the heating and pumping process.

A detailed analysis has been made comparing the quantity and type of fuel burned annually at each of the three stages of the system assuming an eight week planned shut–down of the Hudson #2 unit (Table 6.9–I) and also in the case of a 16 week planned shut–down (Table 6.9–II). In both cases unplanned shut–downs of Unit No. 2 amounting to 25% of the rest of the time were evenly distributed over each month. These figures do not show however the additional fuel used by another unit to generate making up an equivalent of the kWh's lost due to high pressure extraction for heating.

TABLE 6.9-1

Summary of Fuel Burned by Months for the
Three Types of Supplies to the Fully Developed
District Heating System - Hudson #2 out for Maintenance
For 8 weeks Between April and May
Fuel Burned - 10^9 Btu

	Hudson #2			Kearny #12			Boilers
Month	Base Case	Dist. Heat Case	Delta	Base	Dist. Heat Case	Delta	Total
January	2750	2859	109	134	874	740	632
February	2503	2598	95	76	450	374	340
March	2690	2841	151	34	351	317	197
April	0	0	0	65	823	758	383
May	0	0	0	147	316	169	74
June	2156	2182	26	44	44	0	14
July	2372	2394	22	17	43	26	14
August	2375	2422	47	32	88	56	18
September	2468	2520	52	97	130	33	26
October	2817	2930	113	353	357	4	286
November	2720	2817	97	276	433	157	303
December	2806	2904	98	264	715	451	523
TOTAL	25,657	26,467	810	1,539	4,624	3,085	2,810

TABLE 6.9-II

Summary of Fuel Burned by Months for the
Three Types of Supplies to the Fully Developed
District Heating System - Hudson #2 out for Maintenance
For 18 weeks Between February and May
Fuel Burned - 10^9 Btu

	Hudson #2			Kearny #12			Boilers
Month	Base Case	Dist. Heat Case	Delta	Base	Dist. Heat Case	Delta	Total
January	2750	2859	109	134	874	740	632
February	0	0	0	76	982	906	1174
March	0	0	0	34	1010	976	681
April	0	0	0	65	823	758	383
May	0	0	0	147	316	169	74
June	2156	2182	26	44	44	0	14
July	2372	2394	22	17	43	26	14
August	2375	2422	47	32	88	56	18
September	2468	2520	52	97	130	33	26
October	2817	2930	113	353	357	4	286
November	2720	2817	97	276	433	157	303
December	2806	2904	98	264	715	451	523
TOTAL	20,464	21,028	564	1,539	5,815	4,276	4,128

USER CONNECTIONS

The interface between the district heating system and the building heating and domestic water preparation systems is the user connection. It is first of all a heatexchanger, which isolates the relatively high-pressure district heating operation from the low-pressure, low temperature in-house systems. The advantage of this method is found in the safety of the user systems and in the integrity of the D-H system.

Hot water and hot air heating system connections are the easiest. The variable temperature hot water distribution system is best in supplying warm water or hot air in-house systems. There is no change necessary in their physical plant except the boiler is paralleled or replaced by the heatexchanger. Hot air systems can be connected even without a heatex-changer by replacing the air coils with high-pressure ones and feeding D-H water directly (Fig. 6.6.1). This is particularly desirable where the original coils operated on L.P. steam.

The supply of domestic hot water (DHW) could be accomplished the same way, but safety of the system requires the insertion of an intermediate circuit. This way no tube rupture can cause mixing of high temperature and pressure water into the DHW supply.

Following these requirements, Fig. 6.6.2 shows the typical house connection schematics. It also tabulates the proposed standard capacities and the associated flows and pipe sizes.*

One important addition to usually existing in-house systems is the increased DHW storage. This is a requisite for an effective DH since even distribu-tion over 24 hours of the DHW load can materially affect the total capacity of the system. The average 7-10% DHW load, if not supplied by ample storage, can vary from 0 to 100% of peak heating load. Hot water use is normally concentrated to two 3 hour periods of a day. Large storage and the circulating system of heating smoothes out these peaks and lets the DH system, particularly in the off-seasons and during the summer, operate at a

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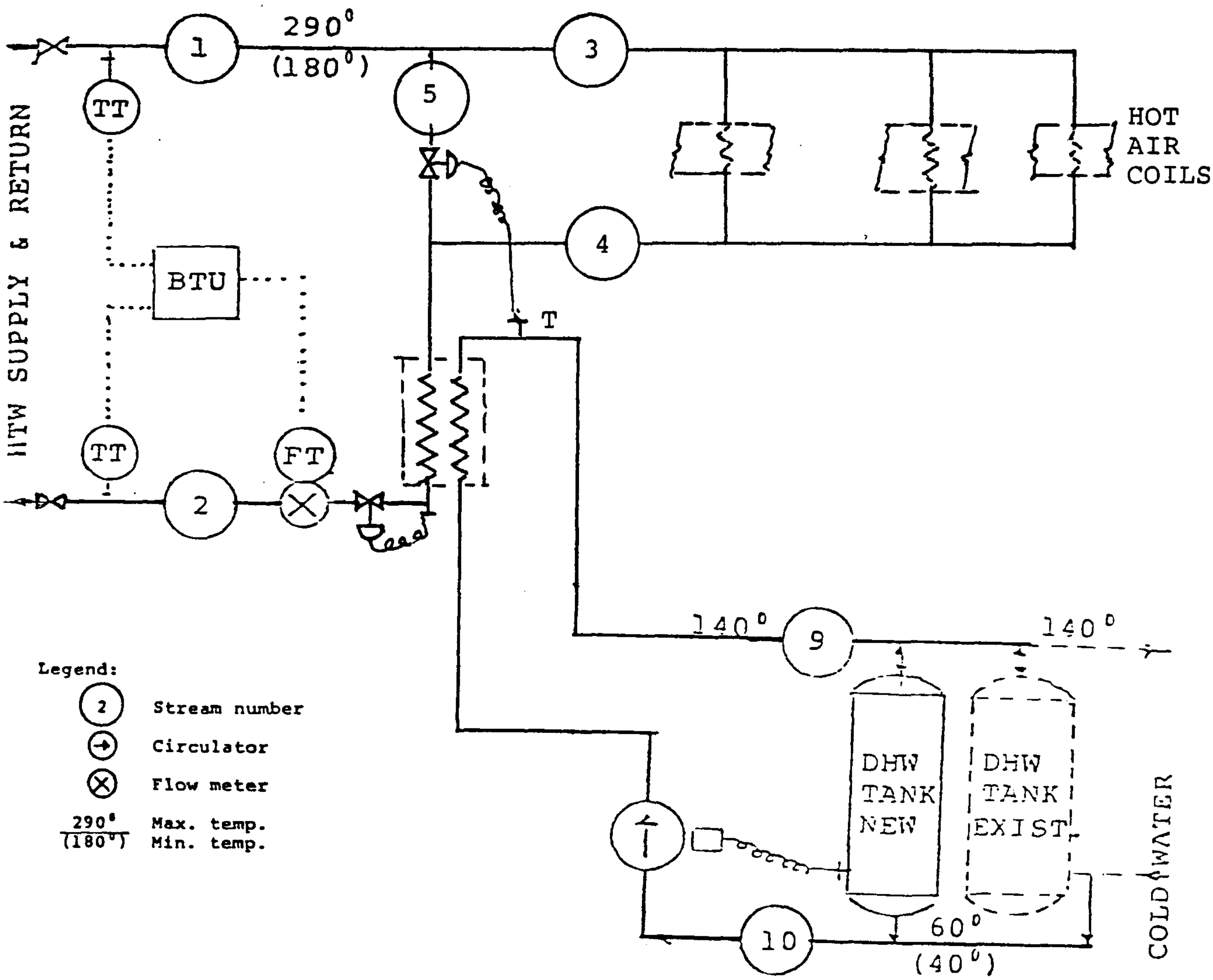
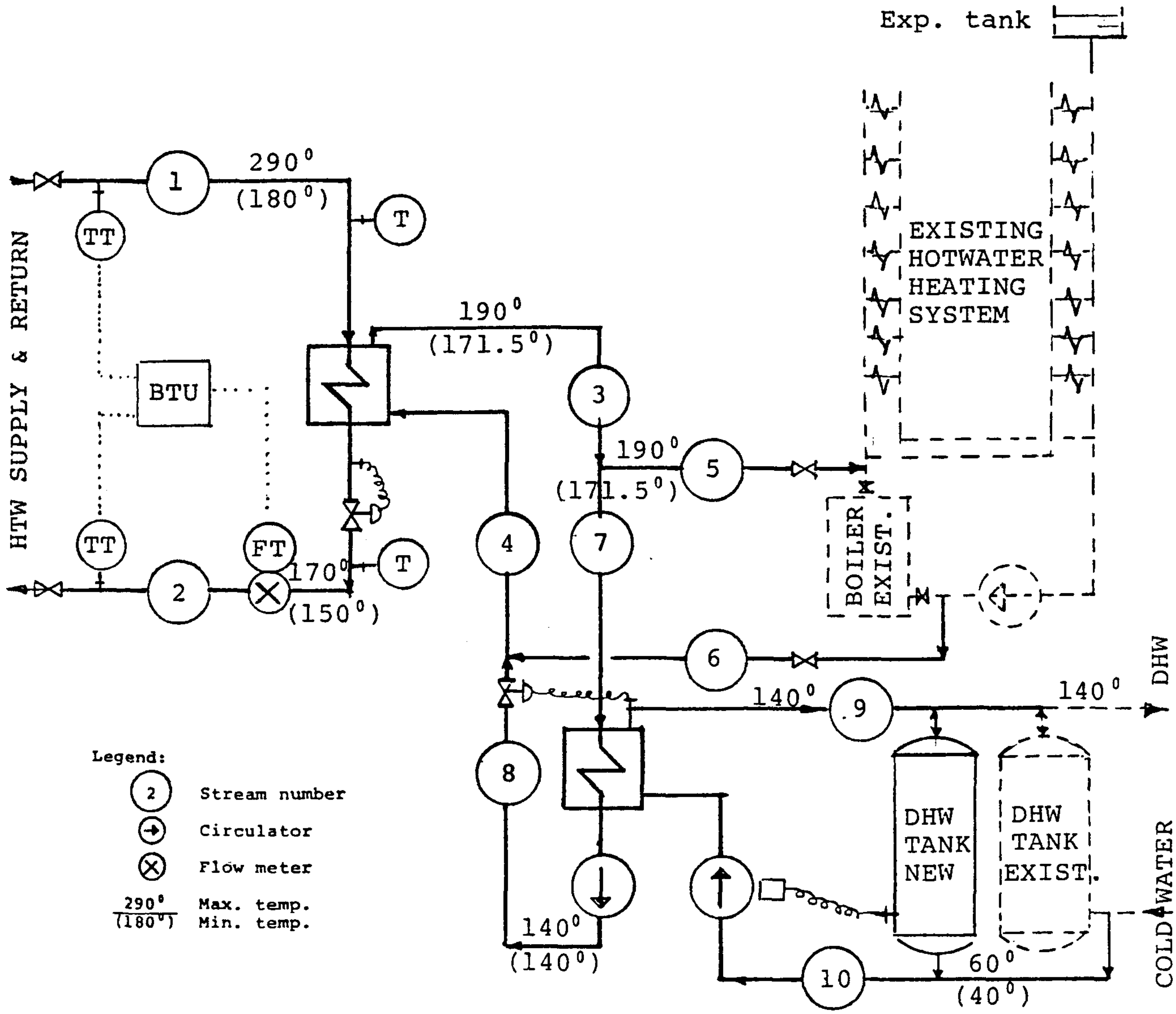
*Figure 6.6.3 shows a simpler, more efficient and less costly schematic using plate type heatexchangers. Since there is no possibility of HP water mixing into the DHW, an intermediate heatexchange step can be safely eliminated.



Type of bldg.	Peak load heating d.h.w. 10^6 BTU/hr		① ② gpm	dia	③ ④ gpm	dia	⑤ gpm	dia	⑦ ⑧ gpm	dia	⑨ ⑩ gpm	dia	DHW storage gal
small apt. - 25 units	.5	.065	7.1	3/4	6.9	3/4	.2	1/2	X	X	1.3	1	825
med. apt. - 50 units	1.0	.13	14.2	1	13.4	1	.8	1/2			2.6	1	1650
½ city block - 35 units	1.5	.195	21.3	1½	20.3	1½	1.0	1/2			2.7	1	10x130
large apt. - 100 units	2.0	.26	28.4	2	26.8	2	1.6	1/2			5.2	1	3300
hi-rise - 250 units	5.0	.65	71.0	2	67.0	2	4.0	3/4			13.0	1½	8000

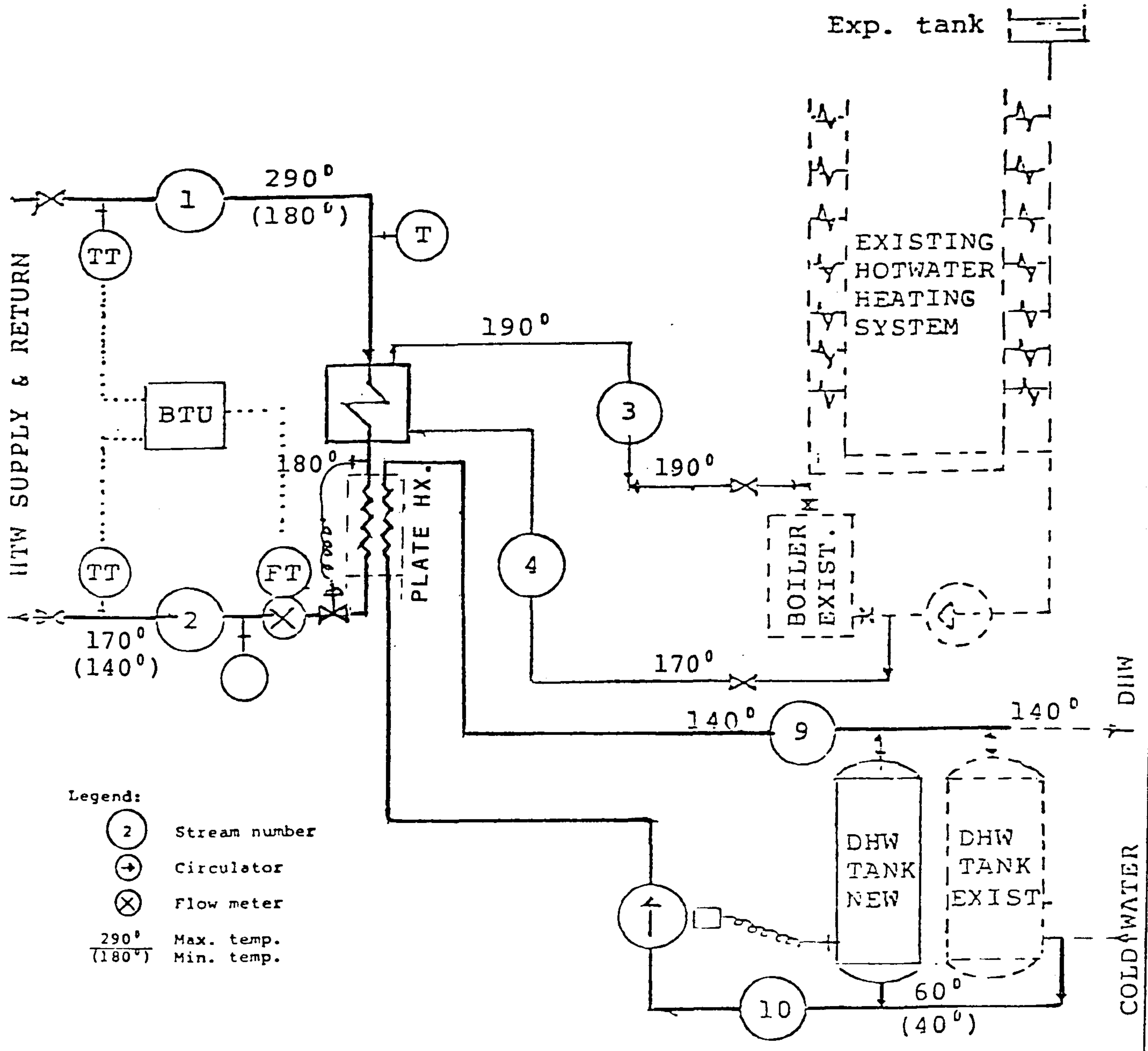
FIG. 6.6.1



Type of bldg.	Peak load heating 10^6 BTU/hr	d.h.w.	① ② gpm	dia	③ ④ gpm	dia	⑤ ⑥ gpm	dia	⑦ ⑧ gpm	dia	⑨ ⑩ gpm	dia	DHW storage gal
small apt. - 25 units	.5	.065	9.4	1	55.2	2	50	2	5.2	1	1.3	1	825
med. apt. - 50 units	1.0	.13	18.8	1½	110.4	3	100	3	10.4	1½	2.6	1	1650
½ city block - 35 units	1.5	.135	28.2	2	160.8	4	150	4	10.8	1½	2.7	1	10x130
large apt. - 100 units	2.0	.26	37.5	2	220.8	4	200	4	20.8	1½	5.2	1	3300
hi-rise - 250 units	5.0	.65	94.0	2	552.0	6	500	6	52.0	2	13.0	1½	8000

FIG. 6.6.2

CUSTOMER CONVERSION UNIT SCHEMATICS - WARM WATER HEATING (A)



Type of bldg.	Peak load heating 10⁶BTU/hr	d.h.w.	① gpm	② dia	③ gpm	④ dia	⑤ gpm	⑥ dia	⑦ gpm	⑧ dia	⑨ gpm	⑩ dia	DHW storage gal
small apt. - 25 units	.5	.065	9.1	1	50	2	X	X	X	X	1.3	1	825
med. apt. - 50 units	1.0	.13	18.2	1½	100	3	X	X	X	X	2.6	1	3650
½ city block - 35 units	1.5	.195	27.3	2	150	4	X	X	X	X	2.7	1	10x130
large apt. - 100 units	2.0	.26	36.4	2	200	4	X	X	X	X	5.2	1	3300
hi-rise - 250 units	5.0	.65	91.0	2	500	6	X	X	X	X	13.0	1½	8000

FIG. 6.6.3

fairly even load. It also assures a low return water temperature to the DH system, an important requisite of its efficiency.

The DHW load and the storage requirements were taken at 8.5 gal/hr peak use in three hours for an apartment in a small house and 4 gal/hr/apt. in a large building. The daily use has been established at 110 gal. and 75 gal. respectively. The hot water heating heat requirements represent 10-11% of the peak space heating load of the same apartments.

The control of the system is simple. Ambient temperature changes are basically compensated for by centrally changing the supply temperature. The control valve in the return line compensates for load reduction on the secondary side in excess of that due to outdoor temperature change. As that load reduces the return temperature increases. Sensing that, the valve closes, reduces the flow and restores return water temperature. Similarly the control valve in the DHW heating circuit reduces flow as the circulating DHW temperature increases above 140°F. That can happen when the tanks are full of hot water.

L.P. Steam heating system connections are much more cumbersome to accommodate, but a significant number of old buildings are steam heated. Most of them are older than 20 years. Even so it may be of importance to accommodate such buildings at the early stages of development.

As long as the system load does not reach 50% of design capacity and there is no economic penalty in operating at a constant, high send out temperature, the distribution system is capable of operating at half the temperature drop and twice the specific water flow per unit heat delivered. Such a system would then send out 290°F water and return 230°F water if all the users are steam customers. Each user will then have an evaporator capable of producing 5-10 psig steam and a DHW heater as before. This is shown on Fig. 6.6.4. The conversion scheme is simple and only insignificantly more expensive than that of a hot water heated building.

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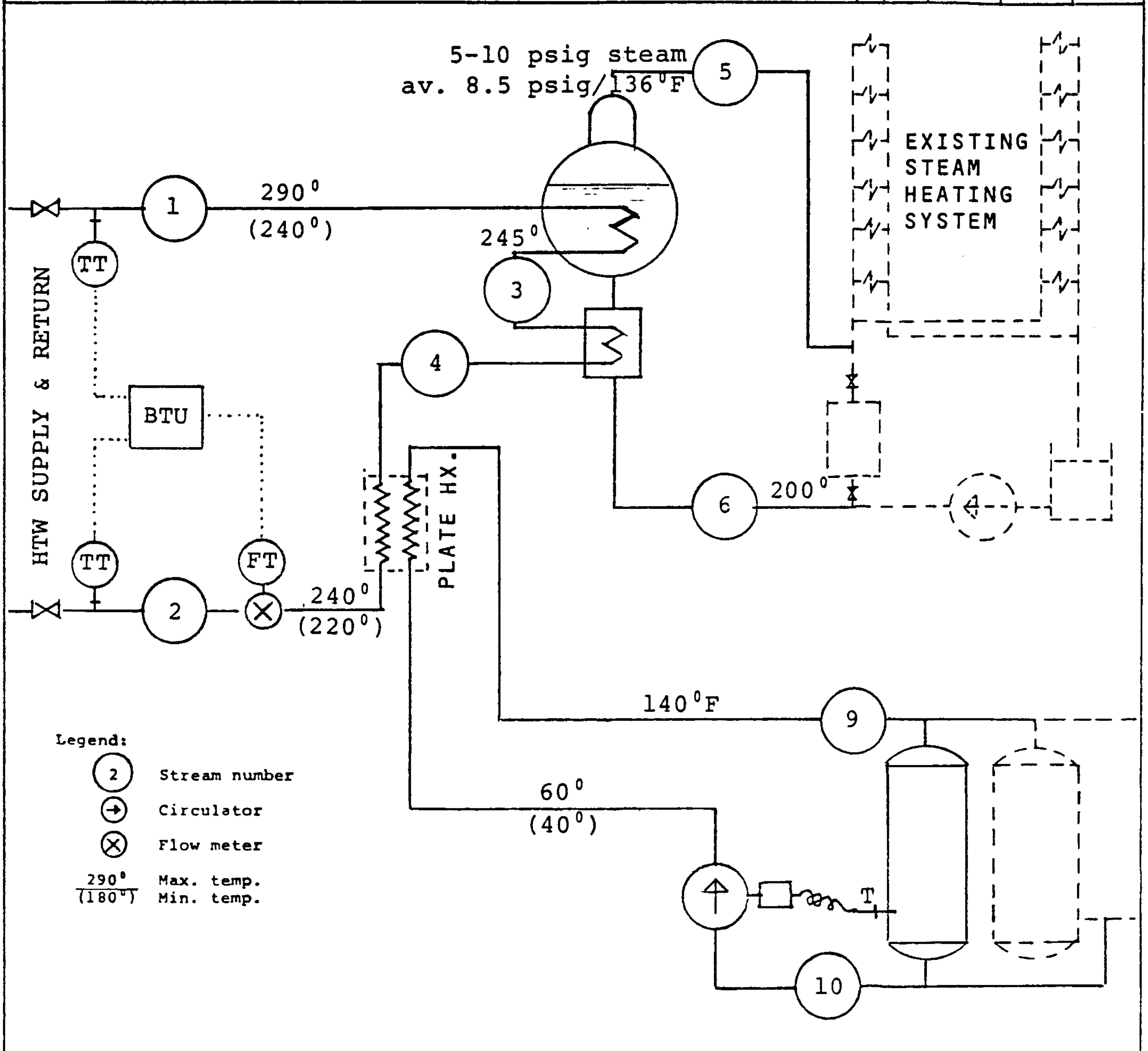

Type of bldg.	Peak load heating 10⁶BTU/hr	d.h.w.	① gpm	② dia	③ gpm	dia	⑤ lb/hr	dia	⑥ gpm	dia	⑨ gpm	⑩ dia	DHW storage gal
small apt. - 25 units	.5	.065	21.3	1¼	21.3	1¼	505	3	1.1	1½	1.3	1	825
med. apt. - 50 units	1.0	.13	42.6	1½	42.6	1½	1010	4	2.2	3/4	2.6	1	1650
½ city block - 35 units	1.5	.195	63.9	2	63.9	2	1515	5	3.3	3/4	2.7	1	10x130
large apt. - 100 units	2.0	.26	85.2	2½	85.2	2½	2020	6	4.4	1	5.2	1	3300
hi-rise - 250 units	5.0	.65	213.0	4	213.0	4	5050	8	11.0	1	13.0	1½	8000

FIG. 6.6.4

CUSTOMER CONVERSION UNIT SCHEMATICS - STEAM HEATING (D-H @ CONST. TEMP.)

The operating cost addition is in increased (double) pumping and heat loss expenses. The hot water or hot air heated buildings will still make full use of the 120°F temperature differential at peak load and return water generally cooled to 170°F or less. This means that the steam heated buildings in an area of Jersey City will amount to 33% of the $300x10^6$ BTU/hr per sq. mi. design load. Thus the distribution system will be able to carry a load of $200x10^6$ BTU/hr maximum. If the steam load is only 15%, then the maximum allowable load increases to $245x10^6$ BTU/hr.

As was said before, the above is true only as long as only fired heaters are the heat source. Should gas turbine heat recovery be the next step of the staged development, the scheme would still hold true. Only the retrofit of the Hudson unit and its incorporation into the system makes low return water temperatures imperative.

At this point the steam user and/or the system have the following choices:

- convert to hot water or hot air heating
- add a heatpump
- use the system at the height of the winter only for heating and for DHW heating only the rest of the time
- disconnect

Most buildings at that time (5-10 years from now) will be forced to convert because of the age of the installation on one hand and also because of the inherent inefficiency of a steam heating system.

Addition of a heatpump as shown on Fig. 6.6.5 makes the buildings fully compatible with the rest of the system. Considerable heatpump development work is in progress at the present time. There is good reason to assume that by the time the need arises, there will be commercially available, proven small units on the market. Most of the presently available ones are suitable only for the larger buildings and they are marginal at the upper end of the required temperature (235°F commercial limitation v. 240°-245°F minimum required).

The heat balance is shown on Table 6.6.I.

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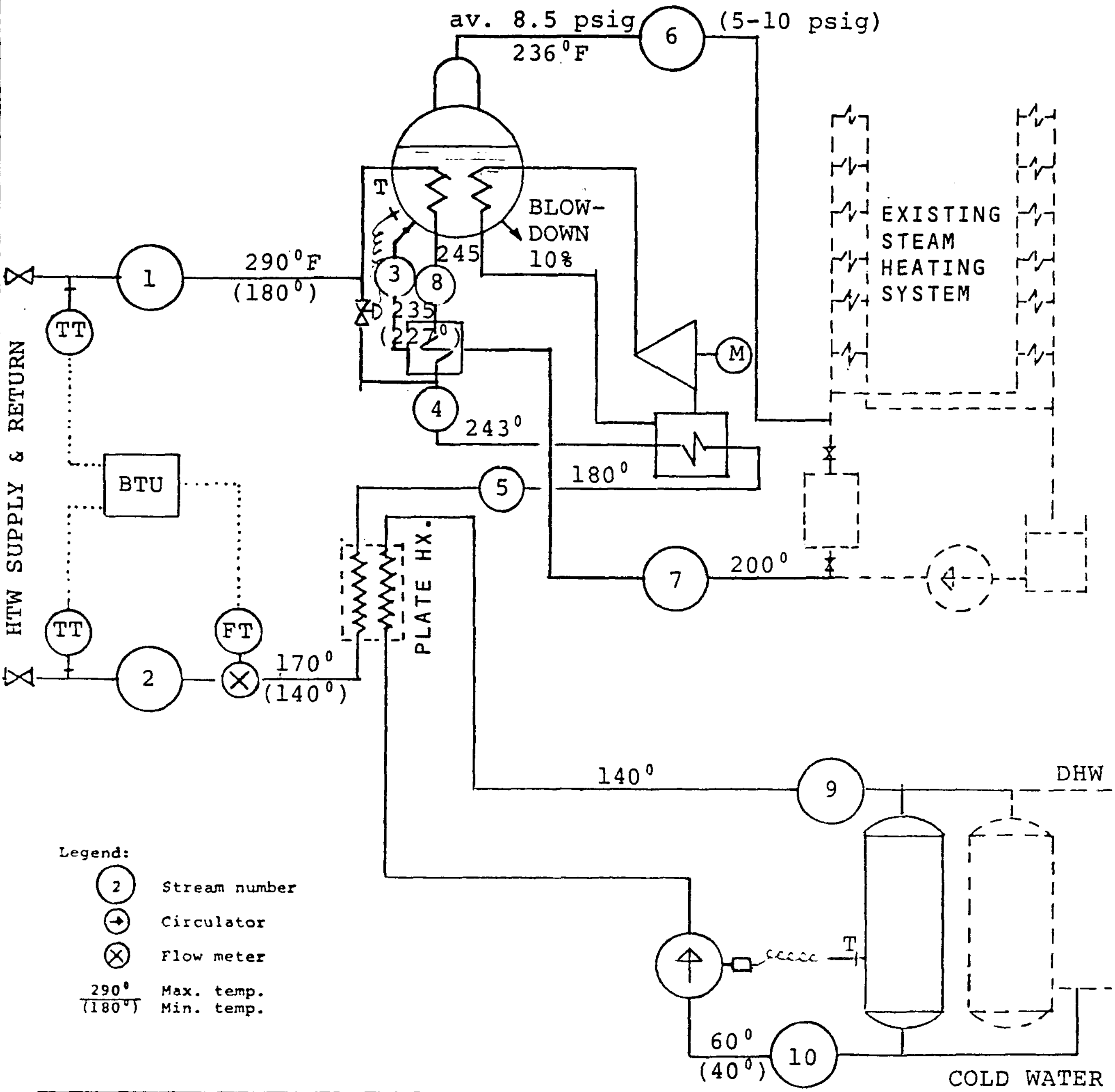


Type of bldg.	Peak load heating 10⁶BTU/hr	d.h.w.	① gpm	② dia	③④⑤ gpm	dia	⑥ lb/hr	dia	⑦ gpm	⑧ dia	⑨ gpm	⑩ dia	DHW storage gal
small apt. - 25	.5	.065	7.3	3/4	7.3	3/4	505	3	1.1	½	1.3	1	825
med. apt. - 20 units	1.0	.13	14.6	1	14.6	1	1010	4	2.2	3/4	2.6	1	1650
½ city block - 35 units	1.5	.195	21.9	1½	21.9	1½	1515	5	3.3	3/4	2.7	1	10x130
large apt. - 100 units	2.0	.26	29.2	2	29.2	2	2020	6	4.4	1	5.2	1	3300
hi-rise - 250 units	5.0	.65	73.0	2	73.0	2	5050	8	11.0	1	13.0	1½	8000

FIG. 6.6.5

CUSTOMER CONVERSION UNIT SCHEMATICS - STEAM HEATING W/HEATPUMP

TABLE 6.6-I

Heat Balance of Heatpump Assisted L.P. Steam User Connection

D-H Evaporation Coil

D-H water entering	259.44BTU;	steam leaving	1160.1		
Leaving evaporator	213.50 " ;	cond. entering	203.8		956.3BTU/lb
	---------		------		
Heat rejected	45.94BTU;	steam produced	45.94 ----- 956.3	=	.048 lb

Cond. preheater

D-H water entering	213.50BTU;	cond. leaving	203.80		
D-H water leaving	211.78 " ;	cond. entering	168.07		35.73BTU/lb
	---------		------		
Heat rejected	1.72BTU;	heat utilized	.048x35.73	=	1.72BTU

Heatpump evaporator / Heatpump condenser coil in evaporator

D-H water entering	211.78BTU				
D-H water leaving (180°F)	147.99 "				

Heat rejected	63.79BTU				
Electric power added .0073kWh	24.81 "				

Total heat converted	88.60BTU;	steam produced	88.60 ----------- 956.3+35.73	=	.089 lb

Totals

- per 1 lb of D-H water			
D-H heat used	259.44BTU;	steam produced	.048
	- 147.99 "		+ .089
	---------		----
	111.45BTU		.137 lb
Electric power converted .0073kWh	24.81 "		

	136.26BTU;	(956.3+35.73).137 =	135.98BTU
- per 1000 lb of steam per hr			
water - lb/hr	7299.2	steam - lb/hr	1000
- gpm	14.5		
electric power - kWh/hr	53.3		

It is to be noted that the D-H system has to supply 18.2 gpm of water, or close to 25% more for a hot water/hot air system than to the L.P. steam customer with the above conversion system. This means that some of the conversion cost can be balanced by the reduced share of such conversion in distribution and heat production installations.

The DHW needs of these buildings are satisfied as those of other buildings. The 180°F water leaving the heatpump evaporator enters the DHW heatexchanger and is cooled to approximately 170°F, completing the cycle.

It is significant to note that the share of the heat-pump generated steam in the peak is 66% while the rest is generated directly by the D-H system. The temperature frequency curve of the system shows that the send-out temperature reaches 240°F at just that load point--that is, 66% of peak. So the additional load above that point can be satisfied by the planned temperature run-up of the system.

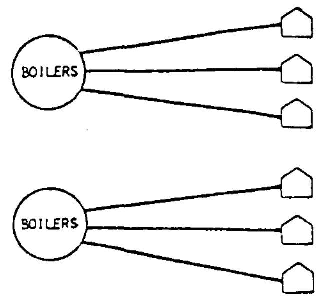
STAGED-DEVELOPMENT SCENARIOS

The staged-development scenarios adopted for this study should not be considered as "rigid" but merely indicative of the manner in which a real district heating system could be built, if a decision to do so is made. There are sufficient potential sites for district heating implementation with characteristics similar to the ones selected for this study so that the analysis is not overly sensitive to changes in development schedules or construction plans of specific new developments which are outside of the influence of PSE&G.

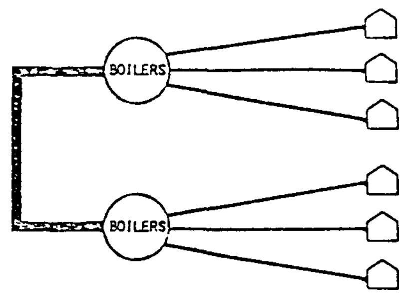
Figure 8.0.1 shows a generalized method for developing a district heating system.

The basis of all economic comparisons is that if a district heating system is not implemented, a conventional heating system supplied either by natural gas or oil would most likely be used in

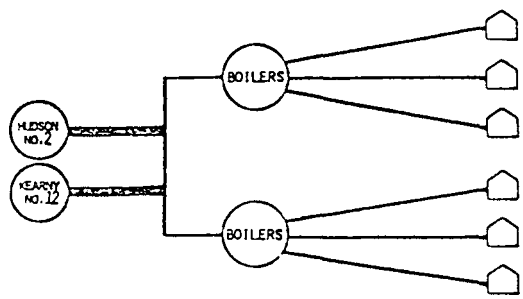
FIG. 8.0.1



STEP 1 - INDIVIDUAL HEATING ISLANDS SUPPLIED BY CONVENTIONAL PACKAGE BOILERS



STEP 2 - INTEGRATION OF HEATING ISLANDS INTO AN INTERCONNECTED SYSTEM



STEP 3 - RETROFIT OF EXISTING GENERATING UNITS FOR HEAT RECOVERY AND INTEGRATION WITH HEATING ISLANDS individual buildings. Since the costs of both natural gas and oil are expected to be generally in parity, with natural gas on the lower side over the long run, for simplicity natural gas was chosen to provide a more conservative comparison with district heating. The boilers in the conventional system would, of course, be customer owned.

Normally there would be two reasons for installing a new boiler:

1) Construction of a new building
2) Replacement of existing older equipment

Some areas have been identified as having a high potential for future new developments. In these cases, it was assumed that all new boilers would be required. In existing areas, factors ranging from 22 to 40% were calculated to account for the boiler age distribution and remaining life. Normally there may or may not be back-up boilers in a conventional system, so that there may be some advantage over a district heating system in boiler capital costs. The conventional system matches the load almost exactly, eliminating the excess capacity inherent with large boilers at centralized sites, but neither is there a factor of coincidence amounting customarily to 8-10% of contracted peaks of a central system.

SCENARIO I - BERRY'S CREEK DISTRICT HEATING SYSTEM

A new commercial/residential development was identified along Berry's Creek of the Hackensack Meadowlands on an approximately 700 acre tract, under the supervision of the Hackensack Meadowlands Development Commission, a State agency. It has been determined that for both technical and political reasons this site is a natural starting point for the introduction of district heating in Northern New Jersey. Its development is scheduled to take place over 10 years and it is estimated to require 200 million BTU per hour for heating on a peak, zero degree day.

It is a mixed development of a shopping center, offices, hotel/motels and residential housing of mid-rise and multi and single-family housing. It is to be located on a tract south of Route 3 and west of the western spur of the N.J. Turnpike.

It was estimated on the basis of square foot building area and projected use that the total development at its completion will present a peak heating load of 300 million BTU/hr. This figure was reduced to 200 million BTU/hr in our further studies to account for improved, energy saving construction and for possible changes in plans.

Tables 8.1-II and 8.1-III show the extent of the pipe work and the heater plant requirements to meet the heating needs of the development as they materialize. Table 8.1-IV gives the equipment installation schedule.

A high temperature water district heating system is to supply the space heating and domestic hot water needs of the entire development. The supply of cooling by this system is subject to negotiations with customers. It has not been included in the proposed operations. The domestic hot water requirements are estimated to be 7.5% of the space heating peak and it is considered constant year-round. The coincident peak load of the large number of users is assumed to be 92.5% of the sum of peaks. Therefore in sizing the facilities the domestic hot water load is neglected. It is included however in the energy use (fuel) calculations.

There are two ways one can supply heat to the complex:

- an extraction steam based system originating at the Hudson G.S., or

- a landfill gas fuel based system.

The Hudson G.S. based system will be developed in stages, starting with three 50 million BTU/hr capacity units fired by natural gas. This will be complemented by a fourth unit by the time the peak load reaches 100 million BTU/hr. That provides 100% stand-by capacity at this point, which will gradually reduce to 33% (one unit) as the load increases during the following years. The layout and the piping schematics of this heater plant is as it was shown previously. At this point there is sufficient load to justify the construction of a 5-1/2 mile transmission line connecting the site to the Hudson G.S. (see Fig. 8.1.8) and to tap the crossover of No. 2 unit. This tap is shown on Fig. 8.1.9 schematically, and along with two heatex-changers and pumps located in a new building, will provide up to 240 million BTU/hr for district heating. It operates as a bleed with no other but D-H water

TRANSFLUX International limited

TABLE 8.1-II

MEADOWLANDS SYSTEM
(BERRY'S CREEK ONLY)
HTW PIPING INSTALLATION SCHEDULE
IN 1000 FT. OF PAIR OF PIPE

	DIA	1984	1985	1986	1987	1988	1989	1990	1991	TOTAL
ALT. 1 - NO LANDFILL GAS										
BERRY'S CREEK	12"		.6							.6
	10"		3.2	1.0	1.0					5.2
	8"		.6							.6
	4"		2.2	.3	.3	1.0	.4	.3	.3	4.8
	3"		.1							.1
	2"		1.6	.2	.1	1.6	.4	.3	.3	4.5
	1-1/2"		1.2			1.2	.2	.2	.2	3.0
HUDSON G.S. -TRANSMISSION	16"					26.5				26.5
TOTAL - ANNUAL			9.5	1.5	1.4	30.3	1.0	.8	.8	45.3
- ACCUMULATIVE			9.5	11.0	12.4	42.7	43.7	44.5	45.3	

ALT. 2 - LANDFILL GAS

same as above, except no transmission line is required and a gas gathering and supply system has to be constructed.

TRANSFLUX international limited

TABLE 8.1-III

MEADOWLANDS SYSTEM
(BERRY'S CREEK ONLY)
INSTALLATIONS & LOAD RUN-UP
ESTIMATE

	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	TOTAL
ALT. 1 - NO LANDFILL GAS											
Berry's Creek											
Heater Plant - 10^6BTU/hr		150		50							200
Distribution - see Table 8.1-II											
Nat. gas service - 10^6BTU/hr		250									250
Hudson G.S.											
Turbine retrofit - partial - 10^6BTU/hr					240						240
Hx's & pumps											
Total - increm.- inst'd. cap.		150		50							200
" - accum. - inst'd. cap.		150	150	200	440	440	440	440	440	4400	440 (spare 240)
ALT. 2 - LANDFILL GAS											
Berry's Creek - 10^6BTU/hr		150		50			50				250
Distribution - see Table 8.1-II											
Gas gathering - 10^3cfh			50	300	50		25	25			350
Back-up serv. - nat. gas - BTU/hr		200									200
Total - increm.- inst'd. cap.		150		50			50				250
- accum. - inst'd. cap.		150	150	200	200	200	250	250	250	250	250 (spare 50)

Note: 16"HW transmission line is not required.

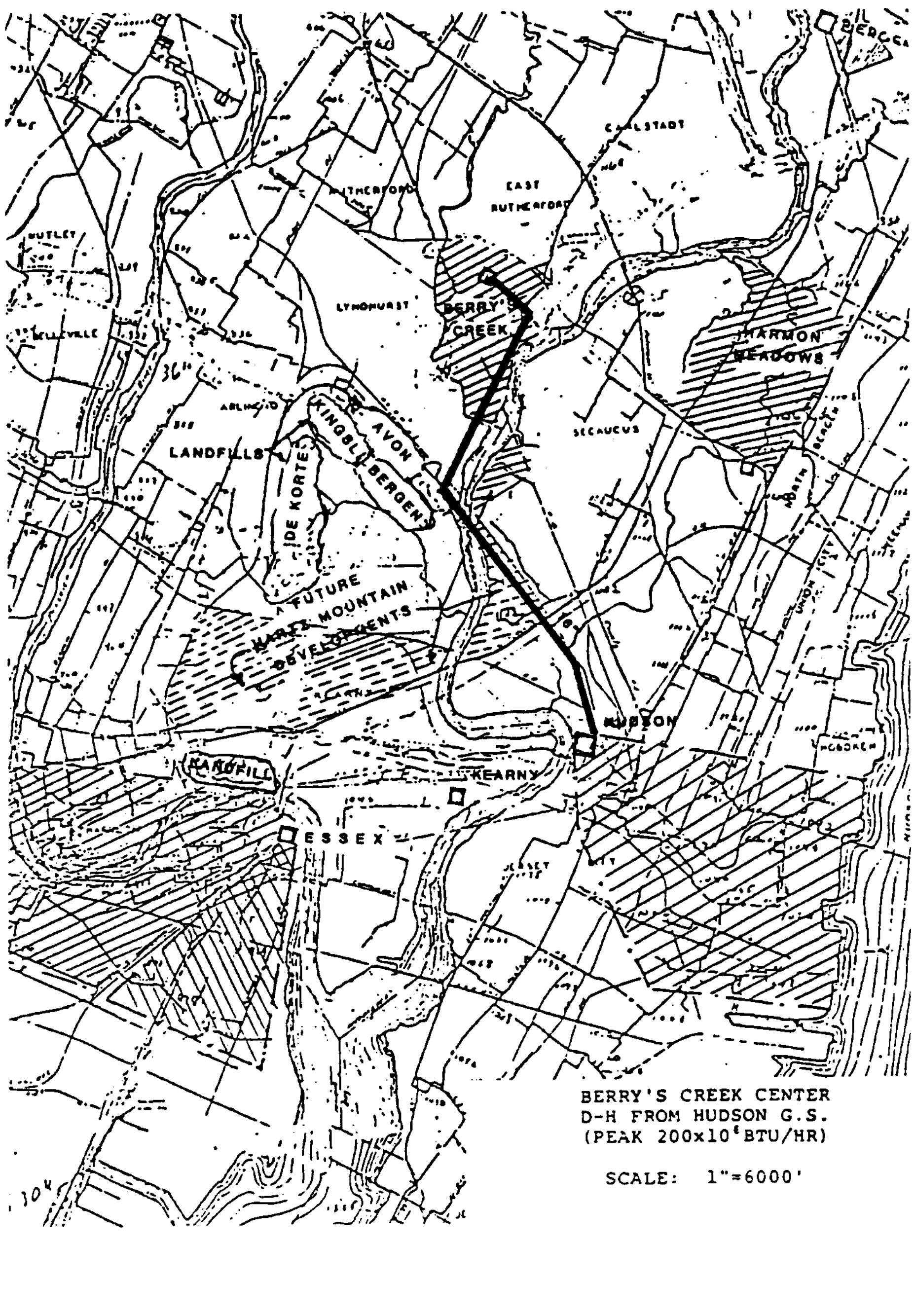
Heat Load	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
							10^6BTU/HR			
Berry's Creek - Accumulative peak		15	70	100	135	150	160	170	180	183
- " heat loss		5	5	9	12	13	14	15	16	17
- " total		20	75	109	147	163	174	185	196	200

TABLE 8.1 -IV

LIST OF
ANNUAL
EQUIPMENT INSTALLATION
REQUIREMENTS

MEADOWLANDS SYSTEM (Berry's Creek only, 200 million BTU/hr. max.)

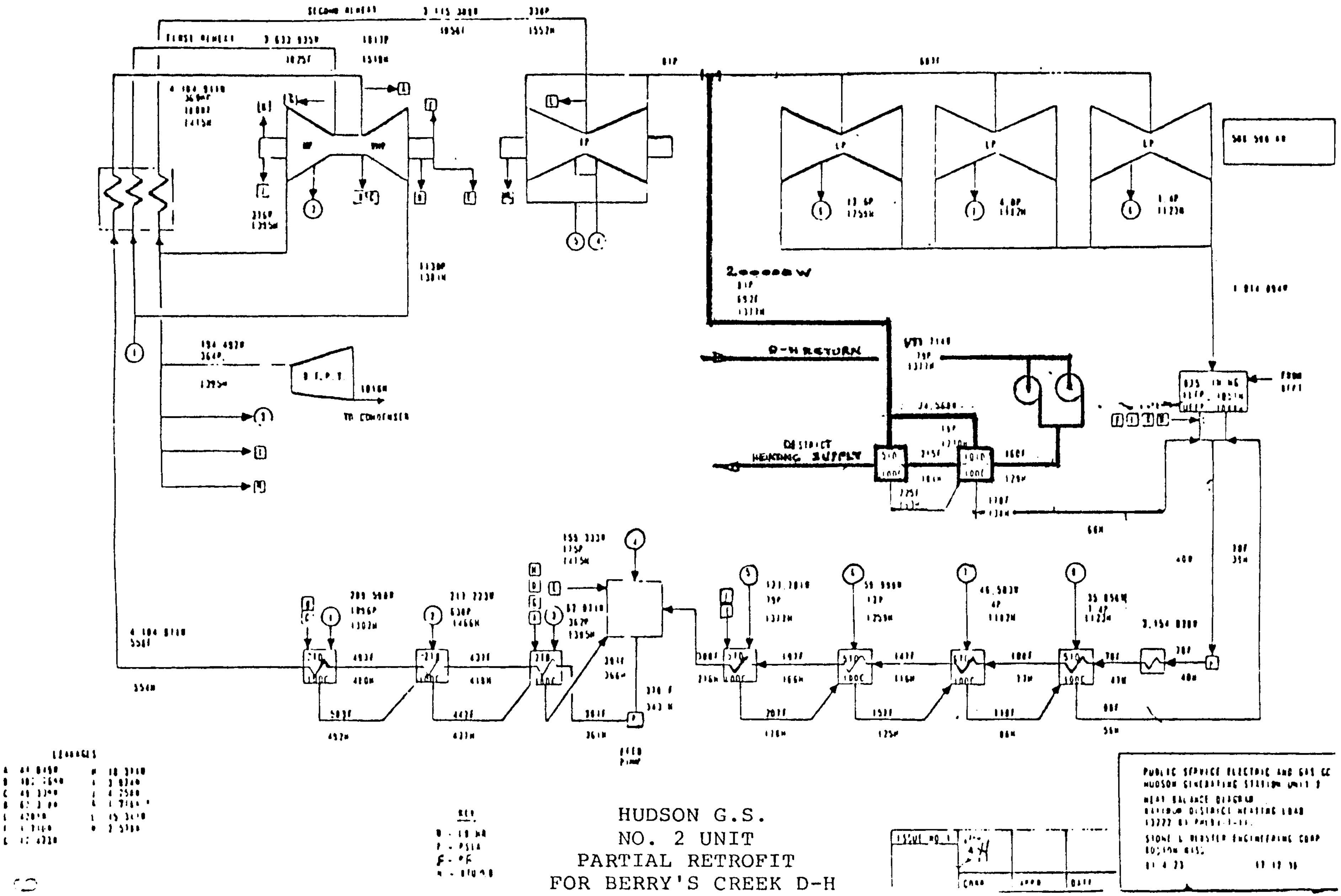
Yr. of Inst.	Peak Load 10^6BTU/hr	Equipment to be installed	Location
ALT. 1 - NO LANDFILL GAS			
1983	-	Engineering and prepayments on equipment	Berry's Creek
1984	15	3 - 50x10^6BTU/hr gas/oil/landfill gas fired water heaters, prefabr. 3 - 2500gpm, 20psi total head, approx. 40HP circulating pumps 3 - 2000gpm, 120psi total head, approx. 125HP syst. circ. pumps 1 - stack (as part of adjoining office bldg.) 1 - building, 18000 sq. ft., 25 ft. high 1 - pressurizing system 1 - 100gpm water softening syst. 1 - 240000cfh natural gas trunk-line Distribution piping: none	
1986	100	1 - 50x10^6BTU/hr fired water heater, as above 1 - 40HP heater circ. pump 1 - 125HP system circ. pumps	Berry's Creek
1987	135	- Hudson No. 2 turbine partial retrofit - - crossover taps	Hudson G.S.
1988	150	2 - heatexchangers - (1 - 130000 lb/hr, 1 - 70000 lb/hr), 235x10^6BTU/hr 3 - 2000gpm, 100psi total head, approx. 150HP syst. circ. pumps ~4½ mile - 16" dia. aboveground transmission lines	Hudson G.S. " Hudson G.S./ Berry's Creek
1992	200	none	
ALT. 2 - LANDFILL GAS			
1983	same as above	- as Alt. 1	Berry's Creek
1984-on	same as above	- construction of a 133x10^6BTU/hr net heat output, 7.8x10^6 cu. ft./day gas gathering and compression system - supply line to heater plant	Avon Avon/Berry's Creek
1985	same as above	- as Alt. 1	Berry's Creek
1988		1 - 50x10^6BTU/hr fired water heater 1 - 20HP heater circ. pump	" "



BERRY'S CREEK CENTER
D-H FROM HUDSON G.S.
(PEAK 200x10^{6}BTU/HR)

SCALE: 1"=6000'

FIG. 8.1.8



HUDSON G.S.
NO. 2 UNIT
PARTIAL RETROFIT
FOR BERRY'S CREEK D-H
(CONCEPTUAL)

FIG. 8.1.9

temperature control, reverse-flow protection and flow limitor. This maximum bleed flow provides 20% more heat than heaterplant which provides 100% back-up. The lost power generation at peak load and full throttle flow accounts for approximately 16MW.

This development, while it is natural gas fired during its first few years of existence, becomes a nearly 100% coal and waste heat based system after the turbine retrofit and the transmission lines are in place. The 100% figure is unattainable only in consideration for planned and unplanned outages of the No. 2 unit. Only total outages will affect the system; power output reductions will seldom, if at all. Neither will full heat output be attainable at less than 75% throttle flow.

An intermediate step in installing a gasturbine plant with heat recovery had also been considered and discarded as uneconomical in this case.

Figure 8.1.12 shows the transmission line development.

The Landfill gas based system is predicated on the developmentof the several hundred acres of recently completed and still active landfill operations within one to four miles south of the Berry's Creek development. Based on PSE&G's previous on-going operations of gas gathering of this type, it is deemed practical to tap this source of energy for the project. It is estimated that up to 10 million cu. ft. of gas per day at an HHV of 500BTU/cu. ft. can be gained within 2 - 2.5 miles of the site. The productive life of the system is said to be an average of 10 years.

The gaining of this gas involves drilling a large number of wells, a network of pipes connecting them to a compressor station, a simple gas clean-up system and a transmission pipe to the user, that is the heaterplant. The cost of the gas produced per million BTU (10 therms) is $0.50-1.00 in royalties and $.05-.10 in operation and maintenance cost plus the cost of the capital recovery. All this adds up to a fuel competitive even with coal on a cost basis, and much cleaner and easier to handle. Its cost compared to other fuels is a fraction.

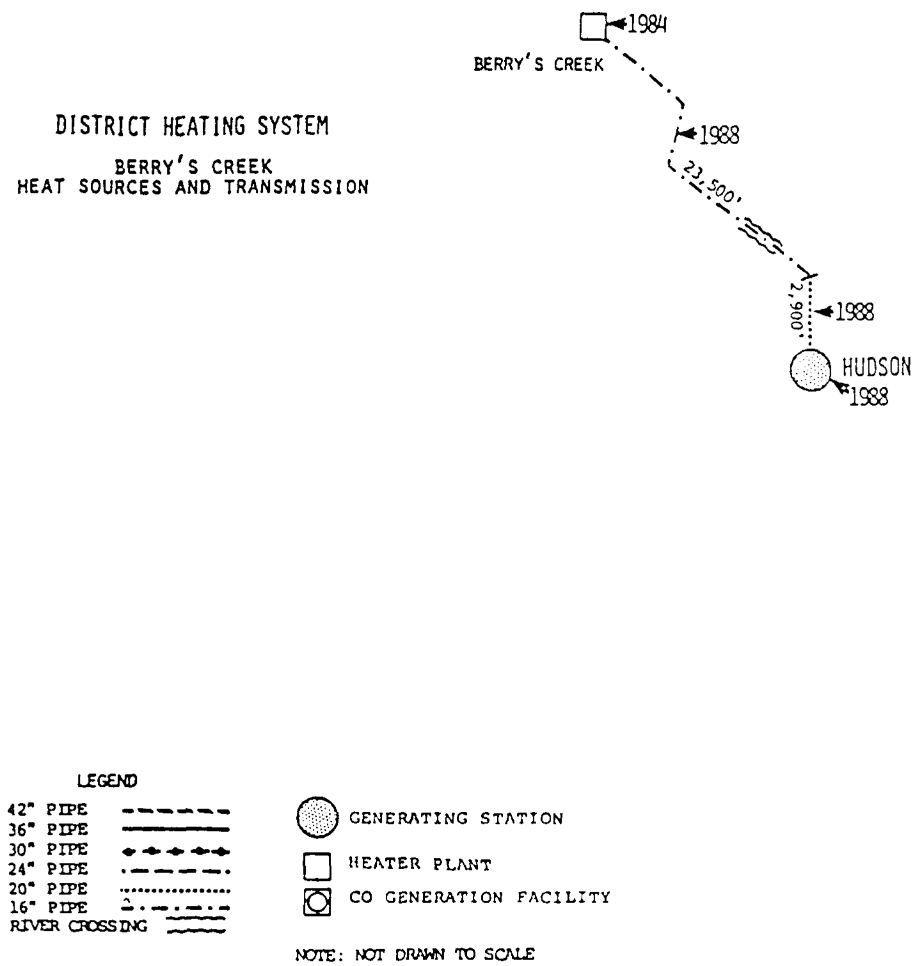

DISTRICT HEATING SYSTEM
BERRY'S CREEK
HEAT SOURCES AND TRANSMISSION
1984
BERRY'S CREEK
1988
23,500'
1988
2,900'
HUDSON
1988
LEGEND
42" PIPE
36" PIPE
30" PIPE
24" PIPE
20" PIPE
16" PIPE
RIVER CROSSING
GENERATING STATION
HEATER PLANT
CO GENERATION FACILITY
NOTE: NOT DRAWN TO SCALE

FIG. 8.1.12

The heaterplant needs only a second gas main and burners capable of firing both landfill gas or natural gas. This plant in its final stage will have five units, where the fifth unit serves as stand-by. There is no change in the distribution system or in the schedule of construction. The tie line to Hudson G.S. and the retrofit of Hudson No. 2 may come into existence as an alternative supply of heat after the fields have been depleted. This can possibly extend as far as 15 years. In any case, the gas system will be written off in 10 years.

Figure 8.1.10 shows the location of landfills, the compressor and heating plants and the gas transmission line connecting them. The line runs on the Transco right-of-way most of its length. The estimated production capacity of the landfills is as follows:

Landfill	Recoverable Capacity (ft^3/day)	Maximum Hourly Supply (ft^3)
Avon	0.9×10^6	37,500
Kingsland	2.0×10^6	83,500
Kingsland Extension (Bergen)	0.8×10^6	33,500
MSLA Site 1C (deKorte Park)	5.2×10^6	220,000
MSLA Site 1D (deKorte Park)	1.2×10^6	50,000
	10.1×10^6	424,500

The proposed development would start with the closest and oldest of these sites, Avon. Since the number of wells and the connection piping is generally proportional to output, it is foreseen that development will be as gradual as the load grows. The compressor station on the other hand will be built at inception, providing ample stand-by capacity at initial start-up, when such is proper to have. Generally the system development will aim at providing sufficient quantities of gas to supply over 90% of the energy needs of the project at all times. In order to achieve that, the maximum rate of gas flow should be sufficient to provide about two-thirds of the peak load. A stand-by natural gas supply line will have to be built in any case and it will be used to supply the peaking energy. Same will be used also to provide fuel for the first year of

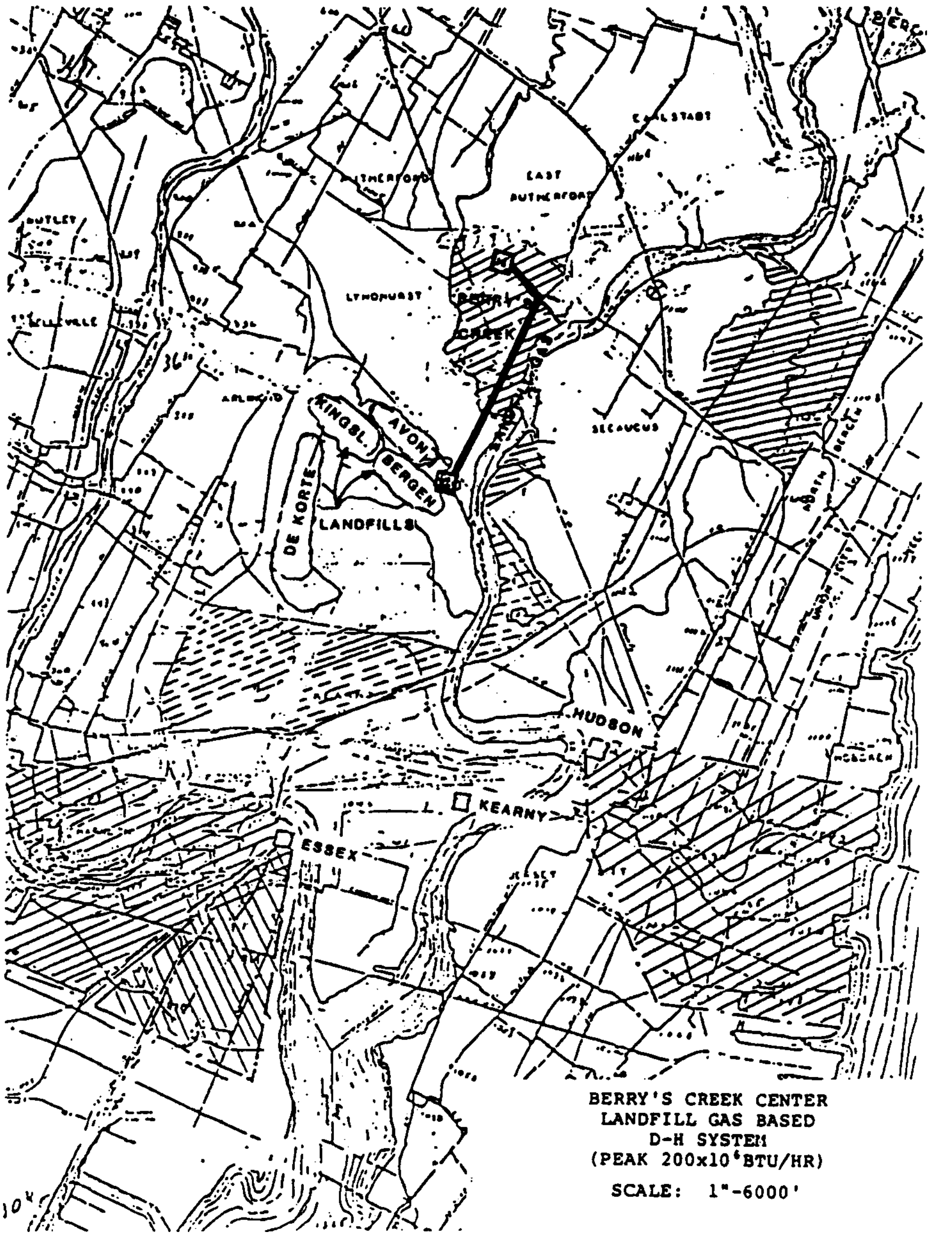

BERRY'S CREEK CENTER
LANDFILL GAS BASED
D-H SYSTEM
(PEAK 200x10⁶BTU/HR)
SCALE: 1"-6000'
BERRY'S CREEK
KINGSL.
AVON
BERGEN
DE KORTE
LANDFILLS
HUDSON
KEARNY
ESSEX
LYNDHURST
EAST RUTHERFORD
SECAUCUS

FIG. 8.1.10

project development when only one building is planned to be erected. This way the large up-front expenses of compressor plant and transmission line are delayed by one year. The adequacy of the supply system will be assured by the development of system capabilities a year ahead of predicted loads. This will also have the side effect of reducing the natural gas fuel use even further during most of the development period. The maximum hourly supply of 425500 cu. ft. of gas, if fully developed, would provide 170 million BTU/hr at 80% fired heater efficiency.

There is no credit given for any other use of the landfill gas system, but for space heating and domestic hot water in our economics calculations. It is to be pointed out however that gas will be generated year-round. Therefore it stands to reason that finding summer uses will further enhance the economics. One logical way of doing that is to put the gas to use for air conditioning. It has been estimated that the project cooling load will grow to 25000T of refrigeration when completed. The gas supply of 7.8×10^6 cu. ft./day is only sufficient to produce not more than half of that requirement using a new, high efficiency (COP $\lesseqgtr$ 1) direct fired absorption cooler. This would involve a landfill gas distribution system at the site and the installation of the proper equipment. Those probably will have to be replaced in 10 years or operated on natural gas at a cost presently unknown.

It was considered using the gas to generate electric power for compression-type air conditioning equipment (COP $\geqq$ 3). It turns out that beyond the large investment in the gasturbine facility considerable monies would have to be spent on a gas clean-up system. These are not only expensive, but since there is very little actual operating experience, it is also risky. For these reasons this alternative, at least for now, had not been included in the economics.

Independent of the source, heat will be distributed to the users by a two pipe, recirculating hot water system. The nominal supply temperature of 290^{0}F and the nominal return temperature of 170^{0}F will only be maintained on the peak heat supply days. At all other times the temperatures could be lower, proportional to and automatically controlled by ambient temperature.

This development will have a zero elevation serveral feet above present ground level. Consequently most of the piping will be laid aboveground and fill will be placed around and above them afterwards. This will present considerable savings in construction cost, not fully accounted for in our estimates, to stay on the conservative side.

Generally the laying of pipes will follow the progress of the development, however mains will be sized for future loads and pipes will be laid at the site preparation stage, ahead of actual building construction.

The heating of multi-family row houses (town houses) and single-family housing is included in our supply system. These are to be supplied by secondary circuits as described previously.

The fully developed system will require 3333 gpm water circulation in a looped main of 12" and 10" initial diameter pipes. Water flow will be halved during the summer, when the load is less than 10% of peak unless absorption air conditioning systems will present a different demand.

It has been assumed that the plant will be attended all the time and therefore five licensed operators are scheduled. This can be modified later when other plants are in existence since full-time attendance of these fully automated water heater plants is not required. There are four other people assumed to perform routine maintenance and other chores. There will be some manpower in supervisory and clerical functions as well as in billing as part of the central PSE&G organiation, not necessarily on full-time duty for this system.

The Hudson retrofit with two heaters and three pumps does not require additional personnel. The few control functions will be automated and the supervisory controls incorporated with the control room of the plant.

The development of pumping cost of the system is shown on Table 8.1-V and is estimated to reach $221000 per annum, and is proportional to connected load at any other point. The water make-up and treatment cost is foreseen as $10000 annually, varying again in straight ratio to system size.

The gas gathering system operation and maintenance of $650000 per year should be allocated as one-half for compressor operations while the rest proportional to system size.

The heaterplant will require annual and long-range maintenance. Cost experience for such on generating plant heating boilers will be used for that purpose.

SCENARIO II - BERRY'S CREEK & HARMON MEADOWS DISTRICT HEATING SYSTEM

Another commercial/residential development is underway in the Hackensack Meadowlands a couple of miles east of Berry's Creek, the Harmon Meadows. This approximately 500 acre tract is being developed by Hartz Mountain Industries Inc. The development plans are approved by the Hackensack Meadowland Development Commission. This development in itself or in conjunction with Berry's Creek can be the starting point for the introduction of district heating in Northern New Jersey. The schedule calls for the construction of several buildings over an 8 year period with an estimated peak heating requirement of at least 200 million BTU/hr.

The Berry's Creek development has been described in detail in the previous section. It is applicable also when the two areas are considered together.

The Harmon Meadows is an area along Mill Creek and Cromakill Creek straddling the eastern spur of the N.J. Turnpike and located just north of Route 3. It is planned as a mixed development of light industrial buildings, research establishments, residential buildings and a local shopping center, office, hotel, theatre complex. Table 8.2-I shows the building mix and the estimated heating load.

The D-H system layout based on the preliminary development plans of Harmon Meadows is shown on Fig. 8.2.1. It is assumed that the light industrial structures will be constructed first at the northeastern tract, followed by the research park, residential buildings and finally by the office/shopping complex. The heater plant installations and the piping construction following this schedule are shown on Tables 8.2-II, 8.2-III and 8.2-IV.

TABLE 8.1-V

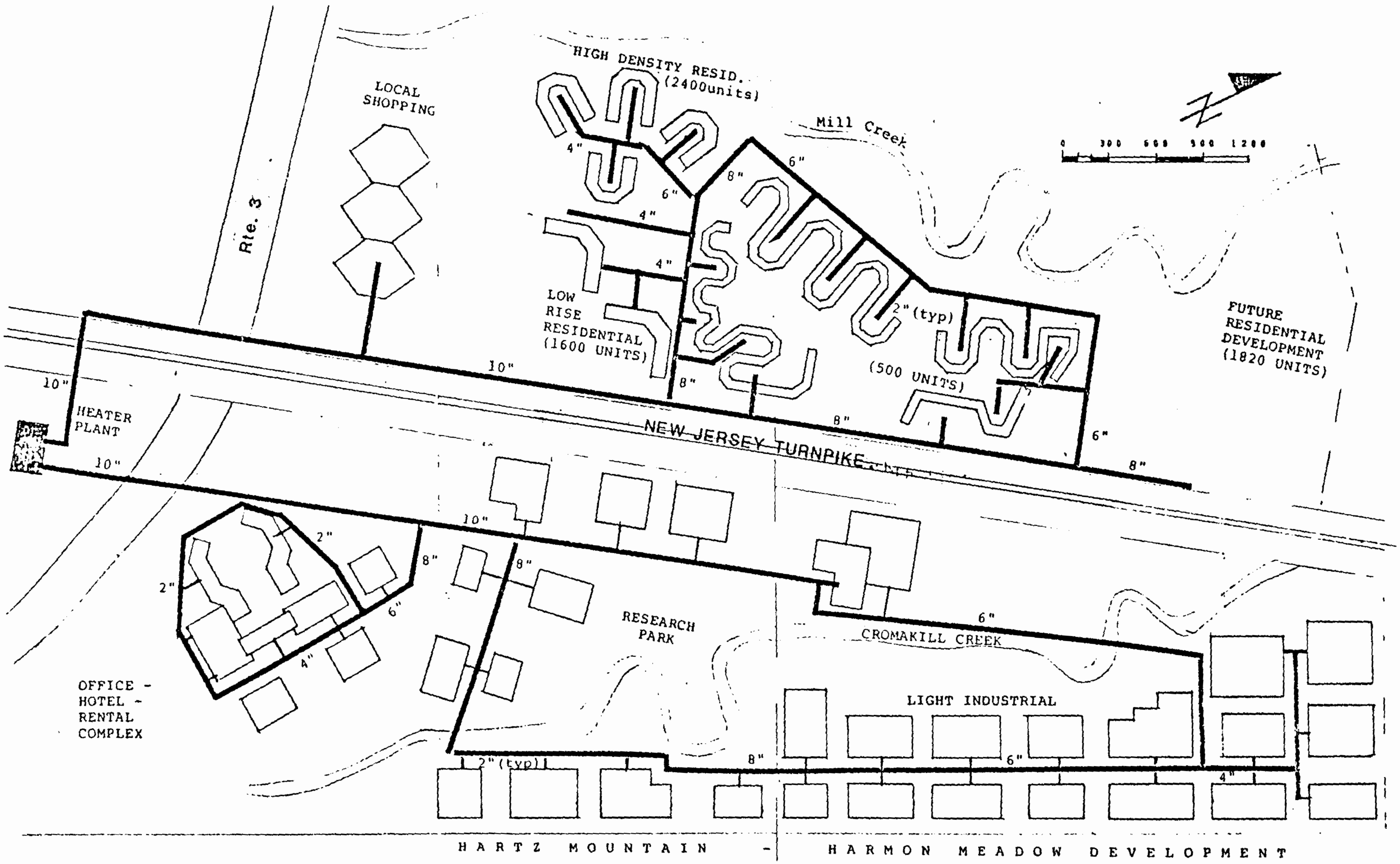
MEADOWLANDS SYSTEM
(BERRY'S CREEK ONLY)
ANNUAL PUMPING COST
ESTIMATE

	DIA	1984	1985	1986	1987	1988 M$	1989	1990	1991	1992	TOTAL
ALT. 1 - NO LANDFILL GAS											
BERRY'S CREEK	12"		3.90								3.90
	10"		6.40								6.40
	8"		1.80								1.80
	4"		4.60	.60	.60	2.10					7.90
	3"		.07								.07
	2"		.35	.04	.02	.35	.09	.07	.07		.99
	1-1/2"		.08		.09	.01	.02	.01	.02		.23
TOTAL - ANNUAL			17.20	.64	.71	2.46	.11	.08	.09		21.29
HEATEXCHANGERS											
-FIRED HEATERS		10.00	10.00		5.00						25.00
-POWERPLANT HX'S & TRANSMISSION LINE						47.70	12.00	11.00	10.50	3.60	84.80
-IN-HOUSE (USER) HX'S		6.75	24.75	13.50	15.75	6.75	4.50	4.50	4.50	9.00	90.00
TOTAL - ANNUAL		16.75	51.95	14.14	21.46	56.91	16.61	15.58	15.09	12.60	221.09
- ACCUMULATIVE		16.75	68.70	82.84	104.30	161.21	177.82	193.40	208.49	221.09	

TABLE 8.2-I

INDUSTRIAL/RESIDENTIAL
DEVELOPMENT
@ RT. 3 & N.J. TPKE EAST SPUR

	land area ac.	bldg. area 10^6 x sq ft	Est. heat/load 10^3BTU/hr
Island Residential	206	3500 units	105000
Research Park	148	1.2	36000
Light Industrial	137	2.0	20000
Comm. Cent. & Shopping	60	.25	7500
			168500



HARMON MEADOWS
D-H SYSTEM

FIG. 8.2.1

TABLE 8.2-II

MEADOWLANDS SYSTEM
(BERRY'S CREEK PLUS HARMON MEADOWS)
HTW PIPING INSTALLATION SCHEDULE
IN 1000 FT. OF PAIR OF PIPE
ESTIMATE

	DIA	1984	1985	1986	1987	1988	1989	1990	1991	TOTAL
ALT. 1 - NO LANDFILL GAS										
BERRY'S CREEK	12"		.6							.6
	10"		3.2	1.0	1.0					5.2
	8"		.6							.6
	4"		2.2	.3	.3	1.0	.4	.3	.3	4.8
	3"		.1							.1
	2"		1.6	.2	.1	1.6	.4	.3	.3	4.5
	1-1/2"		1.2			1.2	.2	.2	.2	3.0
HARMON MEADOWS	10"			2.8	2.3	1.1				6.2
	8"				.7	.7	2.6			4.0
	6"			2.6	2.1	2.0	1.2			7.9
	4"				.6	.7	.7	.7	.8	3.5
	3"						.1			.1
	2"			.8	1.0	1.8	2.0	.2	.8	6.6
	1-1/2"							.2	.1	.3
HUDSON G.S. -TRANSMISSION	20"					3.0				3.0
	16"					23.5			13.5	37.0
TOTAL - ANNUAL			9.5	7.7	8.1	36.6	7.6	1.9	16.0	87.4
- ACCUMULATIVE			9.5	17.2	25.3	61.9	69.5	71.4	87.4	
ALT. 2 - LANDFILL GAS	same as above, except no transmission line is required and a gas gathering and supply system has to be constructed.									

TABLE 8.2-III

MEADOWLANDS SYSTEM
(BERRY'S CREEK PLUS HARMON MEADOWS)
INSTALLATIONS & LOAD RUN-UP
ESTIMATE

	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	TOTAL
ALT. 1 - NO LANDFILL GAS											
BERRY'S CREEK											
Heater Plant - 10^6BTU/hr		150		50							200
Distribution - see Table 8.2-II											
Nat. gas service - 10^6cfh		250									
HARMON MEADOWS											
Heater Plant - 10^6BTU/hr				150		50					200
Distribution - see Table 8.2-II											
Nat. gas service - 10^6cfh				250							
HUDSON G.S.											
Turbine retrofit - 10^6BTU/hr						240					240
Hx's & pumps											
Transmission - see Table 8.2-II											
TOTAL - Annual inst. cap.		150		200		290					
- Accum. inst. cap.		150	150	350	350	640	640	640	640	640	
- firm capacity*		100	100	250	250	400	400	400	400	400	
ALT. 2 - LANDFILL GAS											
BERRY'S CREEK											
Heater Plant - 10^6BTU/hr		150		50			50				250
Distribution - see Table 8.2-II											
Nat. gas service - 10^6cfh		300									
HARMON MEADOWS											
Heater Plant - 10^6BTU/hr				150		50		50			250
Distribution - see Table 8.2-II											
Nat. gas service - 10^6cfh				300							
GAS GATHERING - 10^6cfh			50	30	100	40	40	80	45	40	425
TOTAL - Annual inst. cap.		150		150		50	100	50			
- Accum. inst. cap.		150	150	300	300	350	450	500	500	500	
HEAT LOAD											
Berry's Creek - Accumulative peak		15	70	100	135	150	160	170	180	200	
Harmon Meadows - Accumulative peak				28	60	90	127	170	190	200	
		15	70	128	195	240	287	340	370	400	
Distribution loss		5	5	12	16	20	24	30	32	34	
Accumulative total		20	75	140	211	260	311	370	402	434**	

TABLE 8.2-IV

HARTZ MOUNTAIN-HARMON MEADOWS
10 YR. DEVELOPMENT PLAN OF D-H
(for Berry's Creek see Table 8.1-IV)

Year 1	Heater plant	3 - 50×10^6 BTU heaters 3 - circ. pumps, 40HP - building - stack 2 - syst. circ. pumps, 175HP - gas line - 250×10^6 BTU/hr
		(3 buildings in industrial zone)
Year 2		(5 buildings in industrial zone)
Year 3		1 - 50×10^6 BTU/hr heater 1 - circ. pump, 40HP 2 - syst. circ. pumps, 175HP
		(4 buildings in industrial zone, 2 buildings in research park)
Year 4		(4 buildings in industrial zone, 4 buildings in research park, 200 unit town houses)
Year 5		1 - 50×10^6 BTU/hr heater 1 - circ. pump
		(4 buildings in research park, 300 unit town houses, 1 office building, low rise residential 800 units)
Year 6		(low rise resid. 800 units, health club, cinema)
		(high dens. resid. - 1200 units, hotel, retail)
Year 7		(high dens. resid. - 1200 units, local shopping center)

The combined system for the two areas does not differ in its initial stage from either of the two developing separately and independently. During this timeframe the individual heater plants supply the heating and DHW needs of each. The conditions for comfort cooling are also the same as stated before.

The Alternative sources for the enrgy are also unchanged, that is

- an extraction steam based system originating at the Hudson G.S.

- a landfill gas fuel supply system

The Hudson G.S. based system is developed in stages just as a single area would be. A heater plant is constructed for each of the two areas. The Harmon Meadows plant is proposed to be located south of Route 3 on PSE&G property along a major power distribution point. The layout and growth of this plant will also be identical to the one described previously. Each will be a four-unit plant at its completion. When the combined load of the two plants reaches 200 million BTU/hr peak, the construction of the transmission lines as shown on Figures 8.2.2, 8.2.6 and 8.2.7 becomes necessary along with the partial retrofit of Hudson G.S. No. 2 unit. This retrofit is no different from the one previously described, with one exception, the water flow required is 6600 gpm.

The heater plants with two 50 million BTU/hr standby units in each will still provide 100% back-up in case the No. 2 unit or the transmission line (incl. pumping) are lost.

The utilization of the plant retrofit is greatly improved in comparison with Scheme I. The 200 million BTU/hr heat supply available from the partial retrofit is 50% of the peak in this scheme. The energy supplied by the retrofit can amount to 92.5% of the energy used and to 69% of that potentially available at full utilization during the heating season (Fig. 8.2.3). This is naturally achievable only if there were no unplanned outages during the winter. In addition, it will be supplying all the DHW requirements during all the other times of the year except during the planned outage. Without accounting for the plant outages this means a 49% annual utilization of the potential. This is considerable improvement over the less than 30% utilization expected from Scheme I on the same basis.

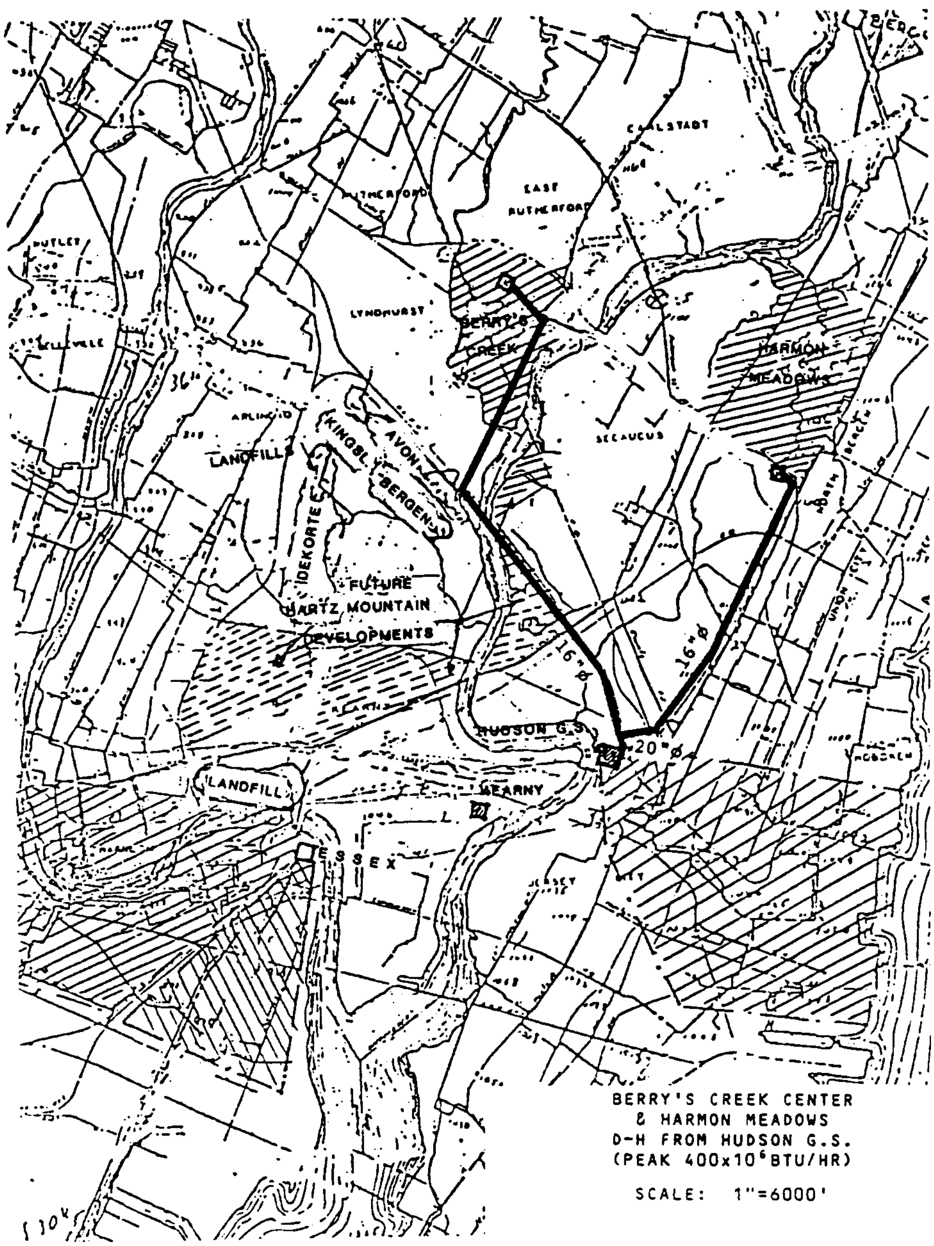

CARLSTADT
EAST RUTHERFORD
LYNDHURST
BERRY'S CREEK
HARMON MEADOWS
SECAUCUS
36"
LANDFILLS
AVON
KINGSL.
BERGEN
IDEKORTE
FUTURE HARTZ MOUNTAIN DEVELOPMENTS
16"ø
16"ø
20"ø
HUDSON G.S.
LANDFILL
KEARNY
ESSEX
BERRY'S CREEK CENTER
& HARMON MEADOWS
D-H FROM HUDSON G.S.
(PEAK 400x10⁶BTU/HR)
SCALE: 1"=6000'

FIG. 8.2.2

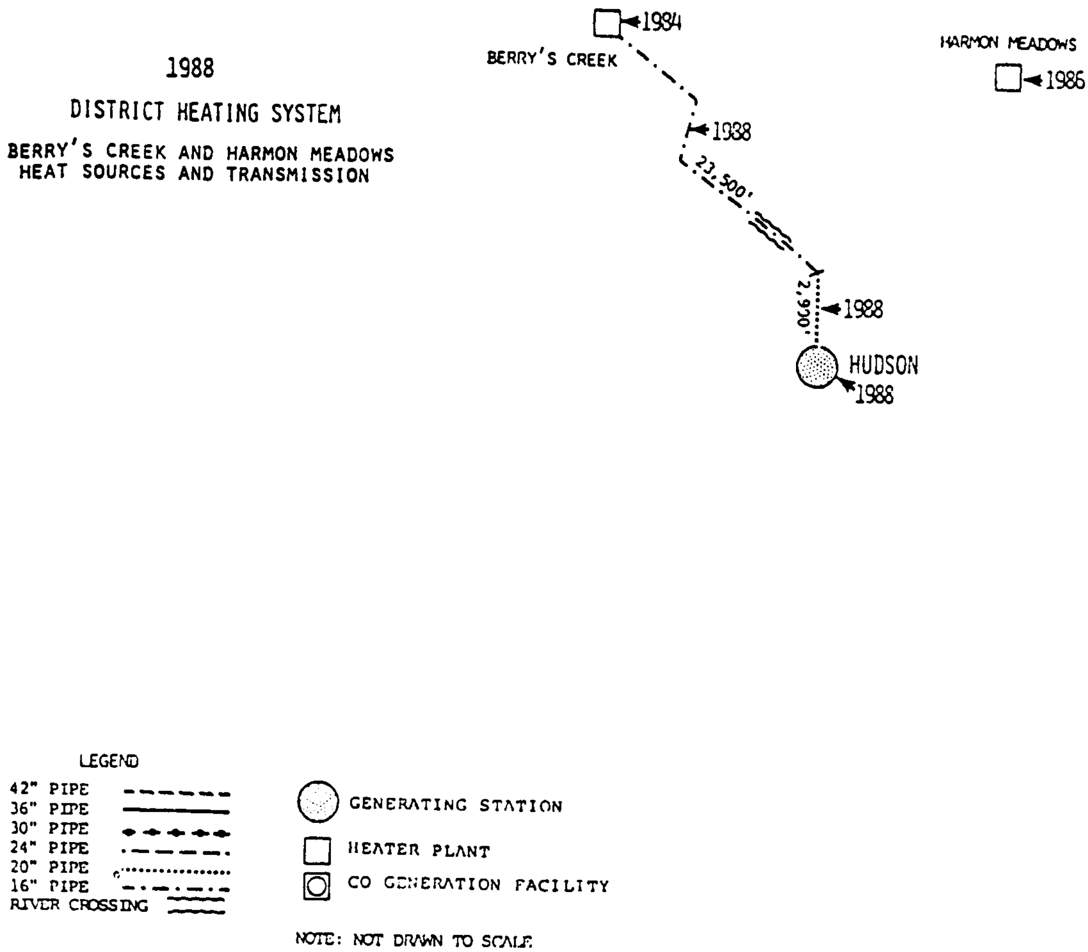

1988
DISTRICT HEATING SYSTEM
BERRY'S CREEK AND HARMON MEADOWS
HEAT SOURCES AND TRANSMISSION
1984
BERRY'S CREEK
1988
22,500'
2,900'
1988
HUDSON
1988
HARMON MEADOWS
1986
LEGEND
42" PIPE
36" PIPE
30" PIPE
24" PIPE
20" PIPE
16" PIPE
RIVER CROSSING
GENERATING STATION
HEATER PLANT
CO GENERATION FACILITY
NOTE: NOT DRAWN TO SCALE

FIG. 8.2.6

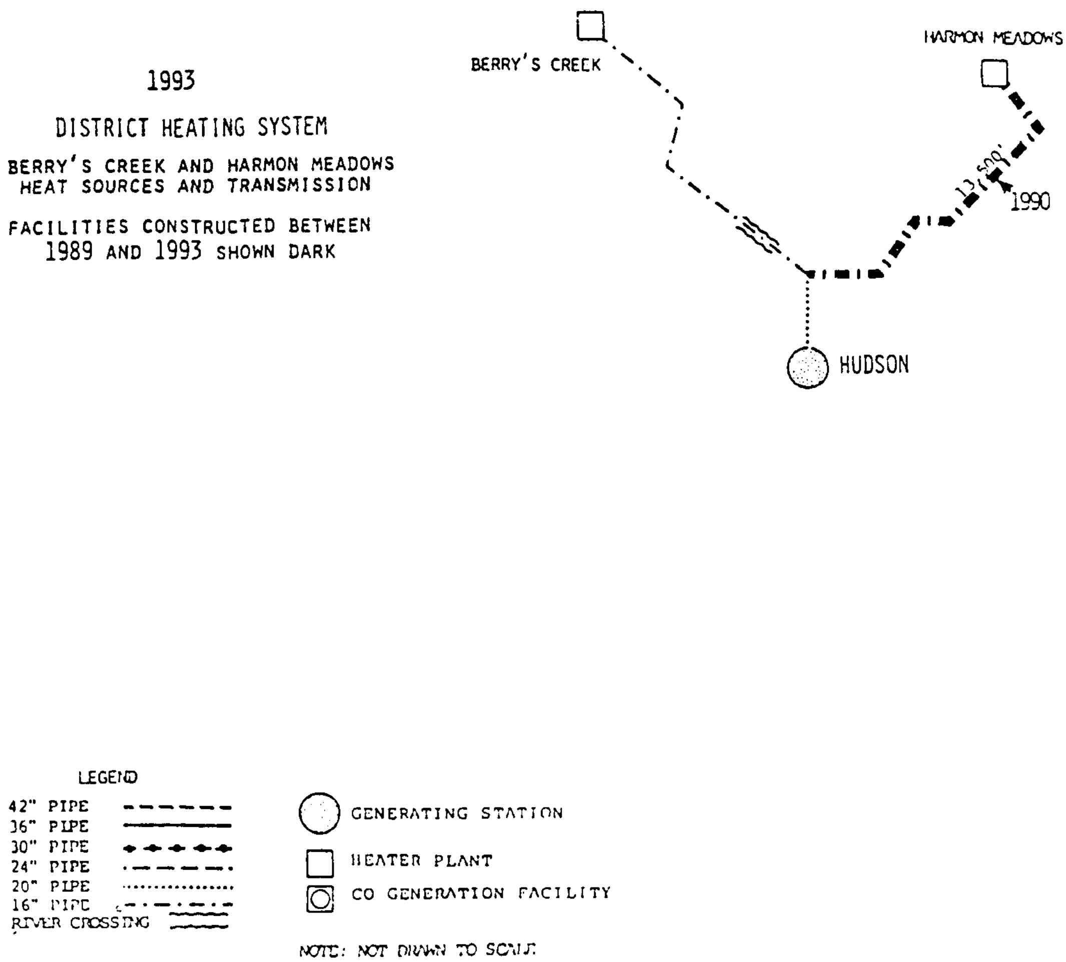
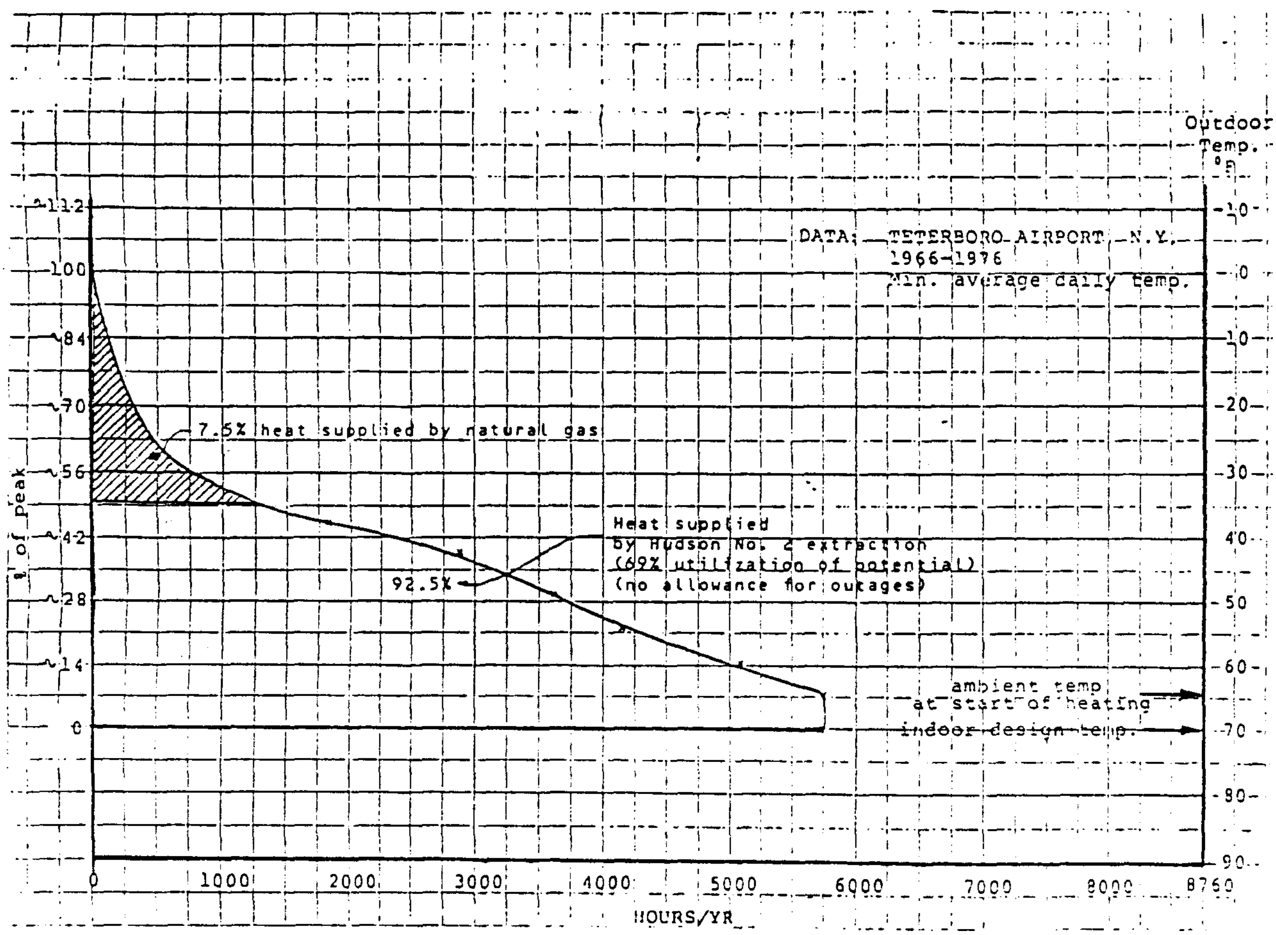

1993
DISTRICT HEATING SYSTEM
BERRY'S CREEK AND HARMON MEADOWS
HEAT SOURCES AND TRANSMISSION
FACILITIES CONSTRUCTED BETWEEN
1989 AND 1993 SHOWN DARK
BERRY'S CREEK
HARMON MEADOWS
13,500'
1990
HUDSON
LEGEND
42" PIPE
36" PIPE
30" PIPE
24" PIPE
20" PIPE
16" PIPE
RIVER CROSSING
GENERATING STATION
HEATER PLANT
CO GENERATION FACILITY
NOTE: NOT DRAWN TO SCALE

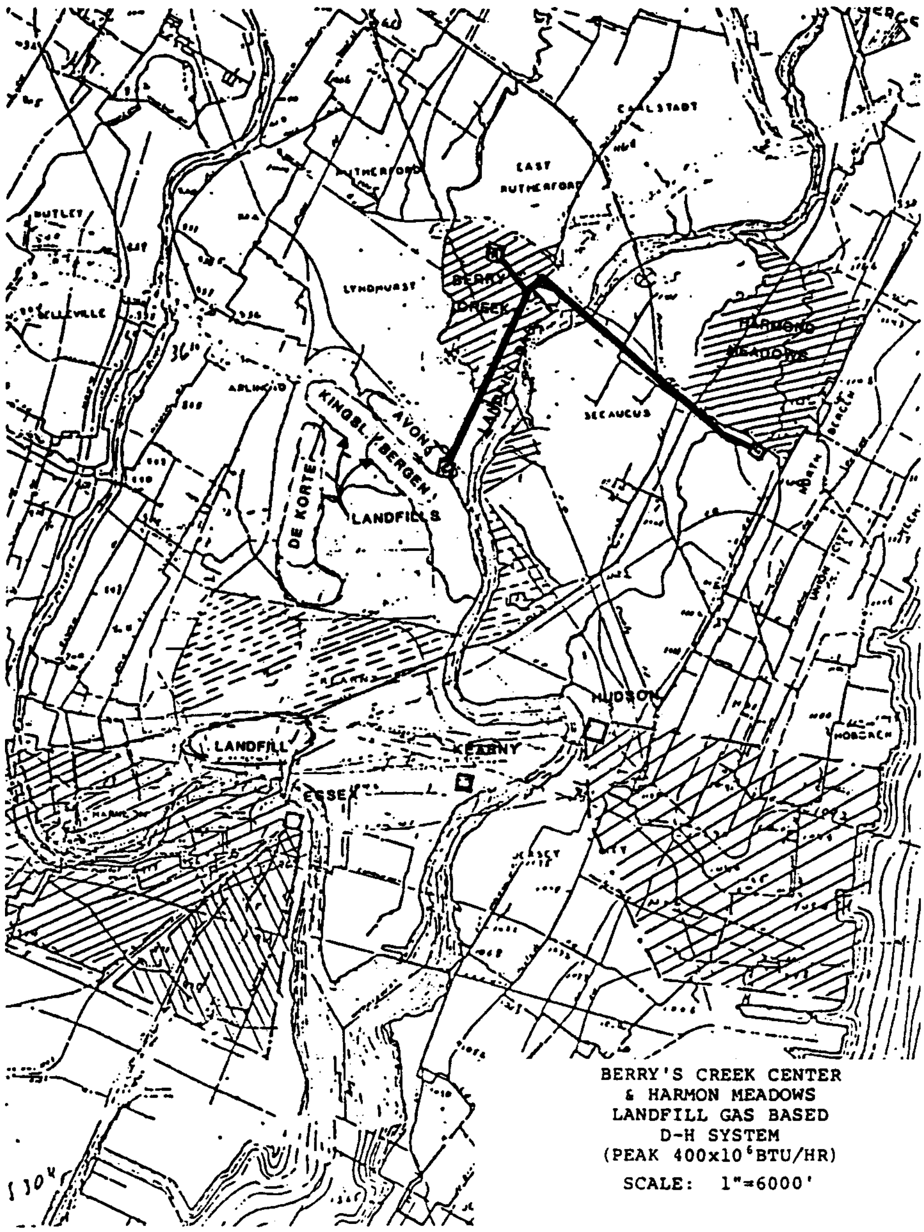
FIG. 8.2.7

FIG. 8.2.3

HEAT SUPPLY DISTRIBUTION
W/HUDSON #2 UNIT PARTIAL RETROFIT

SPACE HEATING





BERRY'S CREEK CENTER
& HARMON MEADOWS
LANDFILL GAS BASED
D-H SYSTEM
(PEAK 400×10^6 BTU/HR)
SCALE: 1"=6000'

FIG. 8.2.4

FIG. 8.2.5

FUEL SOURCE DISTRIBUTION IN A LANDFILL GAS SUPPLIED SYSTEM

SPACE HEATING

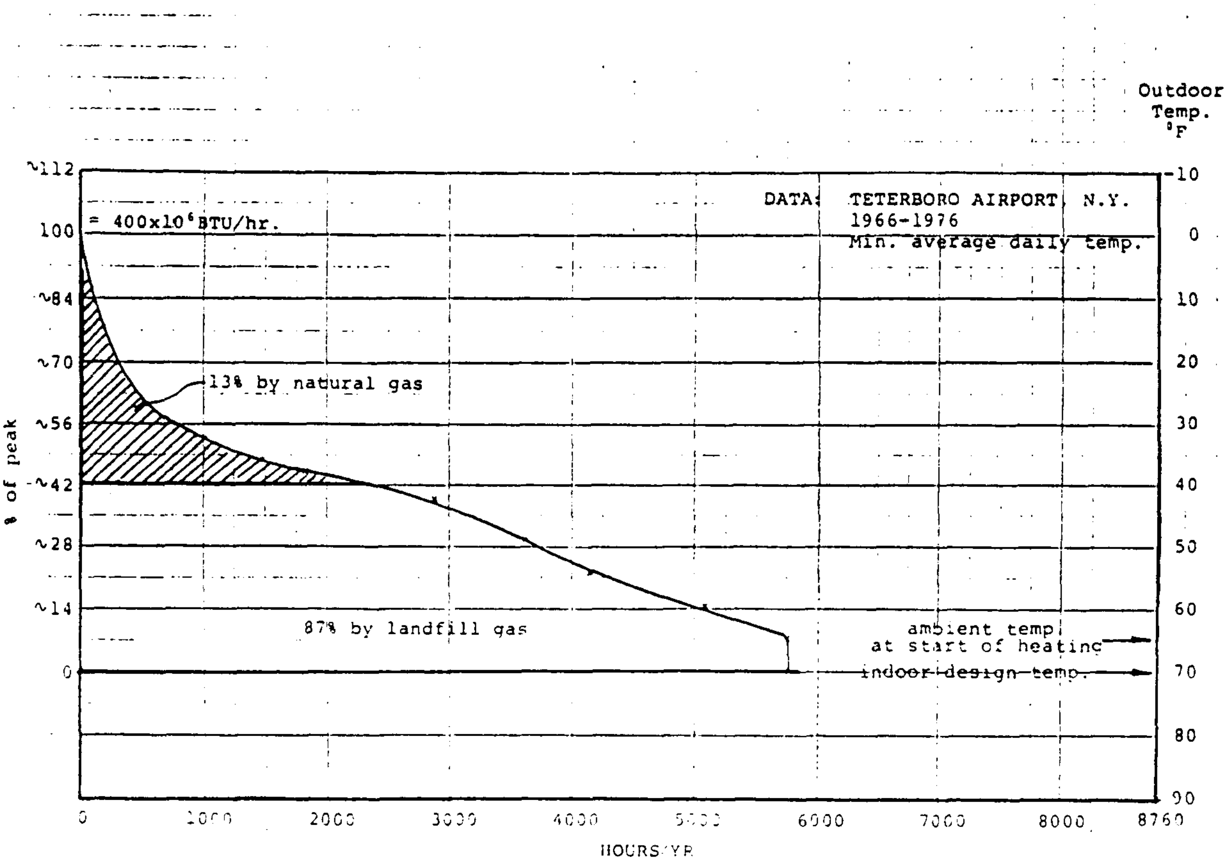


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TABLE 8.2-V

MEADOWLANDS SYSTEM
(BERRY'S CREEK PLUS HARMON MEADOWS)
PUMPING COST SCHEDULE
$1000 PER ANNUM

	DIA	1985	1986	1987	1988	1989	1990	1991	TOTAL
ALT. 1 - NO LANDFILL GAS									
BERRY'S CREEK	12"	3.90							3.90
	10"	6.40							6.40
	8"	1.80							1.80
	4"	4.60	.60	.60	2.10	.80	.60	.60	9.90
	3"	.07							.07
	2"	.35	.04	.02	.35	.09	.07	.07	.99
	1-1/2"	.08		.09	.01	.02	.01	.02	.23
HARMON MEADOWS	10"		6.16	5.06	2.42				13.64
	8"			2.10	2.10	7.80			12.00
	6"		3.90	3.15	3.00	1.80		.30	12.15
	4"			1.26	1.47	1.47	1.47	1.26	6.93
	3"					.06			.06
	2"		.18	.22	.40	.44	.05	.18	1.47
	1-1/2"						.01	.01	.02
HUDSON G.S.									
-TRANSMISSION	20"					31.30	25.20	23.66	80.16
	16"					39.00	41.00	38.40	118.40
TOTAL - INCREMENTAL		17.20	10.88	12.50	11.85	82.78	68.41	64.50	268.12
HEATEXCHANGERS									
-FIRED HEATERS		10.00	20.00	15.00		5.00			50.00
-POWER PLANT HX'S						25.00			25.00
-IN-HOUSE (USER) HX'S		31.50	26.10	30.15	22.50	18.90	26.10	24.75	180.00
TOTAL - INCREMENTAL		58.70	56.98	57.65	34.35	131.68	94.51	89.25	523.12
- ACCUMULATIVE		58.70	115.68	173.33	207.68	339.36	433.87	523.12	

SCENARIO III - FULLY DEVELOPED DISTRICT HEATING SYSTEM (Jersey City, Newark, Meadowlands)

Besides the new developments in the Hackensack Meadowlands discussed in the previous schedules, there are high density commercial/industrial/residential areas within two to five miles distance of the Hudson G.S. These areas are part of Jersey City, Hoboken, Newark and Harrison. Because of the high density construction within the selected areas they are likely targets for an economical D-H network, as shown on Fig. 8.3.1. A heating system based on it would not only benefit from the inexpensive fuel (coal) used but also from the fact that approximately half the heat supplied can be considered as waste heat.

It is proposed to develop this large, close to four billion BTU/hr peak heat supply system, in small increments. A number of local developments constructed at one time _r another will gradually form an increasingly complex and widespread single system. This heat island concept of construction will allow close coordination of expenditures and income growth so as to best support the economic viability of the developing and of the completed system. A system development tree is shown on Fig. 8.3.2.

Scenarios I and II discussed the new Berry's Creek and Harmon Meadows developments and are fully compatible with the larger concept of this scenario. Whether a landfill gas fuel supply will be available for these sites during the first 10-15 years of their existence or not they will in time be connected to Hudson No. 2 unit, as they are compatible with the total concept. After the landfill gas runs out there will be the option of reverting to the Hudson unit the supply of heat by constructing the HTW transmission line. The routing of this line and the partial turbogenerator retrofit needed only for these systems were also described. In this scenario however landfill gas supply to the Meadowlands is not considered.

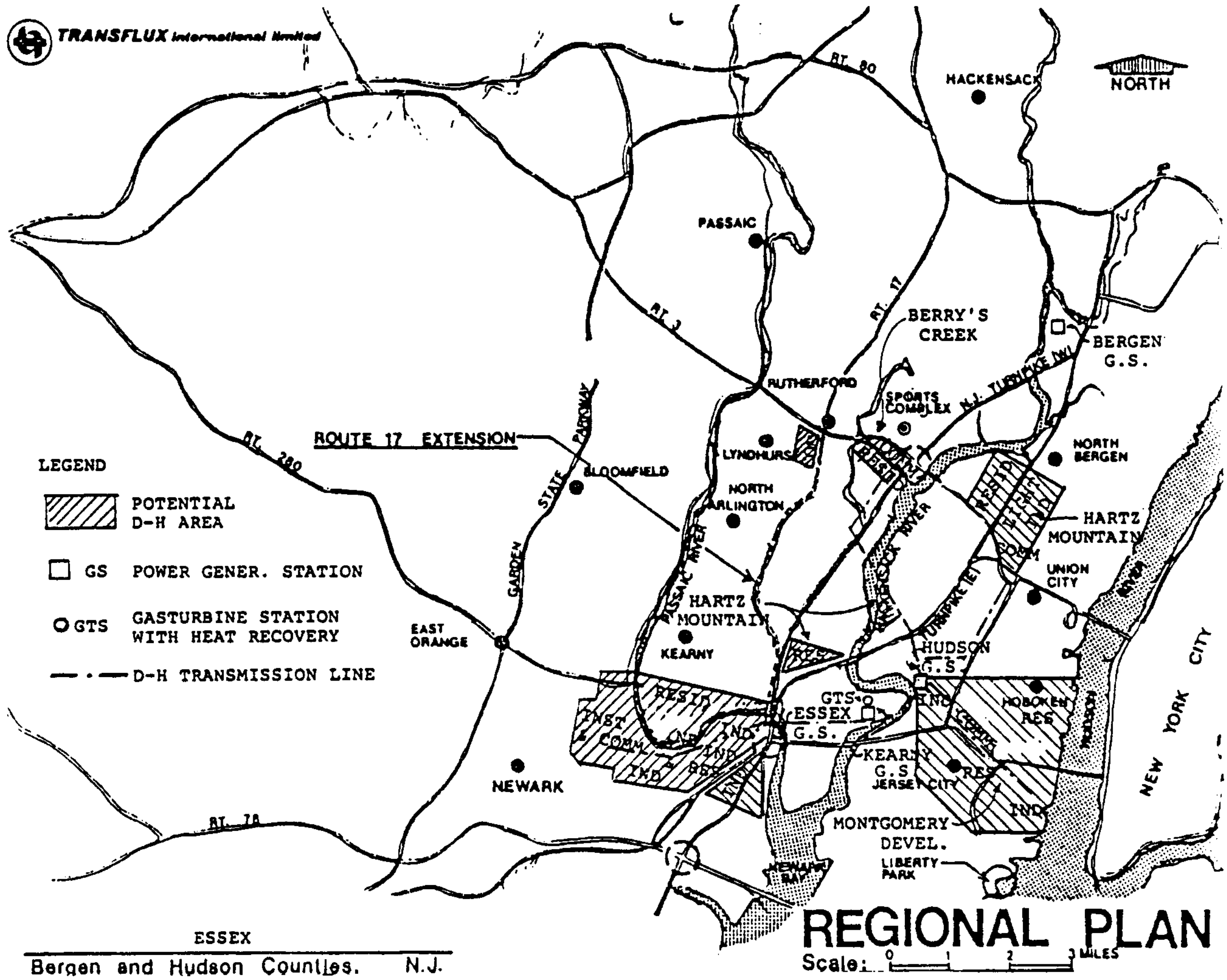
TRANSFLUX International limited
RT. 80
HACKENSACK
NORTH
PASSAIC
RT. 3
RT. 17
BERRY'S CREEK
BERGEN G.S.
RUTHERFORD
SPORTS COMPLEX
N.J. TURNPIKE
LYNDHURST
NORTH BERGEN
ROUTE 17 EXTENSION
RT. 280
BLOOMFIELD
GARDEN STATE PARKWAY
NORTH ARLINGTON
HARTZ MOUNTAIN
UNION CITY
LEGEND
POTENTIAL D-H AREA
GS POWER GENER. STATION
GTS GASTURBINE STATION WITH HEAT RECOVERY
D-H TRANSMISSION LINE
PASSAIC RIVER
HACKENSACK RIVER
HARTZ MOUNTAIN
KEARNY
EAST ORANGE
HUDSON G.S.
GTS
ESSEX G.S.
HOBOKEN
RES
IND
COMM
KEARNY G.S.
JERSEY CITY
NEWARK
RT. 78
MONTGOMERY DEVEL.
LIBERTY PARK
NEWARK BAY
NEW YORK CITY
ESSEX
Bergen and Hudson Counties. N.J.
REGIONAL PLAN
Scale: 0 1 2 3 MILES

FIG. 8.3.1

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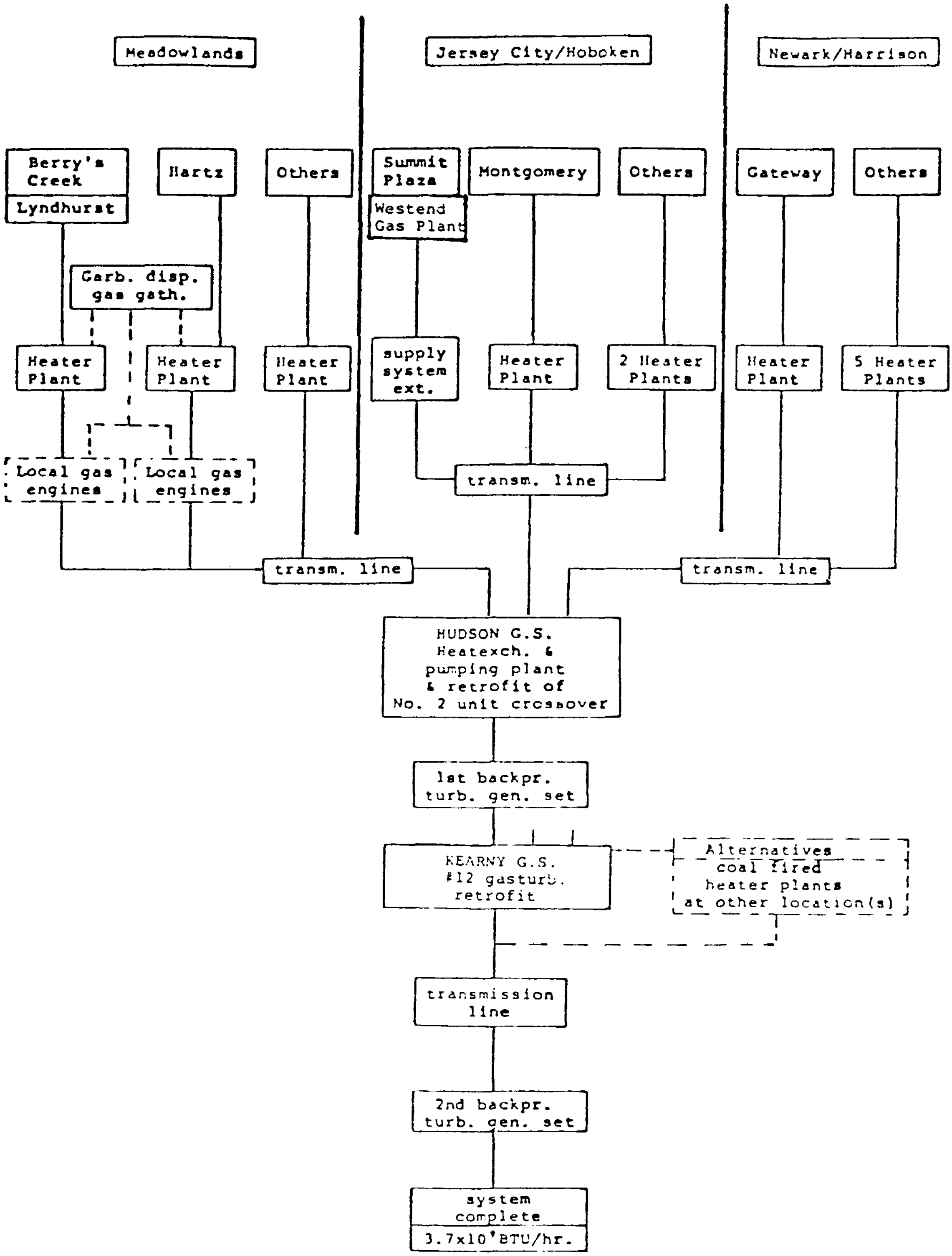

DEVELOPMENT TREE

HUDSON G.S. BASED DISTRICT HEATING SYSTEM

FIG. 8.3.2

The Jersey City/Hoboken supply area is shown on Fig. 8.3.3 located east and southeast of the Hudson G.S. This approximately five sq. mi. encompasses the most densely built-up sections of both cities. Within its confines are located most of the large office buildings, most of the housing developments including high-rises and a large number of institutions, commercial and industrial establishments. In-progress and proposed new developments as the Montgomery St., the Market St., Pavonia Sta., Glimcher Co. (Henderson St.) and a Port Authority development area are all within this territory. So are such existing complexes as the Journal Square Transport. Center, Summit Plaza, St. Johns apt.'s, the Gregory Park apt.'s and five J.C. Housing Authority apartment complexes. The institutional sector is represented by the City Hall, County Courthouse, Jersey City Medical Center, Pollak, Hague, Pl. Christ, St. Mary's hospitals, Dickinson, Ferris and Lincoln high schools and St. Peter's College. There are another 45 schools in the district.

A survey of directories yielded information on industrial/commercial establishments. There are 56 such potential users with more than 30000 sq. ft. of building area each or more than 50 people employed indicating sufficient floor space to consider them as significant users of heat. Only the space heating needs were assessed. Process heat requirements and their compatibility with D-H system parameters will have to be determined on a one-by-one survey basis.

The area delineated for heat supply indicates major concentrations of load by hatching and major industrial/commercial users by letters. There are 8800 apartments in large buildings of 50 apartments or more each. About 200000 people live within this area in 60000 houses. Only about 12% of those are single family structures, while over 60% are 2-9 family buildings, most built as row houses. The estimated total load potential in this area exceeds two billion BTU/hr peak, less than 10% of it commercial/industrial. The load density averages around 400 million BTU/hr, sq. mi.

The Newark/Harrison supply area is shown on Fig. 8.3.4. It is on the average five miles WSW of the Hudson G.S. The approximately eight sq. mi. area includes 40 or so high-rise office

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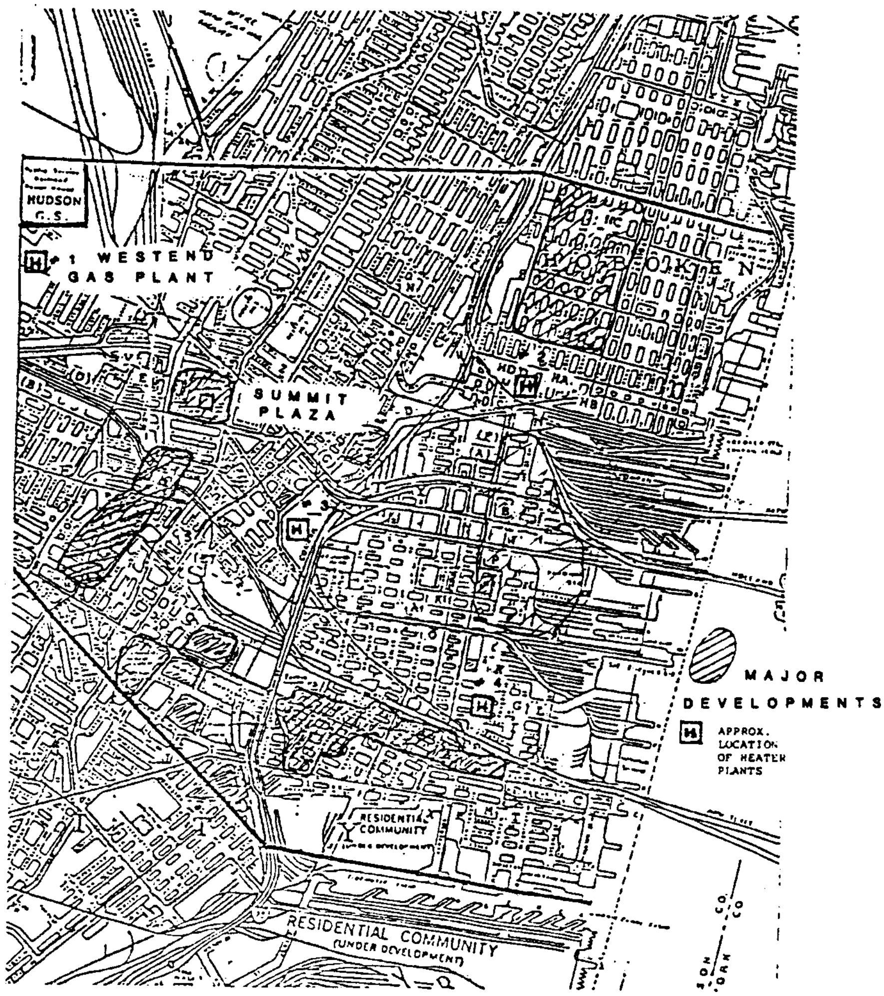

Jersey City/Hoboken
D-H Supply Area

FIG. 8.3.3

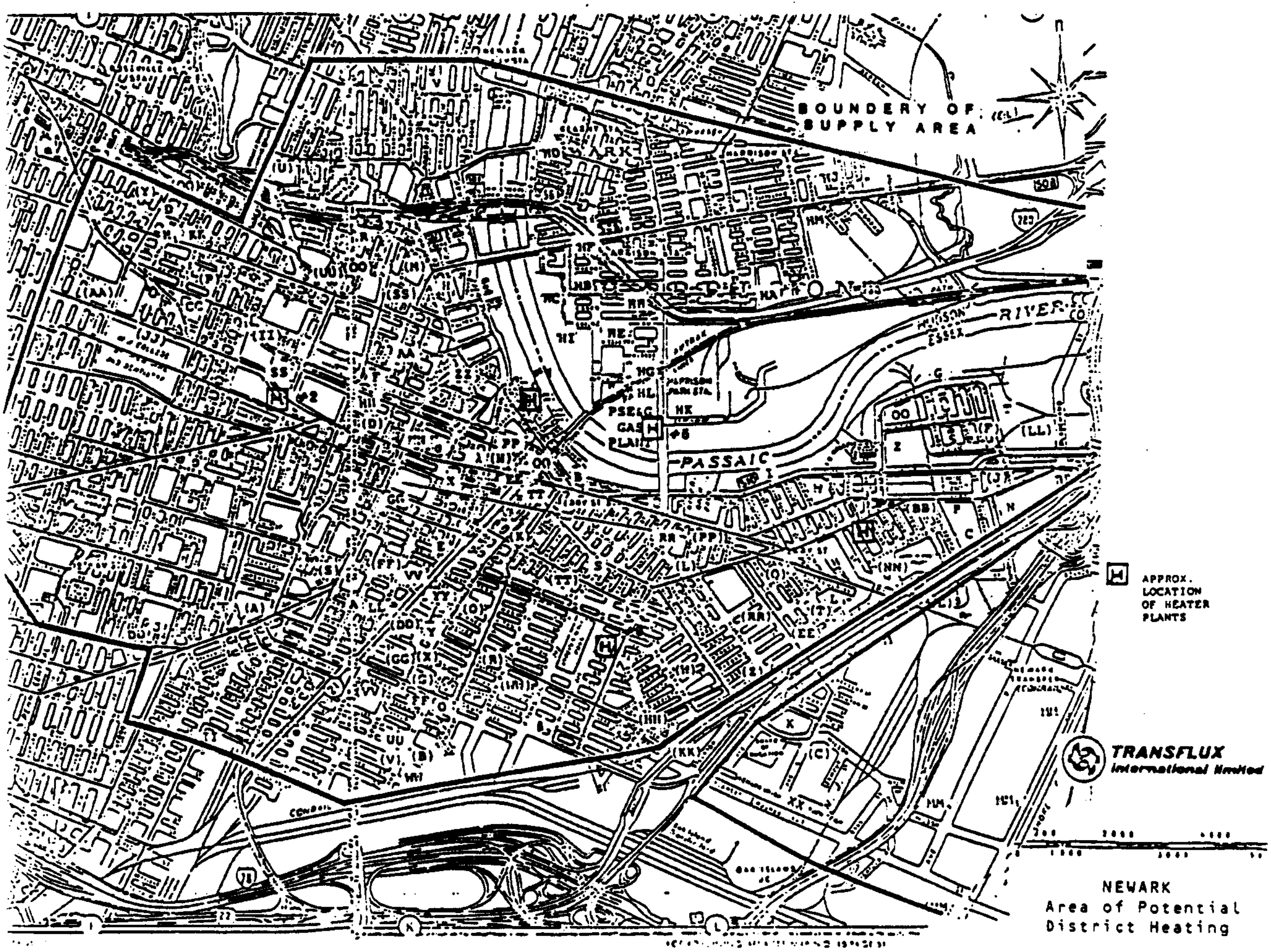
BOUNDERY OF
SUPPLY AREA
RIVER
PASSAIC
APPROX.
LOCATION
OF HEATER
PLANTS
TRANSFLUX
International Limited
NEWARK
Area of Potential
District Heating

FIG. 8.3.4

and residential buildings and also some of the densest residential/industrial neighborhoods.

The only new development in planning is the extension of the Gateway complex. It is in the middle of the area. The major existing complexes are the Gateway buildings, Western Electric, State of N.J. office building, J. Erwin Federal Bldg., Courthouse, City Hall, Prudential Ins. bldg., several high-rises on Park Plaza and south and north of it on Broad St. The N.J. College of Medicine, N.J. Institute of Technology and Rutgers University, Seton Hall Law School; also the Newark Skills Center, United Hospital of Newark, St. Michaels Medical Center, Penn. Central Station, Essex County Administration bldg., Post Office, Library are there. So are 47 schools, six of them high schools.

The different directories of business and industry yielded 240 identifiable large consumers of heat based on building area and/or number of employees. Again process use of heat has not been evaluated.

The large apartment complexes within the area, mostly high-rises, contain 6000 units. Seventy percent of the over-200000 population lives in small multi-family dwellings, mostly row houses, and only 6% lives in single-family structures.

The estimated total load potential in this area exceeds 3.5 billion BTU/hr peak, one-third being commercial/industrial, while the rest residential. The average load density surpasses 460 million BTU/hr, sq. mi.

As Fig. 8.3.1 shows, there are a number of other areas in the southern portion of the Hackensack Meadowlands where future development is planned, first of all, by Hartz Mountain Industries, Inc. These yet undeveloped lands are about 1000 acres in size, comparable to the total of the other new developments. So it is reasonable to assume that they will represent a minimum of 500 million BTU/hr peak load potential. The transmission mains are laid out to accommodate the easy interconnection with this potential load, should it materialize before the full system is completed.

Another development plan, this one by the N.Y.-N.J. Port Authority, may call for the creation of an industrial park along Doremus Ave., just south of the Essex G.S. This was not included in our system, since probably a steam system will be needed to provide process heat requirements along with space heating. There are also two potential sources of heat besides Essex or the D-H system. One is the Passaic Valley Sewage Treatment facility at the south end of this street, while the other is the Essex County garbage disposal and heat recovery facility tentatively planned to be located at a site just to the north.

The district heating for peak space heating within these areas was estimated as follows:

	10^6 BTU/hr
Hackensack Meadowlands	
- Berry's Creek & Harmon Meadows	600
- other areas	500
Jersey City/Hoboken	2000
Newark/Harrison	3700
Total	6800

These same buildings will have an estimated average heat requirement of 500 million BTU/hr for domestic hot water preparation. This load is not considered additional to peak load since a factor of coincidence needs to be applied over the peak rates. This factor was taken to equal the domestic hot water load, at 7.3% of peak heating load.

There is an additional load in the form of transmission and distribution losses. It is estimated that the losses coincident with the peak load will be 8.6% of the total send-out. That would be approximately 500 million BTU/hr for the total load potential. Since most of the losses occur at the local distribution level, it can be fairly accurately proportioned with load.

The supply system developed aims at approximately 50% coverage of the above load potential. This means a system of approximately 3700 million BTU/hr peak send-out and this is what Scenario III is designed for.

As will be shown later approximately 300 million BTU/hr is lost in distribution, leaving actually 3400 million BTU/hr as net billable heat. If some of that capacity is used to supply process heat it will decrease the heat to the space heating and domestic hot water heating customers and increase the use factor of the system to further the economics.

The high temperature water D-H system proposed will be supplied by steam extraction from the Hudson No. 2 turbogenerator unit, by waste heat recovered from the Kearny No. 12 combustion turbogenerator unit and by gas-fired hot water heaterplants located at the center of several areas within the supply territory. Each area supplied by one of these plants is typically one square mile. So the total system will have about 11 of these heaterplants, each having an installed heater capacity of 200-240 million BTU/hr.

The share of each component in the system load and the send-out water temperatures associated with it at peak load condition are as follows:

	10^6BTU/hr(MW_t)	water temp leaving-^{0}F	% peak load
Heat supplied by fired heaters	1050 (307.5)	296.6	28.37
Heat supplied by gasturb. heat recovery	1050 (307.5)	269.7	28.38
Heat supplied by crossover extraction of Hudson No. 2 unit	1600 (469)	222.8	43.25
Return water temp @ flow of 57000gpm		166.6	
	3700 (1084)	Δt = 130	100

The 6.6^{0}F additional supply temperature and the 3.4^{0}F lower return temperature compensate for the line heat losses. The total of 10^{0}F is 8.33% of the 120^{0}F design temperature differential.

The system is proposed to be constructed in 25 years, starting with what has been described in Scenarios I and II. Following those closely, development will start also in Jersey City by utilizing the Westend Gas Plant boiler facilities and possibly the now privately owned Summit Plaza cogeneration plant facilities. The gas plant has four high pressure, oil fired boilers with a total capacity of 270000 lb/hr. The Summit Plaza facility has 26.8 million BTU/hr oil fired hot water heater capacity and heat recovery on 3 MW diesel generator units with a design output of 9.8 million BTU/hr. Its peak heat load is less than 17 million BTU/hr.

By 1988 it is expected to have sufficient connected load to justify the partial retrofitting of the Hudson No. 2 unit and construct transmission lines to the heaterplants already in service. The extent of that partial retrofit, capable of supplying 240 million BTU/hr, was already described as are the next stages of retrofits. Phase I of the full retrofit is needed by 1992 to increase the share in the peak supply of Hudson No. 2 to 800 million BTU/hr. That is half of its final output of 1600 million BTU/hr to be reached by 2002 (Phase II).

Phase I retrofit may or may not coincide with the installation of a backpressure turbine. A pressure reducing station is installed to supply steam to the heatexchanger controlled by leaving water temperature. The turbine parallels that reducing station and it acts as a spinning reducer generating electric power and therefore improving the overall economy of the system. Its installation can be decided on the basis of economics only.

What is called retrofit Phase III is the addition of a second backpressure turbine to the Hudson retrofit. This step also adds only to the efficiency of the system, so its timing is also decided on a purely economic basis.

Further plant developments in Jersey City are predicted by 1993, 1997 and finally by the year 2001. Each subsystem is planned to reach full capacity in eight years.

Development of the systems in Newark is foreseen to be starting by 1997 and growing by the addition of a new system every two years after that, with the last starting in 2005. Each subsystem is planned to reach full capacity also in eight years but start acquiring users at a more rapid rate than in Jersey City. Success in that city and higher load density are the reasons for this assumption.

Table 8.3-I summarizes all of the above. It shows the successive installation of fired heaters, partial and phased full retrofit of Hudson No. 2 unit and that of the Kearny No. 12 combustion turbine unit. It also shows the total peak load run-up as developed and is shown on Table 8.3-II.

Spare capacity to replace any outage of any one single component of the system will be provided on the following basis:

Heaterplants

- at least one full unit as spare at any time during isolated operation
- at least one full unit as spare at any time during operation of two such plants connected
- 100% stand-by capacity in each plant when system is connected to Hudson (2 units out of 4 installed)

Hudson No. 2 unit

- connection through new pressure reducing station to existing tie line with No. 1 unit (190×10^6BTU/hr or $55MW_t$) or 15% of peak output from this source

Combustion turbine recovery

- 7% stand-by capacity (75×10^6BTU or $22MW_t$) by increased heat recovery on all four pairs of turbine exhaust of the $196MW_e$ capacity unit due to lower inlet and leaving water temperatures

This means that on the loss of Hudson No. 2 unit the Hudson No. 1 unit will provide 190 million, the gasturbine heat recovery 75 million and the stand-by heaters (6x100 + 5x120) = 1200 million BTU/hr for a total of 1465 million BTU/hr. This compares favorably

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TABLE 8.3-I

HEAT SOURCE INSTALLATION SCHEDULE
10^6 BTU/HR

	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006-11
BERRY'S CREEK	150		50																				
HARMON MEADOWS			150			50																	
JERSEY CITY																							
#1			200																				
#2										150			50										
#3														150			50						
#4																		150			50		
NEWARK																							
#1														180			60						
#2																180			60				
#3																		180			60		
#4																				180			60
#5																						180	60
HUDSON G.S.																							
Partial					240																		
Ph. I									560														
Ph. II																			800				
Ph. III																			none				
KEARNY G.S.																					1100		
	150	150	550	550	790	840	840	840	1400	1550	1550	1550	1600	1930	1930	2110	2220	2550	3410	3590	4800	4960	5080
Largest unit	50	50	150	150	240	240	240	240	800	800	800	800	800	800	800	800	800	800	1600	1600	1600	1600	1600
Cap. after loss of largest unit	100	100	400	400	550	600	600	600	600	750	775	750	800	1130	1130	1310	1420	1750	1810	1990	3200	3360	3480*
System peak load	20	75	160	255	350	457	565	650	715	770	795	840	900	995	1115	1280	1500	1735	1980	2255	2555	2810	3695
Connected to Hudson #2 unit					170	184	565	650	715	755	755	755	755	955	1005	1040	1085	1280	1930	2175	2415	2785	3695

*These figures do not account for the 190x10 BTU/hr heat available from the existing Hudson #1 unit to #2 unit bypass line.

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TABLE 8.3-II

TOTAL DISTRICT HEATING SYSTEM
INCREMENTAL & ACCUMULATIVE LOAD GROWTH
ESTIMATE
(Million BTU per hr.)

	'84	'85	'86	'87	'88	'89	'90	'91	'92	'93	'94	'95	'96	'97	'98	'99	2000	'01	'02	'03	'04	'05	'06	'07-'11	
BERRY'S CREEK	15	55	30	35	15	10	10	10	20																200
HARMON MEADOWS			28	32	35	32	43	20	10																200
JERSEY CITY #1			20	20	40	55	50	45	35	35															300
JERSEY CITY #2										15	20	40	55	50	45	35	40								300
JERSEY CITY #3														15	20	40	55	50	45	35	40				300
JERSEY CITY #4																		15	20	40	55	50	45	75	300
NEWARK #1														25	45	50	65	75	50	30	20				360
NEWARK #2																25	45	50	65	75	50	30	20		360
NEWARK #3																		25	45	50	65	75	50	50	360
NEWARK #4																				25	45	50	65	175	360
NEWARK #5																						25	45	290	360
INCREMENTAL GROWTH	15	55	78	87	90	97	103	75	65	50	20	40	55	90	110	150	205	215	225	255	275	230	225	590	
ACCUM.GROWTH	15	70	148	235	325	422	525	600	665	715	735	775	830	920	1030	1180	1385	1600	1825	2080	2355	2585	2810	3400	3400
ACCUM.HEAT LOSS	5	5	12	20	25	35	40	50	50	55	60	65	70	75	85	100	115	135	155	175	200	225	245	295	295
TOTAL ACCUM.GROWTH	20	75	160	255	350	457	565	650	715	770	795	840	900	995	1115	1280	1500	1735	1980	2255	2555	2810	3055	3695	3695

with the 1600 million BTU/hr lost by the total default of the Hudson No. 2 unit. The missing 135 million BTU/hr capacity is 3.68% of total system peak and reduces the indoor temperature 2.5°F on a 0°F day. No coincident failure of other equipment is contemplated in accordance with European practice at many similar systems.

Table 8.3-I compares the peak load each year--both total system load and that connected to the Hudson unit--with the firm capacity available. This comparison indicates shortages during the years 1991 through 1996 amounting to 50-100 million BTU/hr. Since the Hudson No. 1 unit to No. 2 unit tie line can supply much more heat than that, there is no need for additional sources. Shortage in firm capacity develops again by 2001, lasts through 2003 and amounts to a maximum of 185 million BTU/hr. It is again within the capability of the tie-line.

There is a possibility to eliminate any shortage in firm capacity during these latter years by switching the installation of the gasturbine retrofit and Phase II of the Hudson retrofit. This produces 800 million BTU/hr more firm capacity in the years 2000 to 2003. Economics of this choice will be the decisive factor.

Exceptions to the heater plant construction scheme discussed previously, the Jersey City No. 1 plant, as described before, is based on existing facilities. Modernization of controls, possible addition of gas burners, installation of pressure reducing/desuperheating station and heatexchangers will be required at the Westend Gas Plant. If the Summit Plaza facility is acquired, a 24" ϕ main will have to be built to connect the two plants. System circulating pumps will be added to each of the facilities. Because of its location it is also foreseen that the plant(s) will be connected to Hudson at the partial retrofit stage (1988) by the extension of the 24" ϕ line.

The Newark No. 1 plant may be housed in an existing PSE&G building on Passaic Place, which also has a more than adequate stack. Newark No. 5 plant (Harrison) may make use of the boilers of the Harrison gas plant if available at that time (2005). None of these opportunities for reducing investment requirements have been made part of the economic calculations.

The transmission lines are shown on Fig. 8.3.5, while their development (shown on Figs. 8.3.7 through 8.3.13) schedule is detailed in Table 8.3-III. Most of the lines are routed so as to utilize PSE&G right-of-ways. The load and capacity development is also shown diagrammatically on Fig. 8.3.14.

The construction schedule reflects the growth of load in each area and the availability of heat sources. Berry's Creek is connected to Hudson when the load reaches 150 million BTU/hr and the partial retrofit at Hudson is completed. Harmon Meadows reaches the same load two years later and gets connected at that time.

As described before, a section of the 24" ø transmission main in Jersey City may be constructed early to make use of the Summit Plaza facility. It gets also extended in 1990 to utilize the economies of the partial retrofit to its full advantage.

The second phase of transmission line construction does not start until 1997. That time the successive Jersey City plants will be connected to the central heat supply.

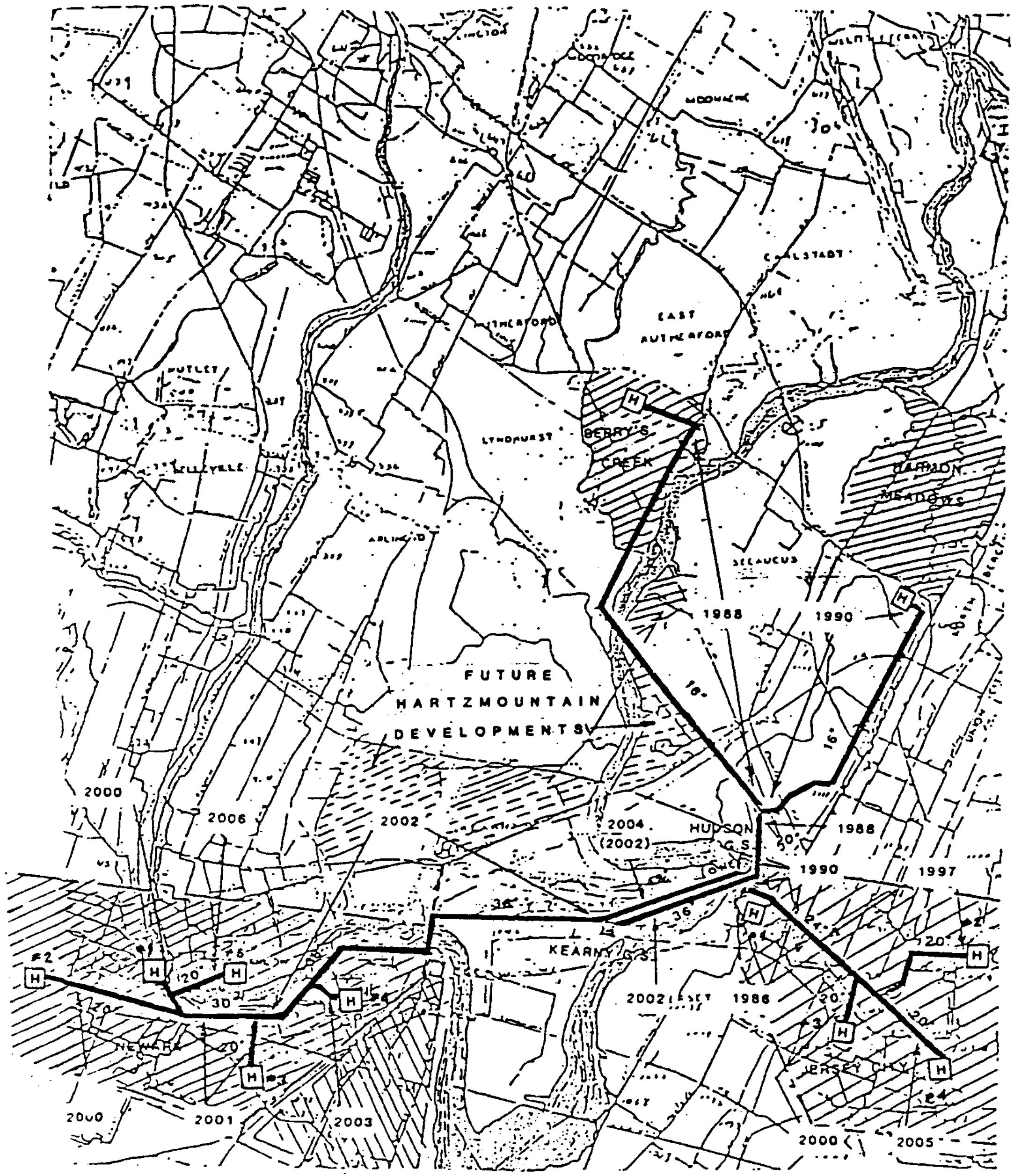
In the years 2000 and 2001, two and then three of the Newark plants are respectively tied together to provide spare capacity for each other.

In 2002 the Newark-Hudson transmission line is constructed, completing the centralization of the system. At this point the pair of 36" ø lines leaving the Hudson G.S. feed the Newark users only, as shown on Fig. 8.3.6. When the Kearny gasturbine retrofit has been completed, then a 42" ø line will take the total flow from Hudson to Kearny and one of the 36" ø lines will become the main supply line to the Meadowlands/Jersey City area (Fig. 8.3.6).

There will be approximately 23 miles of transmission mains (pair of pipe) in the system.

Table 8.3-III also shows the schedule of distribution pipe installations. There will be approximately 185 miles of distribution piping (pair) in the system.

The schedule of the secondary piping installations and of the conversion units is not included in the referred tables. Their schedule and cost will be considered on a pro rata basis in the economics calculations.



SCALE: 1" = 6000'

FIG. 8.3.5

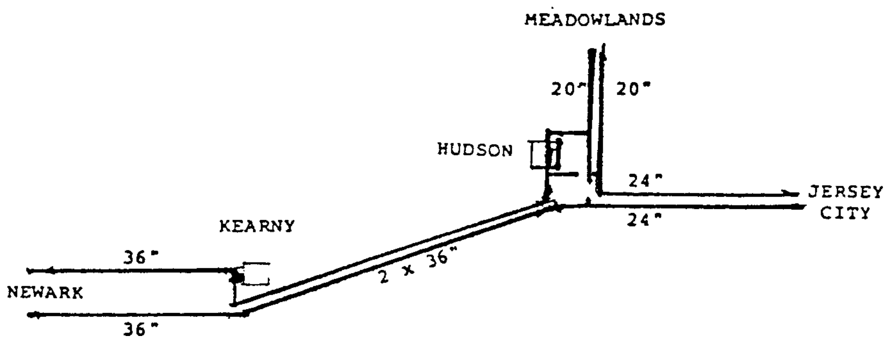
TRANSFLUX international limited

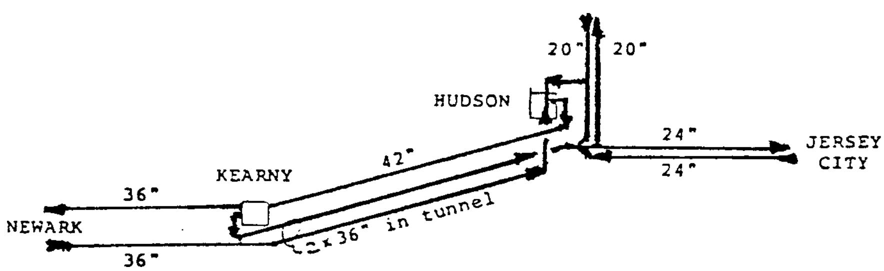
TABLE 8.3-III

PIPING INSTALLATION SCHEDULE
IN 1000 FT. OF PAIR OF PIPE

	DIA	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007-11	TOTAL
BERRY'S CREEK	12"	.6																							.6
	10"	3.2	1.0	1.0																					5.2
	8"	.6																							.6
	4"	2.2	.3	.3	1.0	.4	.3	.3																	4.8
	3"	.1																							.1
	2"	1.6	.2	.1	1.6	.4	.3	.3																	4.5
	1-1/2"	1.2			1.2	.2	.2	.2																	3.0
HARMON MEADOWS	10"		2.8	2.3	1.1																				6.2
	8"			.7	.7	2.6																			4.0
	6"		2.6	2.1	2.0	1.2																			7.9
	4"			.6	.7	.7	.7	.6	.2																3.5
	3"					.1																			.1
	2"		.8	1.0	1.8	2.0	.2	.8																	6.6
	1-1/2"						.2	.1																	.3
JERSEY CITY	10"		1.4		1.3		1.4		1.3	1.4		1.3		2.7		2.7		2.7		2.7		1.4		1.3	21.6
	8"		1.0		1.1		1.0		1.1	1.0		1.1		2.1		2.1		2.1		2.1		1.0		1.1	16.8
	4"		6.6	4.8	10.2	15.0	10.8	6.4	4.8	13.0	4.8	10.2	15.0	17.4	11.2	15.0	21.4	17.4	13.0	15.0	21.4	10.8	6.4	11.2	261.8
	2"		2.1	1.5	3.3	4.8	5.1	3.1	2.3	5.1	1.5	3.3	4.7	7.2	4.6	5.6	7.8	7.2	4.6	5.6	7.8	5.1	3.1	5.4	100.8
NEWARK	10"													1.4		2.7		4.0		5.4		5.4		8.1	27.0
	8"													1.0		2.1		3.2		4.2		4.2		6.3	21.0
	4"													6.9	5.1	17.6	20.9	28.6	27.6	33.7	34.3	33.7	34.3	97.3	340.0
	2"													2.1	2.7	5.7	8.6	10.8	12.8	14.0	15.5	14.0	15.5	45.8	147.5
TOTAL		9.5	18.8	14.4	26.0	27.4	20.2	11.8	9.7	20.5	6.3	15.9	19.7	40.8	23.6	53.5	58.7	76.0	58.0	82.7	79.0	75.6	59.3		983.9
TRANSMISSION	42"																				10.8				10.8
	36"																		26.9						26.9
	30"																	2.5							2.5
	24"		3.0				3.0							5.5											11.5
	20"				2.9									7.5			11.0	3.0		2.5			3.0		29.9
	16"				23.5		13.5																		37.0
TOTAL			3.0		26.4		16.5							13.0			11.0	5.5	26.9	2.5	10.8		3.0		118.6

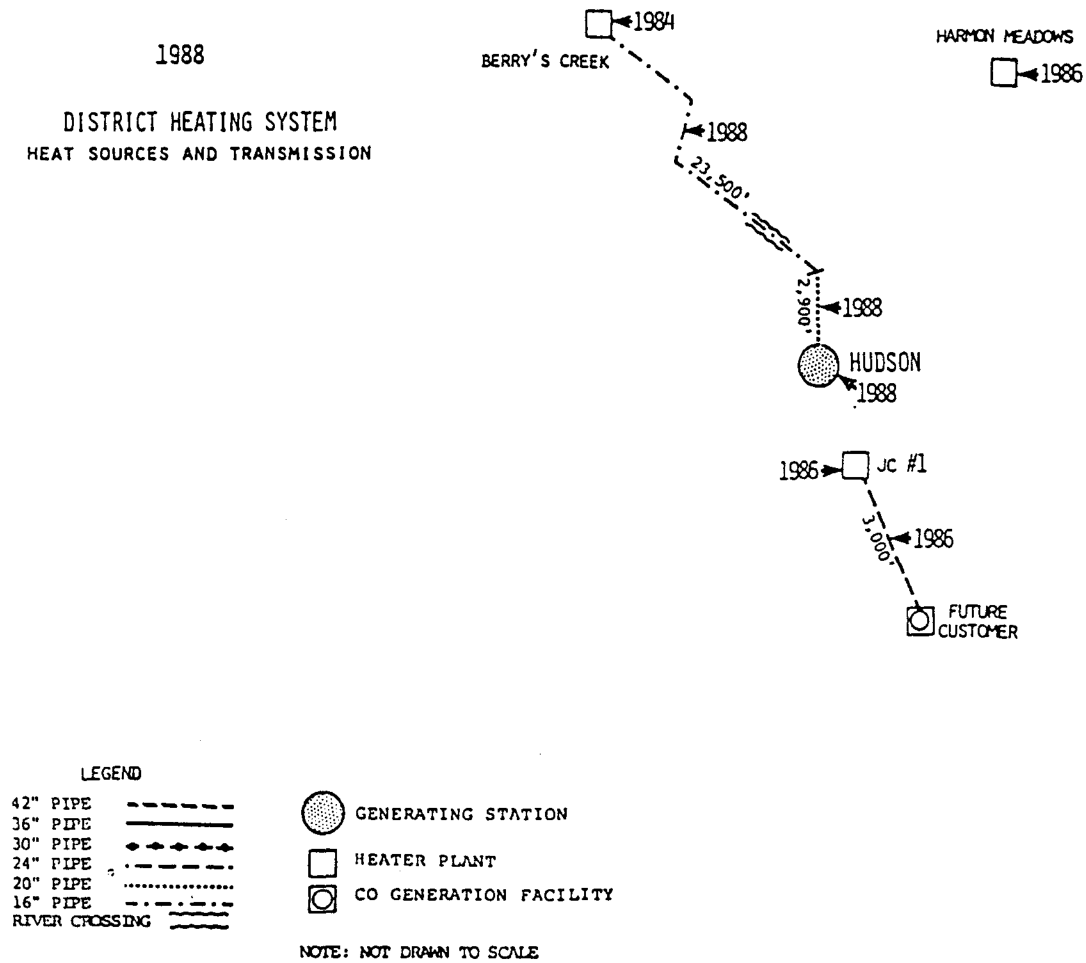
TRANSFLUX International limited





TRANSMISSION MAINS
DEVELOPMENT BETWEEN
HUDSON & KEARNY G.S.

FIG. 8.3.6



1988
DISTRICT HEATING SYSTEM
HEAT SOURCES AND TRANSMISSION
1984
BERRY'S CREEK
1988
23,500'
2,900'
1988
HUDSON
1988
HARMON MEADOWS
1986
1986
JC #1
3,000'
1986
FUTURE CUSTOMER
LEGEND
42" PIPE
36" PIPE
30" PIPE
24" PIPE
20" PIPE
16" PIPE
RIVER CROSSING
GENERATING STATION
HEATER PLANT
CO GENERATION FACILITY
NOTE: NOT DRAWN TO SCALE

FIG. 8.3.7

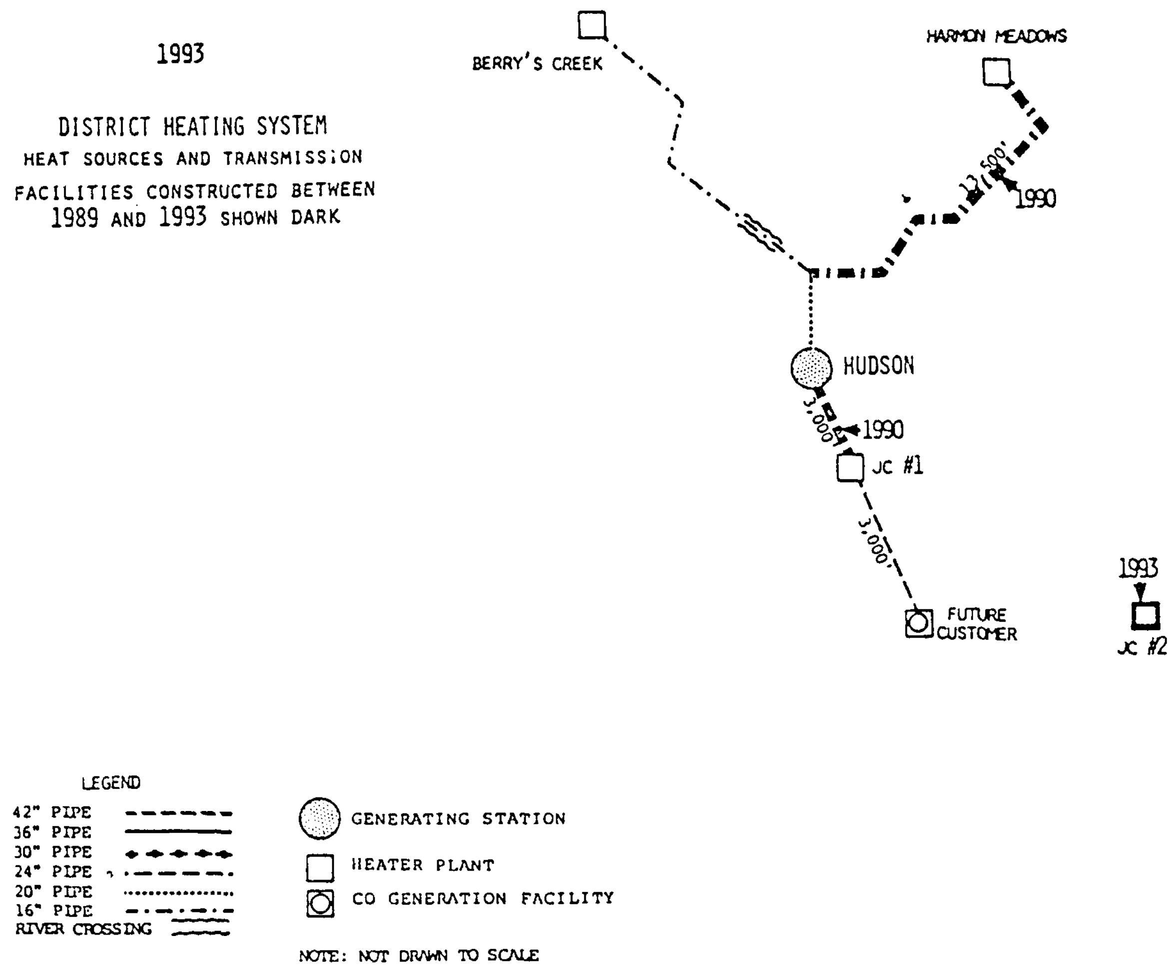

1993
DISTRICT HEATING SYSTEM
HEAT SOURCES AND TRANSMISSION
FACILITIES CONSTRUCTED BETWEEN
1989 AND 1993 SHOWN DARK
BERRY'S CREEK
HARMON MEADOWS
1990
HUDSON
1990
JC #1
FUTURE CUSTOMER
1993
JC #2
LEGEND
42" PIPE
36" PIPE
30" PIPE
24" PIPE
20" PIPE
16" PIPE
RIVER CROSSING
GENERATING STATION
HEATER PLANT
CO GENERATION FACILITY
NOTE: NOT DRAWN TO SCALE

FIG. 8.3.8

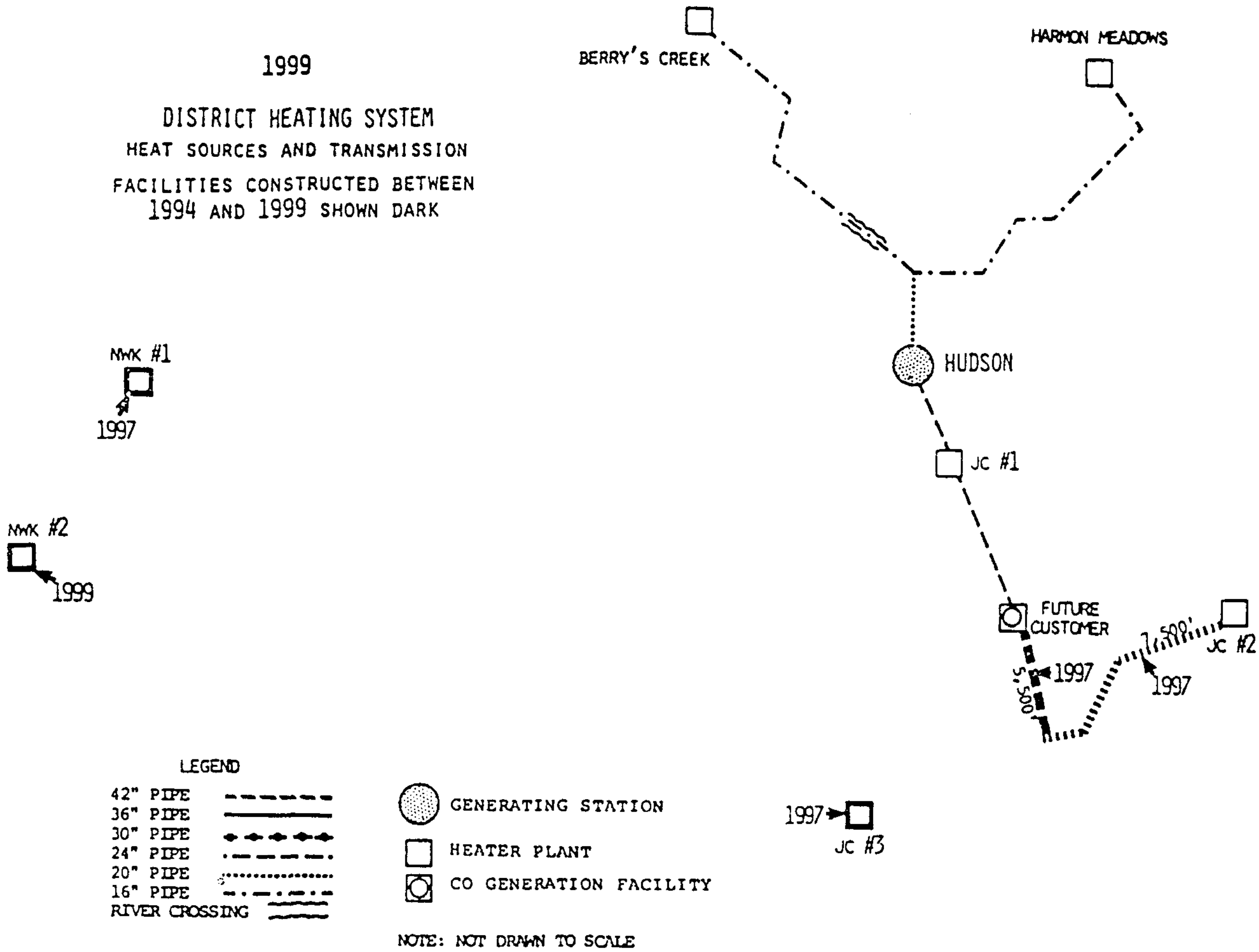

1999
DISTRICT HEATING SYSTEM
HEAT SOURCES AND TRANSMISSION
FACILITIES CONSTRUCTED BETWEEN
1994 AND 1999 SHOWN DARK
BERRY'S CREEK
HARMON MEADOWS
HUDSON
JC #1
FUTURE CUSTOMER
JC #2
5,500'
7,500'
1997
1997
NWK #1
1997
NWK #2
1999
1997
JC #3
LEGEND
42" PIPE
36" PIPE
30" PIPE
24" PIPE
20" PIPE
16" PIPE
RIVER CROSSING
GENERATING STATION
HEATER PLANT
CO GENERATION FACILITY
NOTE: NOT DRAWN TO SCALE

FIG. 8.3.9

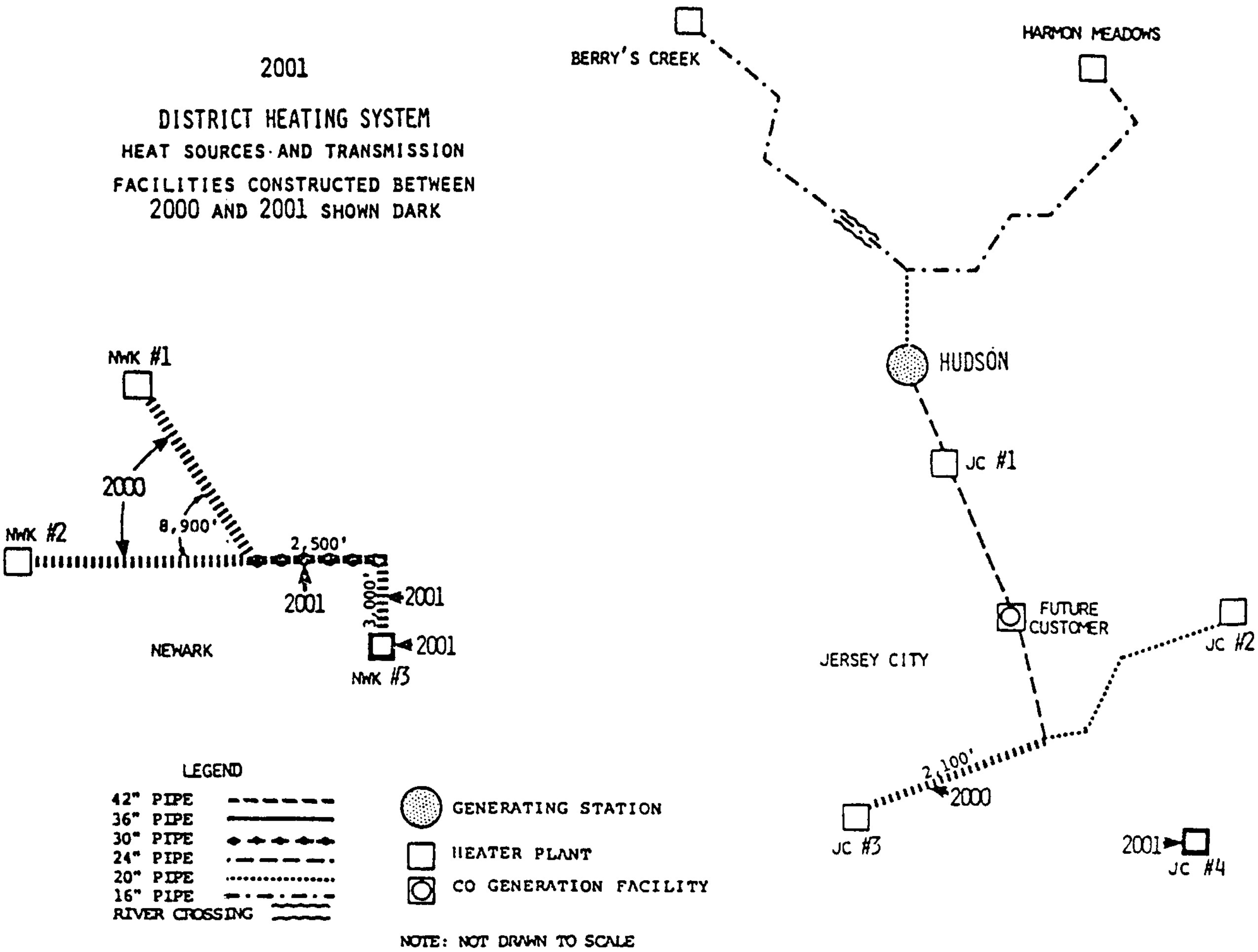

2001
DISTRICT HEATING SYSTEM
HEAT SOURCES AND TRANSMISSION
FACILITIES CONSTRUCTED BETWEEN
2000 AND 2001 SHOWN DARK
BERRY'S CREEK
HARMON MEADOWS
HUDSON
JC #1
FUTURE CUSTOMER
JC #2
JERSEY CITY
2,100'
2000
JC #3
2001
JC #4
NWK #1
2000
8,900'
NWK #2
2,500'
2001
3,000'
2001
2001
NEWARK
NWK #3
LEGEND
42" PIPE
36" PIPE
30" PIPE
24" PIPE
20" PIPE
16" PIPE
RIVER CROSSING
GENERATING STATION
HEATER PLANT
CO GENERATION FACILITY
NOTE: NOT DRAWN TO SCALE

FIG. 8.3.10

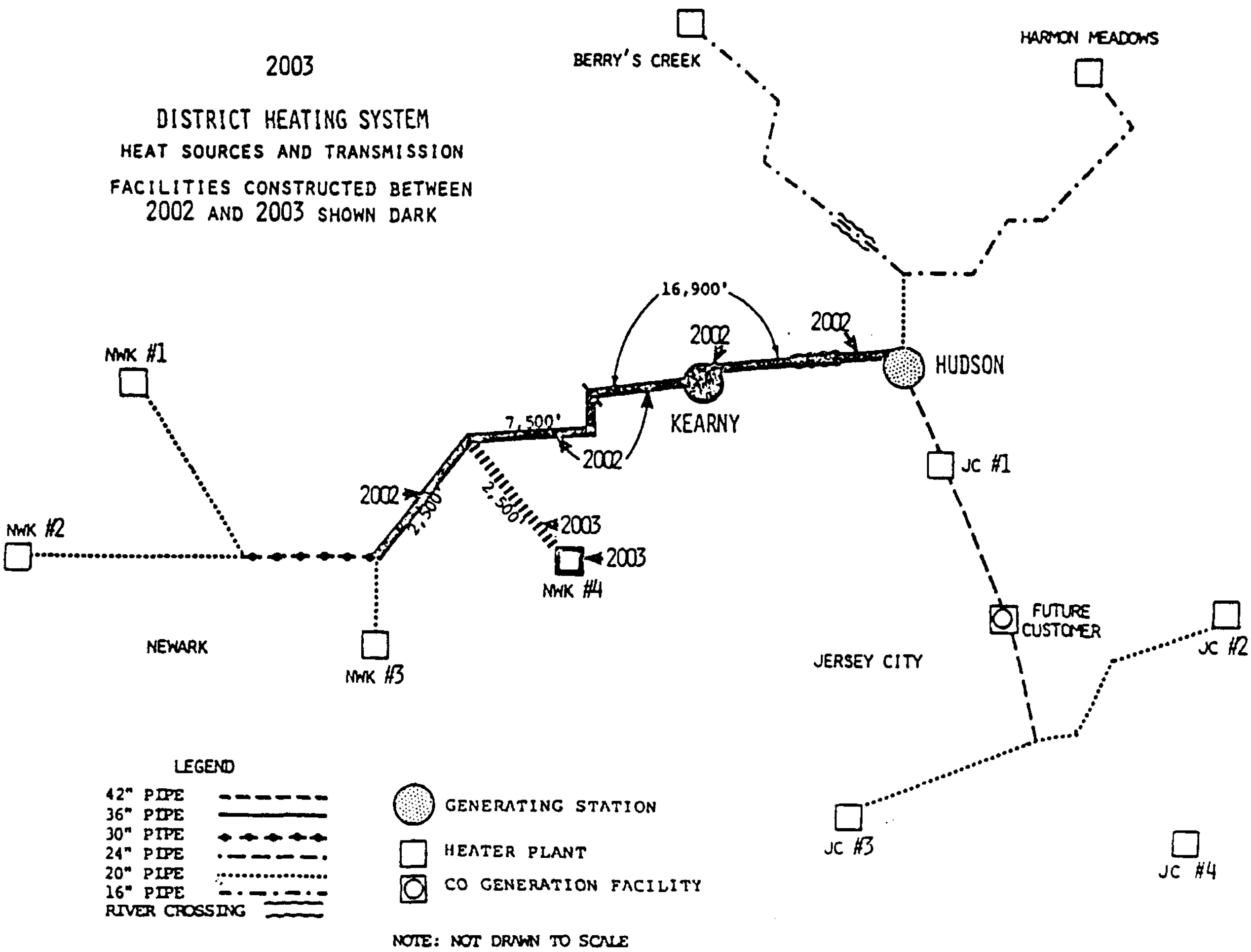

2003
DISTRICT HEATING SYSTEM
HEAT SOURCES AND TRANSMISSION
FACILITIES CONSTRUCTED BETWEEN
2002 AND 2003 SHOWN DARK
BERRY'S CREEK
HARMON MEADOWS
16,900'
2002
2002
HUDSON
KEARNY
7,500'
2002
JC #1
NWK #1
2002
2,500
2,500
2003
NWK #2
2003
NWK #4
FUTURE CUSTOMER
JC #2
NEWARK
NWK #3
JERSEY CITY
LEGEND
42" PIPE
36" PIPE
30" PIPE
24" PIPE
20" PIPE
16" PIPE
RIVER CROSSING
GENERATING STATION
HEATER PLANT
CO GENERATION FACILITY
NOTE: NOT DRAWN TO SCALE
JC #3
JC #4

FIG. 8.3.11

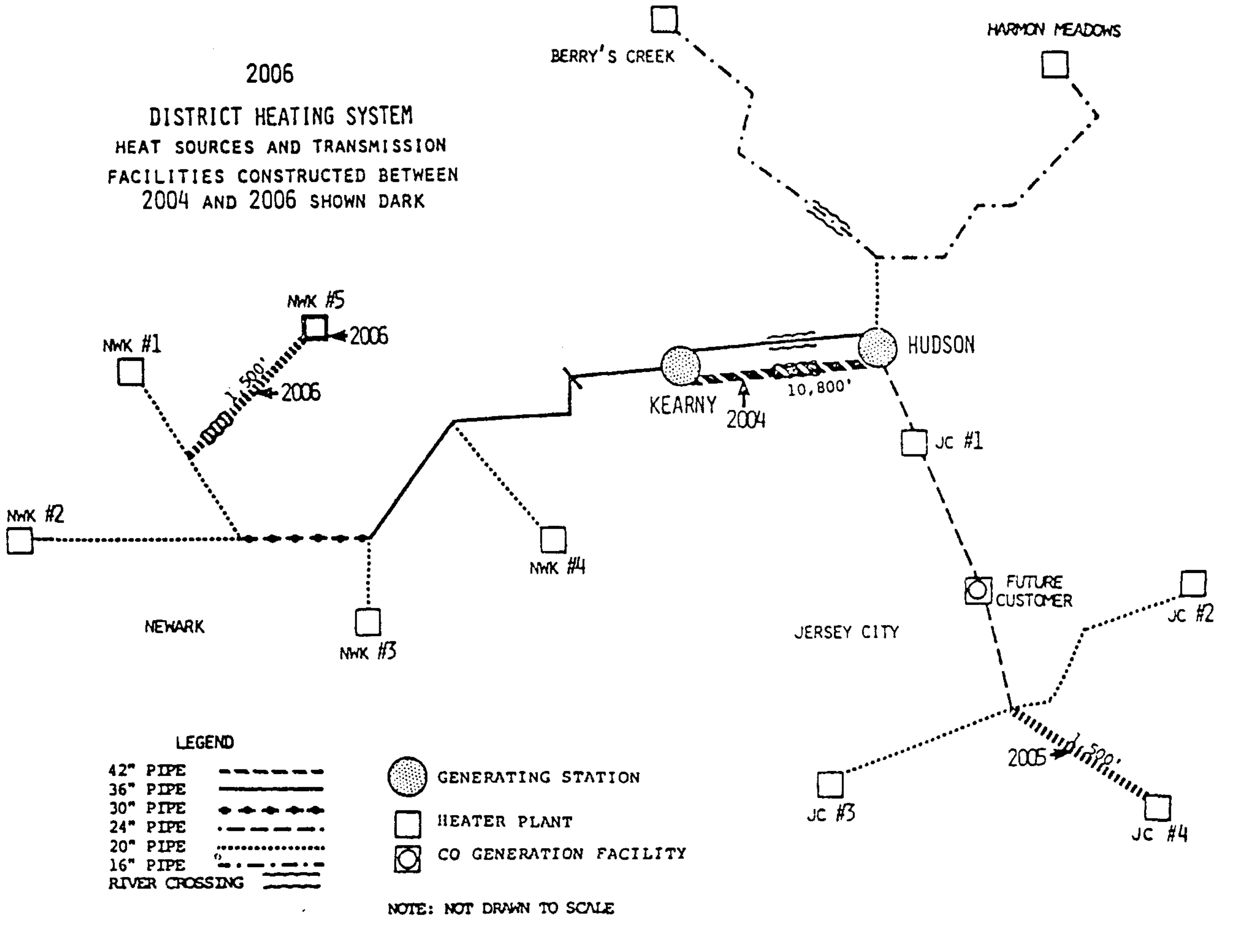

2006
DISTRICT HEATING SYSTEM
HEAT SOURCES AND TRANSMISSION
FACILITIES CONSTRUCTED BETWEEN
2004 AND 2006 SHOWN DARK
BERRY'S CREEK
HARMON MEADOWS
NWK #5
2006
NWK #1
1,500'
2006
HUDSON
KEARNY
2004
10,800'
JC #1
NWK #2
NWK #4
FUTURE
CUSTOMER
JC #2
NEWARK
NWK #3
JERSEY CITY
2005
1,500'
JC #3
JC #4
LEGEND
42" PIPE
36" PIPE
30" PIPE
24" PIPE
20" PIPE
16" PIPE
RIVER CROSSING
GENERATING STATION
HEATER PLANT
CO GENERATION FACILITY
NOTE: NOT DRAWN TO SCALE

FIG. 8.3.12

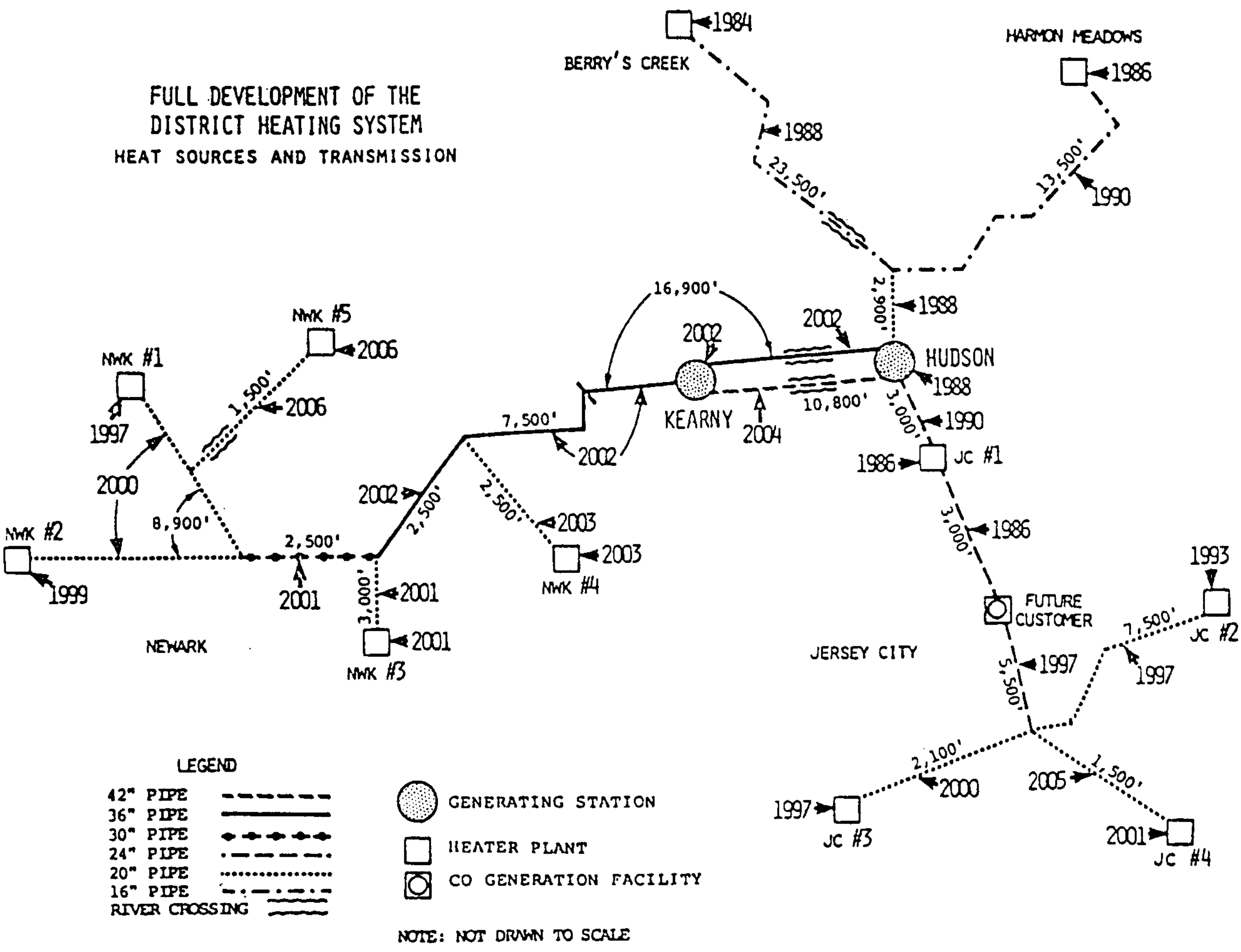

FULL DEVELOPMENT OF THE
DISTRICT HEATING SYSTEM
HEAT SOURCES AND TRANSMISSION
BERRY'S CREEK
1984
1988
23,500'
HARMON MEADOWS
1986
13,500'
1990
2,900'
1988
16,900'
2002
2002
HUDSON
1988
KEARNY
2004
10,800'
3,000'
1990
1986
JC #1
3,000'
1986
7,500'
2002
NWK #5
2006
1,500'
2006
NWK #1
1997
2000
8,900'
NWK #2
1999
2,500'
2001
2002
2,500'
2,500'
2003
2003
NWK #4
3,000'
2001
2001
NWK #3
NEWARK
FUTURE CUSTOMER
JERSEY CITY
1993
7,500'
JC #2
1997
5,500'
1997
2,100'
2000
1997
JC #3
2005
1,500'
2001
JC #4
LEGEND
42" PIPE
36" PIPE
30" PIPE
24" PIPE
20" PIPE
16" PIPE
RIVER CROSSING
GENERATING STATION
HEATER PLANT
CO GENERATION FACILITY
NOTE: NOT DRAWN TO SCALE

FIG. 8.3.13

FULL DISTRICT HEATING SYSTEM
LOAD AND CAPACITY EXPANSION
1984-2011

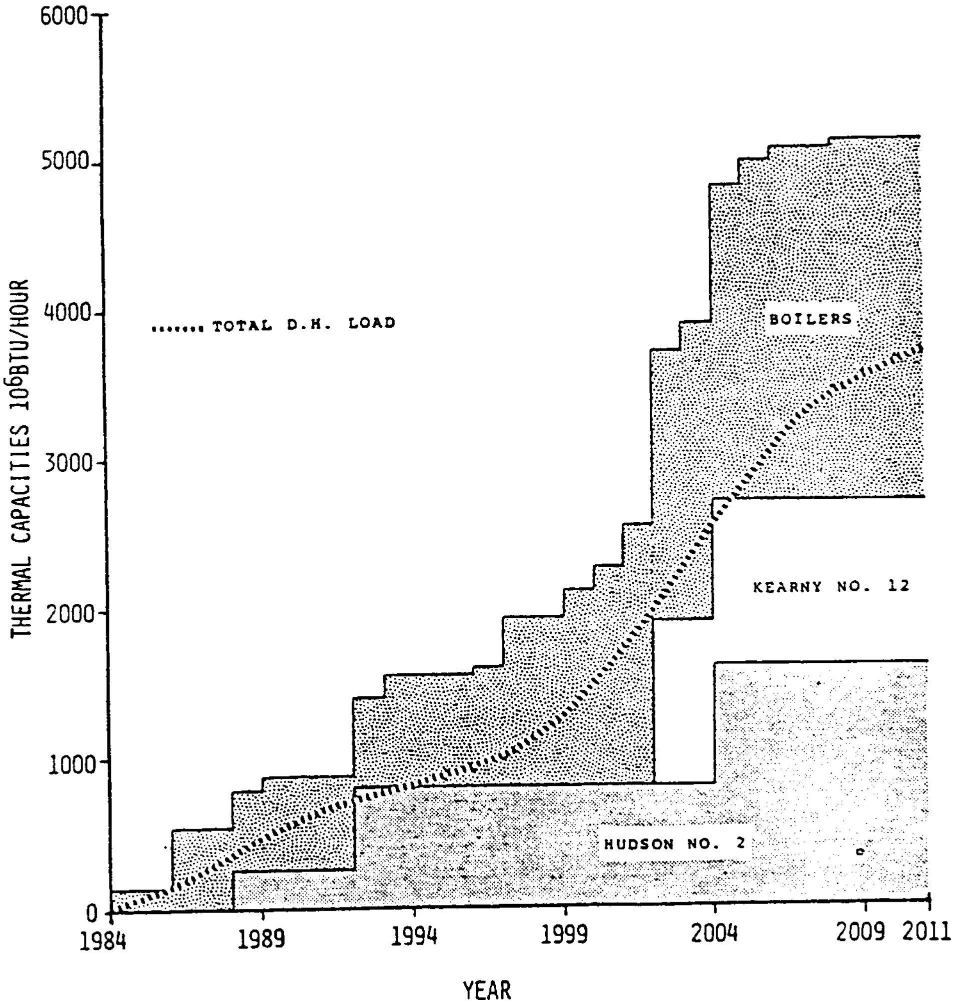


FIG. 8.3.14

The cost of operating the system, that is those beyond the cost of fuel and the cost of replacement power, is

- heat losses
- pumping cost
- operation and maintenance expenses

Fuel and replacement energy costs were calculated by the PSE&G incremental power cost program. The other operating cost items were developed as follows.

Heat losses, that is the amount of heat lost over the transmission and distribution systems during a year's operation, are shown in Table 8.3-IV for the development in annual increments and accumulated annually. The dollar value of these losses was as calculated by the incremental cost computer program.

The average annual heat loss works out to 3.1% of net heat supplied. This can be broken down further to 3.6% average during the six winter months and 2.4% during the summer.

Pumping cost is the cost of circulating the hot water through the heaters, the transmission lines, the distribution system, the house connections and the user equipment. The results are shown in Table 8.3-V. The annual increments were calculated in accordance with the development schedules shown on Tables 8.3-II and 8.3-III and so was the accumulative cost. All the costs are based on the present average replacement cost of power, that is $69 per MWh.

The average cost of pumping for the fully developed system in 1981 dollars is $.65 per net 10^6BTU supplied.

TRANSFLUX International Limited

TABLE 8.3-IV

PIPING HEAT LOSS SCHEDULE
10^6 BTU PER ANNUM

	DIA	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007-11	TOTAL
BERRY'S CREEK	12"	206																							206
	10"	954	298	298																					1550
	8"	149																							149
	4"	420	57	57	191	76	57	57																	915
	3"	17																							17
	2"	204	25	13	204	51	38	38																	573
	1-1/2"	146			146	24	24	25																	365
HARMON MEADOWS	10"		835	686	328																				1849
	8"			173	173	645																			991
	6"		595	480	457	275																			1807
	4"			115	134	134	115	38																	670
	3"					17																			17
	2"		102	128	230	255	25	102																	842
	1-1/2"						24	12																	36
JERSEY CITY	10"		417		388		417		388	417		388		805		805		805		805		417		388	6440
	8"		248		273		248		273	248		273		520		520		520		520		248		273	4164
	4"		1261	917	1950	2867	2065	1223	917	2485	917	1950	2867	3326	2141	2867	4090	3326	2485	2867	4090	2065	1223	2141	50040
	2"		268	191	421	612	651	395	293	651	191	421	600	919	587	715	995	919	587	715	995	651	395	689	12861
NEWARK	10"													417		805		1193		1610		1610		2415	8050
	8"													248		520		793		1041		1041		1561	5204
	4"													1319	975	3364	3995	5467	5276	6442	6556	6442	6556	18599	64991
	2"													268	344	727	1097	1378	1633	1786	1978	1786	1978	5844	18819
TOTAL-INCREMENTAL		2096	4106	3058	4895	4956	3683	1967	1909	3801	1108	3032	3467	7822	4047	10323	10177	14401	9981	15786	13619	14260	10152	31910	180556
TRANSMISSION	42"																				18405				18405
	36"																		33685						33685
	30"																	2158							2158
	24"		1790				596							2685											5071
	20"				1540									3985			6908			2390				1594	18011
	16"				9302		5344																		14646
TOTAL-INCREMENTAL		2096	5896	3058	15737	4956	9673	1967	1909	3801	1108	3032	3467	14492	4047	10323	17085	18153	43666	18176	32024	14260	10152	33504	272532
-ACCUMULATIVE		2096	7992	11050	26787	31743	41366	43333	45242	49043	50151	53183	56650	71142	75189	85512	102597	120750	164416	182592	214616	228876	239028	272532	

TRANSFLUX international limited

TABLE 8.3-V

PUMPING COST SCHEDULE
$1000 PER ANNUM

	DIA	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007-11	
PIPING																									
BERRY'S CREEK	12"	3.90																							
	10"	6.40																							
	8"	1.80																							
	4"	4.60	.60	.60	2.10	.80	.60	.60																	
	3"	.07																							
	2"	.35	.04	.02	.35	.09	.07	.07																	
	1-1/2"	.08		.09	.01	.02	.01	.02																	
HARMON MEADOWS	10"		6.16	5.06	2.42																				
	8"			2.10	2.10	7.80																			
	6"		3.90	3.15	3.00	1.80		.30																	
	4"			1.26	1.47	1.47	1.47	1.26																	
	3"					.06																			
	2"		.18	.22	.40	.44	.05	.18																	
	1-1/2"						.01	.01																	
JERSEY CITY	10"		3.08		2.86		3.08		2.86	3.08		2.86		5.94		5.94		5.94		5.94		3.08		2.86	[illegible]
	8"		3.00		3.30		3.00		3.30	3.00		3.30		6.30		6.30		6.30		6.30		3.00		3.30	[illegible]
	4"		13.86	10.08	21.42	31.50	22.68	13.44	10.08	27.30	10.08	21.42	31.50	36.54	23.52	31.50	44.94	36.54	27.30	31.50	44.94	22.68	13.44	23.52	54
	2"		.46	.33	.73	1.06	1.12	.68	.51	1.12	.53	.73	1.03	1.58	1.01	1.23	1.72	1.58	1.01	1.23	1.72	1.12	.68	1.19	[illegible]
NEWARK	10"													3.08		5.94		8.80		11.88		11.88		17.82	[illegible]
	8"													3.00		6.30		9.60		12.60		12.60		18.90	[illegible]
	4"													14.49	10.71	36.96	43.89	60.06	57.96	70.77	72.03	70.77	72.03	204.33	7
	2"													.46	.59	1.25	1.89	2.37	2.81	3.08	3.41	3.08	3.41	10.80	[illegible]
TOTAL-INCREMENTAL		17.20	31.28	22.91	40.16	45.04	32.09	16.56	16.75	34.50	10.41	28.31	32.53	71.39	35.83	95.42	92.44	131.19	89.08	143.30	122.10	128.21	89.56	282.00	160
	42"																				412.00				41
	36"																		753.20						7
	30"																	57.50							[illegible]
	24"		31.50				10.50							47.25											[illegible]
	20"				30.45									78.75			136.50	31.50		47.25				31.50	35
	16"				169.20		97.20																		26
TOTAL-INCREMENTAL		17.20	62.78	22.91	239.81	45.04	139.79	16.56	16.75	34.50	10.41	28.31	32.53	197.39	35.83	95.42	228.94	220.19	842.28	190.55	532.10	128.21	89.56	313.50	354
HEATEXCHANGERS																									
-FIRED HEATERS		10.00	15.00	5.00						5.00		5.00		11.00		16.00	12.00	11.00		12.00		12.00		6.00	12
-POWER PLANT HX'S					25.00				50.00	35.00									45.00	45.00	10.00	20.00	20.00	10.00	26
-HEAT RECOVERY HX'S																					40.00	40.00	40.00	40.00	16
-IN-HOUSE(USER)HX'S		31.50	35.10	41.40	40.50	43.65	50.85	29.25	27.00	22.50	11.25	18.00	29.25	54.00	51.75	76.50	94.50	108.00	105.75	121.50	130.50	155.25	99.00	285.75	166
TOTAL-INCREMENTAL		58.70	112.88	69.31	305.31	88.69	190.64	45.81	93.75	97.00	21.66	51.31	61.78	262.39	87.58	187.92	335.44	339.19	993.03	369.05	714.60	355.46	248.56	655.25	574
-ACCUMULATIVE		58.70	171.58	240.89	546.20	634.89	825.53	871.34	965.09	1062.09	1083.75	1135.06	1196.84	1459.23	1546.81	1734.73	2070.17	2409.36	3402.39	3771.44	4486.04	4841.50	5090.06	5745.31	

The operation of the fully developed system, consisting of a heating plant at Hudson G.S., a retrofitted gasturbine at Kearny and 11 heater plants scattered over the supply territory will require an organization of 105 people. This estimate is based on the assumption that none of the heater plants will be permanently manned. Roving crews of operators/maintenance men will be kept on constant radio call. On the other hand, the plant at Hudson G.S. will have its round-the-clock attendance. The requirements on that basis are as follows:

Plant operators -		
Hudson G.S. facility - 3 shift	12	
11 heating plants, 2 x 3 men crews/shift	24	
crew supervisor (licensed) 1/shift	5	
shift supervisor	5	
load dispatcher	5	51
	--	
Maintenance -		
all shifts - 3/shift	12	
day shift (additional)	5	
storekeeper	5	
supervisor	1	23
	--	
Billing -		
meter readers	3	
bookkeepers	3	
accountants	3	
comptroller	1	10
	--	
Engineering -		
engineers - mech.	3	
- civil	1	
- electrical	1	
draftsmen	3	
gov. liaison, permits	1	
in-house liaison	1	
manager	1	11
	--	

Bal. fwd.		95
Management -		
Pres., treasurer, secretary	3	
chief eng., purch. manager,	2	
clerical	5	10
	--	---
Total personnel		105

Again the cost of this is included in the economic cost calculations using the standard wage rates and overhead experience for the rest of PSE&G's personnel.

Maintenance and other costs are rough estimates, since there is no U.S. experience with this kind of heating system. European experience is applicable only to a limited extent, particularly during the initial 10-20 years of operation of the system, when little deterioration of plant should be experienced.

Using the values shown in the Phase I report and escalated for the three years elapsed, the total system annual maintenance cost is estimated to be $2,000,000 for plants, transmission and distribution and $120,000 per year for customer conversion equipment. These are mostly material cost, since labor cost is already included with the personnel costs.

The total $2,120,000 annual cost averages $.25 per million BTU net supplied for the fully developed system.

Other costs, as general overhead, cost of capital during construction, taxes, permits, etc. are all dealt with in the Economics section.

COST ESTIMATES

The conceptual plan and development schedule for the various district heating scenarios were developed by Transflux International Ltd., an energy and district heating consultant firm, in cooperation with PSE&G and other subcontractors. Transflux developed the conceptual designs and layouts for the local heater plants and the Kearny 12 gas turbine retrofit. The Hudson No. 2 full, staged and limited retrofit conceptual designs were developed by Transflux, Stone and Webster, and PSE&G. Stone and Webster then developed capital cost estimates for the local heater plants, the intermediate plant (Kearny No. 12) and the full, staged and limited retrofits of Hudson No. 2. These cost estimates (except for the limited retrofit) were then reviewed by the PSE&G Engineering Department, which increased them as shown in Table 7-I. The large change in the Hudson retrofit cost reflects differences in engineering design philosophy regarding specifications, contingencies and field overheads.

The cost of natural gas service and landfill gas transport pipeline were estimated by the PSE&G Gas Transmission and Distribution Department which has extensive experience in underground gas line design and construction.

The landfill gas supply cost estimate was prepared by PSE&G R&D Department personnel engaged in the design, construction and commercial operation of similar landfill gas recovery systems presently operating and under development.

The foregoing cost estimates are summarized in Table 7-I.

Conceptual designs for the customer conversion packages (interfaces), which convert the district heating system hot water into the thermal services (e.g. space heating and domestic hot water) needed by the customer, were developed by Transflux and Stone & Webster, and costed by Stone and Webster. These designs and cost estimates are shown in Table 7-II. Stone and Webster also estimated costs of heat metering, given in Tables 7-IV and 7-V.

DISTRICT HEATING LANDFILL GAS SUPPLY

Capital Expenditures by Years

		1983 $
1984		$2,550,000
1985		1,570,000
1986		755,000
1987		410,000
1988		860,000
1989		175,000
1990		290,000
1991		410,000
	Total	$7,020,000

TABLE 7-1

CAPITAL COST ESTIMATES
HEAT SUPPLY

DESCRIPTION	Cost Estimate (Million $)	
	Stone & Webster	PSE&G
Local Heater Plants (1981$) (each)	4.0	4.4
Intermediate Plant (Kearny 12) (1981$)	8.2	10.0
Full Hudson 2 Retrofit (1981$) ($1.6 \times 10^9$ BTU/hr)	43.0	80.0
Partial Hudson Retrofit (200×10^6 BTU/hr)		
Original Estimate (1981$)	6.2	-
Alternate I (1982$)	6.6	-
Alternate II (1982$)	5.9	-
Alternate III (1982$)	4.9	-
Natural Gas Service (1981$) (each heater plant)	-	0.06
Landfill Gas Supply (1983$)	-	7.0
Landfill Gas Pipeline (1981$) (7000 ft., 7.8×10^6 ft^3/day)	-	0.7

TABLE 7-II

CAPITAL COST ESTIMATES

Customer Conversion Units (1981$)

Description	Unit Cost (1)*	Sq. mi. in Newark	Sq. mi. in Jersey City
Multi-Family Dwelling (4 units, 136×10^3 BTU/hr, peak)	$ 3,000	–	–
Multi-Unit Apartment House (100 units, 2×10^6 BTU/hr, peak)	14,000	(1)x80 = 1,120,000	(1)x65 = 910,000
Block of Multi-Family Houses (1.2-1.4 $\times 10^6$ BTU/hr, peak)	10,600	(1)x85 = 901,000	(1)x75 = 795,000
	TOTALS	$2,021,000	$1,705,000

*Stone & Webster, reviewed and accepted by PSE&G Customer & Marketing Dept.

TABLE 7-IV

COST ESTIMATES

District Heating Capital Related		Estimated Cost*
		$
Boilers		
50x10^6BTU/hr		1,100,000
60x10^6BTU/hr		1,320,000
Hudson #2 Retrofit		
Partial (Phase I)		6,196,000
Phase II		25,093,000
Phase III		48,711,000
Kearny #12 Retrofit		10,000,000
Natural Gas Service		60,000 per heater plant site
Customer Conversion Costs		
Jersey City		5,950/10^6BTU/hr
Newark		5,890/10^6BTU/hr
Berry's Creek & Harmon Meadows		2,700/10^6BTU/hr
Metering Costs		163/10^6BTU (1982$)
Transmission Costs		
Pipe Diameter	Type of Construction	
42"	Right-of-Way	450/ft
36"	Right-of-Way	400/ft
36"	Urban	856/ft
36"	Suburban	697/ft
30"	Urban	718/ft
24"	Right-of-Way	287/ft
24"	Urban	594/ft
20"	Right-of-Way	250/ft
20"	Urban	513/ft
16"	Right-of-Way	200/ft
Distribution Costs		
Jersey City Plants 1 & 3		97,959/10^6BTU/hr
Jersey City Plants 2 & 4		59,950/10^6BTU/hr
Newark		85,274/10^6BTU/hr
Berry's Creek		6,000,000 TOTAL
Harmon Meadows		6,000,000 TOTAL

* All costs are in 1981$ unless otherwise noted.

TABLE 7-V

COST ESTIMATES

District Heating Fuel Related	Estimated Cost*
	$
Production Cost Increase	**
Boiler Fuel	
Natural Gas	$5.80/10*BTU (1984$)
Landfill Gas	$1.00/10*BTU
Operation & Maintenance Related	
Manpower	Various - depending on job responsibilities
Water & chemicals - annual	58/10*BTU/hr peak (1983$)
Materials - annual	59/10*BTU/hr peak (1983$)
Pumping Energy	Various - depending on system size and replacement energy costs.
Landfill	$.10/10*BTU
Conventional System Capital Related	
Boilers	22,000/10*BTU/hr
Natural gas service	6,000/10*BTU/hr
Conventional System	
Natural Gas Cost	6.23/10*BTU (1984$)
Manpower Cost	7,546/10*BTU/hr peak (1983$)
Escalation Rates	
Capital related	8% annually
O&M related (excluding fuel)	8% annually
Fuel	Various - based on PSE&G annual estimates of commonly used fuels

* All costs are in 1981$ unless otherwise noted.
** Calculated annually using PSE&G chronological Production Cost Program

0224K(17).

District heating transmission and distribution (T&D) costs were estimated as follows: (1) Stone and Webster obtained the material cost of the prefabricated piping by averaging, for each pipe diameter, cost data obtained from eight (8) manufacturers of district heating pipe, (2) The PSE&G Gas T&D department utilized their recent experience in the contracting and installation of underground gas lines to estimate the installation cost, per foot, of each diameter of pipe for four environments: rural, suburban, urban and "right-of-way" (completely virgin territory, with no interfering utilities or paving, e.g. under an electric transmission line). This latter was the lowest cost environment. These costs were adjusted to account for differences in joining and installing gas and (insulated) district heating pipe, (3) The material and installation costs were added, for each diameter of pipe to give a table of total installed cost, per foot, for each pipe diameter (Table 7-VII). Stone and Webster then used this table and the transmission and distribution conceptual plan and routing layout developed with Transflux and PSE&G to cost the district T&D piping system. The estimates are listed in Table 7-III.

The landfill gas supply system development plan and cost estimate is given in the enclosed tabulation.

Table 7-IV tabulates cost estimates in the form used by the System Planning Department as input to perform the Economic Evaluation.

Labor rates were estimated at PSE&G rates, fuel according to PSE&G Corporate Fuel Price Projections, and escalation according to guidelines used for all other corporate planning. Manpower requirements for the district heating system were estimated by Transflux. Manpower for the conventional (individual boiler) alternative was estimated by typical customer boiler room staffing data obtained from the PSE&G Customer and Marketing Department.

In the course of the current study, visitors from Scandinavia had remarked that the district heating T&D piping cost estimates we had derived were much higher than those in Europe. Recognizing that U.S. construction costs could differ considerably from those in Europe, review of our results was requested from recognized district

TABLE 7-VII

2. INSTALLED CAPITAL COST FOR
PREFABRICATED PIPING SYSTEM
(MATERIAL & LABOR)

Cost in $/100 L.F. of Trench

Pipe Size (Inches)	Right-of-Way* Welded	Rural Welded	Rural Slip JT.	Suburban Welded	Suburban Slip JT.	Urban Welded	Urban Slip JT
1	-	4,600	4,500	9,100	8,700	13,500	12,900
1-1/2	-	4,800	4,700	9,300	8,900	13,700	13,100
2	-	4,900	4,800	9,500	9,100	14,000	13,400
3	-	8,020	-	13,200	-	18,400	-
4	-	8,500	-	14,000	-	19,400	-
6	-	10,900	-	16,800	-	22,700	-
8	-	13,600	-	20,000	-	26,300	-
10	-	17,100	-	24,100	-	31,000	-
12	-	19,600	-	27,100	-	34,600	-
14	-	22,700	-	31,300	-	39,800	-
16	20,000	25,200	-	34,200	-	43,200	-
18	-	26,300	-	40,900	-	45,500	-
20	25,000	31,100	-	41,200	-	51,300	-
24	30,000	36,600	-	48,000	-	59,400	-
30	35,000	45,300	-	58,600	-	71,800	-
36	40,000	53,800	-	69,700	-	85,600	-
42	45,000	60,000	-	78,400	-	96,700	-
48	-	70,200	-	89,300	-	108,300	-

NOTE: 1. The above prices are based upon installing two (2) pipes, per trench. (Supply & Return)

*2. Prices for right-of-way welded pipe were developed using PSE&G Gas T&D Department figures.

TABLE 7-III

DISTRICT HEATING TRANSMISSION AND DISTRIBUTION PIPING
COMPARISON OF COST ESTIMATES FROM VARIOUS SOURCES
MILLIONS OF $(1983 EXCEPT AS NOTED)

				Distribution (1 square mile)		
Source	Transmission	River Crossings	Total	Jersey City	Newark	Urban New Development
Stone&Webster/(1981$) Gas T&D	53.5	7.6	61.2	29.4	30.7	18.0
Danpower (Denmark)	91.4	8.0	99.4	26.0	27.0	17.0
St. Paul Project (Report and information from Hans Nyman, reviewed by M. Kurz)	-	-	-	29 (1) 14 (2)	-	-
Peter Margen (Sweden) Studsvik/FVB)	42.	-	-	* 14. (our pipe lengths) * 6.8 (3)	-	-

*Based on Willmar, MN costs.
N.J. would be 5% higher

(1) St. Paul design had 1.5x the pipe length per square mile and 1.5x the cost, or the same cost per unit length. However, St. paul had 3x the thermal load density as assumed for Jersey City.

(2) Mr. Kurz's rough estimate of reduction possible at higher load density.

(3) Reduced pipe length in accordance with Swedish practice.

heating authorities with experience under both European and U.S. conditions. These were

(1) Mr. Peter Margen, Studsvick FVB. Mr. Margen performed the original study for the St. Paul district heating system.

(2) Mr. Hans Nyman, President of the St. Paul District Heating Company

(3) Danpower Inc., a consortium of Danish district heating consultants

They were given a draft of this report, giving pipe diameters, routing and lengths, but with the price table and costs deleted, and asked to provide independent estimates. All the responses are tabulated in Table 7–III which compares (1) Mr. Margen's T&D piping cost estimates, (2) the original Stone & Webster/Gas T&D estimates from our study, (3) a review of a report and data on the St. Paul system provided by Mr. Hans Nyman and reviewed by Mr. M. G. Kurz, and (4) a review by Danpower Inc. who were given the same information from our study that Mr. Margen had received.

The following conclusions may be drawn:

1. Mr. Margens' transmission cost estimate is roughly in agreement with our study, but the Danpower estimate is nearly twice as high

2. The Danpower distribution cost estimates agree well with our own study, and with the St. Paul data. Mr. Margen's estimates are 1/2 to 1/4 of these.

3. When experts disagree so widely, careful site–specific studies, including quotations from construction contractors, seem needed. Dr. Ishai Oliker (Burns & Roe), the manager of an EPRI–funded district heating study, has noted that slight changes in routing can change piping costs by "a factor of two" thus, "street–specific" estimates and detailed information on subsurface conditions and interferences seem essential in future studies.

The cost of the fully developed system is then estimated (worst case), in terms of 1981-83 dollars, as follows:

		Million $	
11 heater plants		61.6	10.9%
Natural gas service to heater plants		.77	
Kearny #12 retrofit		11.7	2.0%
Transmission lines	59.5		
River crossings	8.5	68.0	11.8%
Hudson retrofit		93.3	16.3
Distribution			
New developments	40.0		
Jersey City	131.5		
Newark	136.5	308.0	53.5%
Sub-total		543.37	94.5
Landfill gas & distr.		7.7	1.3
		551.07	95.8
Customer conversion			
New Developments	N/A		
Jersey City	9.5		
Newark	14.0		
Metering	.63	24.13	4.2
Cost total system		575.20	100.0

When consideration is given to the 25 year span this program is planned for, the cost of the investment in current dollars will be $2,335 million.

As a comparison, the conventional boiler plants in the individual buildings would cost $72.6 million in 1983 dollars and $344 million in current dollars over the 25 years.

FINANCIAL CONSIDERATIONS

A detailed study was done by Coopers & Lybrand of ownership and financing options for district heating systems and the tax implications of each option. The Coopers & Lybrand study is made part of Section 5 of this report.

After study of the Coopers & Lybrand list of options, the R&D and System Planning Departments of PSE&G selected the five cases shown in Table 5–I for further study. These included conventional financing of conventional heating and district heating, and tax–exempt, leasing and non–utility status district heating cases.

An analysis of short term financial and rate considerations was made. This analysis is necessary because even the most economic plan in the long run may have short run effects that render it unattractive.

The analysis summarized below was done using corporate modelling techniques. The input to a corporate model consists of all of the year–by–year construction expenditures, operating and maintenance expenses, and various financial data for each plan. The corporate model produces yearly income statements and balance sheets for each plan. The present analysis was conducted for a 10 year period (1984–1993).

Three important results are presented for each plan started:

1. Cost of heat to the customer.
2. Total construction expenditures.
3. Percent of construction expenditures financed internally.

These three results provide a picture of the rate and financial attractiveness of each plan.

The rate and financial analysis was conducted for the fully developed system compared to a conventional system, and for Berry's Creek without Hudson 2 Retrofit compared to a conventional system. In addition, in order to test the effect of various financing schemes, the financing schemes shown in Tabel 5-I were analyzed. Table 5-II shows the financial assumptions employed.

In all cases it is assumed that the heating business would be rate of return regulated with an overall cost of capital of 11.9% as shown in Table 5-II.

Table 5-III shows the results for key financial variables for the period 1984-1993 for the fully developed system. As can be seen, total construction expenditures and percent internally generated funds are most favorable in the conventional system case. In three of the four district heating cases, the average percent internally generated funds is below the Company's target of 50% of capital requirements.

Three important results are presented for each plan studied:

. The reduction of interest expense in the tax-exempt case is more than offset by the increase in taxes; thus, internally generated funds and net cash flow are reduced relative to the district heating base case.

. Exclusion of Gross Receipts and Franchise Tax and shorter tax lives in the non-utility status case serve to improve both cash flow and cost relative to the district heating base case.

. The approximate 10% reduction in capital investment in the lease case is almost entirely offset by a combination of the reduction in depreciation and ITC tax benefits and their respective accruals and the increase in O&M expense due to the least payment. The net effect is financial performance very similar to the district heating base case with little effect on average cost.

However, the conclusion of the financial analysis is that while the financing plan has an effect on the average cost to PSE&G of providing heat,

TABLE 5-I

FULLY DEVELOPED SYSTEM
DESCRIPTION OF CASES

Conventional Heating	• Conventional financing • Rate of return regulated
District Heating Base	• Conventional financing • Rate of return regulated
District Heating Tax-Exempt	• Distribution plant financed with Industrial Development Bonds (IDB) @ 7.5% • Straight line depreciation of distribution plant over the ACRS tax life • Remaining capital conventionally financed • Rate of return regulated
District Heating Lease	• Heater plant leased at an annual payment of 11.3% of capital cost • Total investment reduced by heater plant capital investment • Remaining capital conventionally financed
District Heating Non-Utility Status	• No gross receipts and franchise tax • All plant depreciated over five years for tax purposes

TABLE 5-11

DISTRICT HEATING ANALYSIS
FINANCIAL ASSUMPTIONS

Long Term Cost of Capital (All Cases)

	Ratio	Cost	Weighted Cost
Debt	43%	10.5%	4.5%
Preferred Stock	12	9.5	1.1
Common Stock	45	14.0	6.3
Total	100%		11.9%

District Heating Tax-Exempt Case - Distribution plant financed with 7.5% industrial development bonds.

District Heating Lease Case - Heater plant leased at an annual payment of 11.3% of capital cost.

TABLE 5-III

FULLY DEVELOPED SYSTEM 1984-1993

	Average Price of Heat		Total Construction Expenditures		% Internal Generation	
Case	$/mBtu	Rank	$Million	Rank	%	Rank
Conventional System	27	1	27	1	77	1
Dist. Heating Base	42	4	199	3	43	3
Dist. Heating Tax-Exempt	40	3	199	3	37	5
Dist. Heating Lease	42	4	172	2	42	4
Dist. Heating Non-Utility	36	2	199	3	52	2

it has a small effect on overall financial performance, as shown in Table 5–III.

Table 5–IV shows the price of heat to the customer from the total system ($3.7x10^9$ BTU/hr) for the first ten years of the study period. The extremely high first year costs for the district heating scenarios are artefacts of heavy front–end capital loading of district heating. They could be moderated by capitalization of first year interest charges or by long–term contracts with customers to level out costs and allow competitive prices from the beginning.

Table 5–IV shows only the district heating non–utility status case as developing a significant cost advantage over conventional heating. Since thermal sales would increase from $35x10^9$BTU/yr in 1984 to $1691x10^9$BTU/yr in 1993, the cost advantage of option (5) later in the study period is applied to a higher volume of sales than the earlier cost disadvantage. Figure 4.2 shows the cumulative cost difference (undiscounted) between district heating and conventional heating. A BTU–weighted price is more informative than an un–weighted year–by–year price average.

A possible combination of the district heating tax exempt and lease cases is possible, which would involve IDB tax exempt financing of distribution with leasing of the heater plant. This combination, not examined in the analysis, might perform slightly better than either of its components alone.

As was the case in the economic analysis, district heating at Berry's Creek is more attractive than for the fully developed system. As shown in Table 5–V, internal generation of funds, while lower for the district heating alternative, is still well above acceptable levels. Although the 10 year total expenditure of $26 million is four and one–half times higher than the conventional plan, it is still a relatively modest amount.

TABLE 5-IV

DISTRICT HEATING (TOTAL SYSTEM)
1984-1993
PRICE OF HEAT
($/mBtu)

Year	(1)	(2)	(3)	(4)	(5)
1984	13.89	106.24	104.76	108.39	92.35
1985	20.44	42.40	40.94	40.45	36.87
1986	22.11	33.99	32.15	33.93	29.17
1987	24.03	31.62	29.43	29.32	26.77
1988	25.70	32.88	30.39	31.61	27.56
1989	27.56	31.54	28.77	30.95	26.13
1990	29.79	32.46	29.44	31.98	26.70
1991	32.19	33.28	30.16	33.01	27.28
1992	34.85	36.36	33.19	36.24	29.77
1993	37.60	41.00	37.77	41.11	33.50

(1) Conventional Heating System
(2) District Heating - Base Case
(3) District Heating - Tax-Exempt
(4) District Heating - Lease
(5) District Heating - Non-Utility Status

Comparison of Total District Heating System
with Conventional Heating

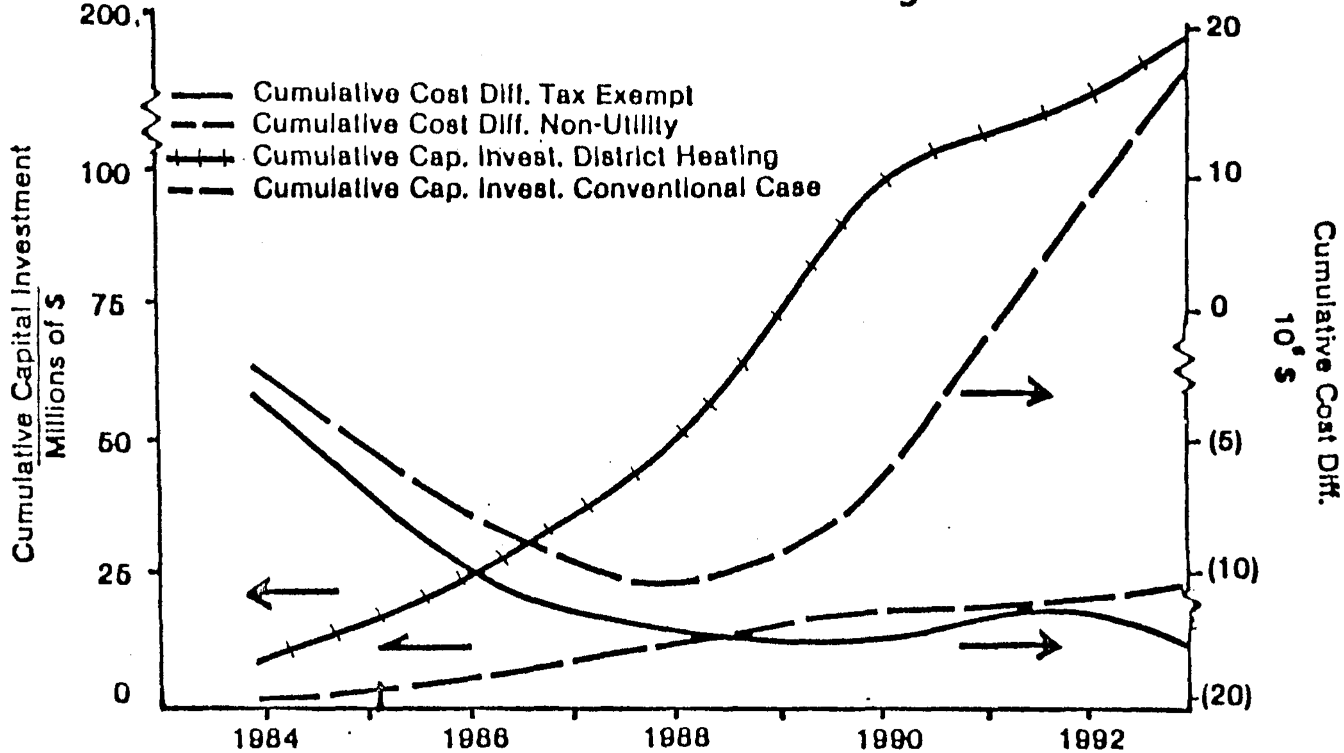


FIG. 4.2

TABLE 5-V

BERRY'S CREEK
WITHOUT HUDSON RETROFIT (WITH LANDFILL GAS)
1984-1993

Case	Average Price of Heat		Total Construction Expenditures		% Internal Generation	
	$/mBtu	Rank	$Million	Rank	%	Rank
Conventional System	26	2	6	1	83	1
District Heating	22	1	26	2	72	2

Table 5–VI shows a comparison of prices of heating for the conventional and district heating cases. While the pattern of these price projections is the same as the fully developed system, the district heating system becomes cheaper in a much shorter period of time, four years, and even the unweighted average price in the district heating system is cheaper over the 10 year period. The BTU–weighted average price would be even more favorable to district heating.

In summary, the financial analysis described above shows that a relatively small scale district heating project at Berry's Creek is worthy of further consideration, while the fully developed system is financially unattractive. These results agree with the economic analysis.

It should be noted that much more detailed financial and rate analyses would be required prior to PSE&G committing funds to a district heating project. The results of the analysis are extremely sensitive to the timing and amounts of construction expenditures, the exact method of revenue regulation, and some of the institutional considerations discussed elsewhere in this report. Such detailed financial analysis is not possible at this time since these considerations are open to considerable variation.

TABLE 5-VI

BERRY'S CREEK
WITHOUT HUDSON RETROFIT (WITH LANDFILL GAS)
1984-1993
PRICE OF HEAT
($/mBtu)

	Conventional	District Heating
1984	10	21
1985	14	22
1986	17	23
1987	21	21
1988	25	20
1989	28	21
1990	28	22
1991	34	23
1992	39	25
1993	43	26

ECONOMIC EVALUATION

An economic evaluation is performed to determine the plan with the lowest overall costs over a period of time. The method of economic evaluation used by PSE&G is based on the Minimum Revenue Requirement Methodology which is widely accepted by utilities throughout the United States.

The comparison was made between various district heating scenarios and their conventional alternate utilizing natural gas fueled boilers located at individual buildings and owned by customers. The conventional system is used as a "benchmark" for comparison purposes. In general, it is the magnitude of the difference between district heating and the conventional alternate that indicates the overall economic merit of district heating. An indication of economic merit does not necessarily reflect the profitability or desirability of district heating from the utility point of view. It must be kept in mind that investments made for a district heating system by an electric utility are for a "venture" which should be viewed differently from investments made to assure safe and reliable electric and gas service.

The evaluation is based on an important criterion: All costs associated with district heating should be covered by the revenues from the district heating customers and no such costs should be passed on to existing electric and gas customers.

The district heating scenarios evaluated and compared with the conventional alternate "base" case, were:

- Berry's Creek
- Berry's Creek with landfill gas
- Berry's Creek with partial Hudson #2 retrofit
- Berry's Creek & Harmon Meadows
  - with Hudson #2 retrofit
  - with Hudson #2 retrofit and landfill gas
- Fully developed system
- Fully developed system with landfill gas

The Levelized Annual Minimum Revenue Requirement (LAMRR) for each of these scenarios is given in Tables 9-I through 9-IV which itemize costs in capital related, fuel related, O&M and GR&FT categories. The percentage of the LAMRR contributed by each cost item is also given. The "bottom-line" savings or penalties from these tables are summarized in the first four columns of Table DS-I.

The scenario for Berry's Creek with a Hudson #2 retrofit (Table 9-I) for 200 x 10^6BTU/hr of steam extraction is about 4% higher in cost than the conventional alternative, which is within the normal accuracy for estimates of this type. They are thus economically equivalent, and there is no economic incentive to choose this district heating scenario. It should be noted that replacement electric power due to the derating of Hudson #2 by steam extraction represents 35% of the LAMRR for this scenario. It should be noted that this derating might be eliminated by operating the Hudson #2 turbine at 5% overpressure and increased throttle flow, a condition never actually used but considered feasible by the turbine manufacturer (Appendix B, paper by G. Kan and G. Silvestri). If feasible, this approach would make this district heating scenario appear economically more favorable.

The Berry's Creek scenario without a Hudson #2 retrofit (Table 9-II) has an LAMRR 22% lower than that of a conventional system when the district heating fuel is natural gas, and 34% lower when landfill gas is the base-load district heating fuel. It thus appears that this district heating scenario has an economic advantage over a conventional system, even considering some normal uncertainties in the cost estimates.

The scenario considering Berry's Creek plus Harmon Meadows with a partial retrofit of Hudson #2 (Table 9-III) is really equivalent to the combination of (Berry's Creek with Hudson #2 partial retrofit) and (Berry's Creek without Hudson #2 partial retrofit), with an added connecting hot water line between the two developments. This is because the landfill gas supply and the Hudson #2 partial retrofit have the same peak capacities as in the earlier scenarios, and Harmon Meadows and

TABLE 9-I

LEVELIZED ANNUAL MINIMUM REVENUE REQUIREMENTS
FOR BERRY'S CREEK WITH A PARTIAL HUDSON #2 RETROFIT
1983 $X10[3]

Capital Related	District Heating		Conventional	
	$	%	$	%
Boilers	663	5	531	4
Hudson #2 Retrofit	829	6		
Natural Gas Service	8	-	145	1
Customer Heat Exchangers	142	1		
Metering	4	-		
Transmission	763	6		
Distribution	725	6		
Fuel Related				
Increased Electric System Production Costs	4,569	35		
Natural Gas	2,406	19	9,286	75 (1)
O&M Costs				
Manpower	657	5	2,485	20
Pumping Energy	405	3		
Materials	250	2		
Gross Receipts and Franchise Taxes	1,485	12	0	0 (2)
Total	12,906	100	12,447	100
Savings (Penalties)	(459)			

(1)Based on LVG rate which includes GR&FT
(2)GR&FT is included in fuel price

TABLE 9-II

LEVELIZED ANNUAL MINIMUM REVENUE REQUIREMENTS
FOR BERRY'S CREEK WITHOUT A HUDSON #2 RETROFIT
(1983$ x 10^3)

Capital Related	District Heating Without Landfill Gas		District Heating With Landfill Gas		Conventional	
	$	%	$	%	$	%
Boilers	805	8	805	10	531	4
Natural Gas Service	8	-	8	-	145	1
Customer Heat Exchangers	142	1	142	2		
Metering	4	-	4	-		
Distribution	725	7	725	9		
Landfill Collection & Transmission	-	-	1,001	12		
Fuel Related						
Natural Gas	5,630	58	1,351	16	9,286	75(1)
Landfill Gas Royalties	-		1,001	12		
O&M Costs						
Manpower	657	7	736	9	2,485	20
Pumping Energy	366	4	366	4		
Materials	250	3	250	3		
Additional Costs Associated With Landfill	-		914	11		
Gross Receipts and Franchise Taxes	1,116	12	949	12	0	0(2)
Total	9,703	100	8,252	100	12,447	100
Savings (Penalties)	2,744		4,195			

(1)Based on LVG rate which includes GR&FT
(2)GR&FT is included in fuel price

TABLE 9-III

LEVELIZED ANNUAL MINIMUM REVENUE REQUIREMENTS
FOR BERRY'S CREEK AND HARMON MEADOWS
WITH HUDSON #2 RETROFIT
(1983 $ x 10^3)

Capital Related	District Heating Without Landfill Gas $	District Heating Without Landfill Gas %	District Heating With Landfill Gas $	District Heating With Landfill Gas %	Conventional $	Conventional %
Boilers	1,283	5	1,283	6	1,912	7
Hudson #2 Retrofit	829	3	829	4		
Natural Gas Service	15	-	15	-	282	1
Customer Heat Exchangers	277	1	277	1		
Metering	7	-	7	-		
Transmission	1,093	5	1,093	5		
Distribution	1,428	6	1,428	7		
Landfill Collection & Transmission	-		1,184	5		
Fuel Related						
Increased Electric System Production Costs	8,767	37	6,008	28		
Natural Gas	5,394	23	2,493	12	19,125	74(1)
Landfill Gas Royalties			1,441	7		
O&M Costs						
Manpower	706	3	706	3	4,741	18
Pumping Energy	792	3	792	4		
Materials	472	2	472	2		
Additional Costs Associated With Landfill	-		1,027	5		
Gross Receipts and Franchise Taxes	2,738	12	2,477	12	0	0(2)
Total	23,801	100	21,532	100	26,060	100
Savings (Penalties)	2,259		4,528			

(1)Based on LVG rate which includes GR&FT
(2)GR&FT is included in fuel price

Berry's Creek have equivalent thermal loads. Not surprisingly, this combined scenario shows savings intermediate between those of the two earlier scenarios of which it is composed: 9% savings without and 17% with landfill gas.

The fully developed district heating system of 3.7 x 10^9BTU/hr peak output (Table 9–IV), comprising Berry's Creek, Harmon Meadows and portions of Newark and Jersey City is examined in Table 9–IV. It has an LAMRR 4% higher than the conventional system, which changes to 2% higher when landfill gas is used. These differences are within the normal accuracy of the estimates. This district heating scenario is thus economically equivalent to the conventional system. There is thus no economic incentive to build this extensive system.

Table 9–IV shows that replacement electric power is 14–16% of the LAMRR for the fully developed district heating scenario. This is a result of derating a base-loaded, coal fired unit and replacing the generation lost with more expensive oil-fired generation. Table 9–IV also shows that hot water transmission (6%) and distribution (21–22%) comprise the largest cost item in the district heating scenarios. If innovative technology could reduce the installed cost of district heating piping, the economic picture could change.

There is only limited American experience in retrofitting a large existing generating unit, such as Hudson #2, and each generating unit tends to be quite unique. Therefore, a sensitivity analysis was performed primarily to assess the impact of varying these retrofit costs on the study results.

For the sensitivity analysis, the original cost estimate for the Hudson retrofit was reduced by 50%, the Kearny #12 retrofit estimate reduced by 20%, and the package boiler estimates by 10%. The sizes of these cost reductions reflect the relative uncertainty of each item.

Table 9–V shows the range of capital costs used for evaluating sensitivity.

TABLE 9-IV

LEVELIZED ANNUAL MINIMUM REVENUE REQUIREMENTS
FOR FULLY DEVELOPED DISTRICT HEATING SYSTEM
(1983 $X10^3)

	District Heating Without Landfill Gas		District Heating With Landfill Gas		Conventional	
Capital Related	$	%	$	%	$	%
Boilers	5,426	6	5,426	6	3,978	4
Hudson #2 Retrofit	7,569	8	7,569	8		
Kearny Retrofit #12	835	1	835	1		
Natural Gas Service	61	-	61	-	1,622	2
Customer Heat Exchangers	1,590	2	1,590	2		
Metering	42	-	42	-		
Transmission	5,415	6	5,415	6		
Distribution	20,274	21	20,274	22		
Landfill Collection and Transmission			788	1		
Fuel Related						
Increased Electric System Production Costs	15,279	16	12,973	14		
Natural Gas	13,394	14	10,454	11	67,407	75
Landfill Gas Royalties			1,846	2		
O&M Costs						
Manpower	8,245	9	8,245	9	16,932	19
Pumping Energy	2,988	3	2,988	3		
Materials	1,688	2	1,688	2		
Additional Costs Associated With Landfill			1,237	1		
GROSS RECEIPTS AND FRANCHISE TAXES	10,765	12	10,586	12	0	0(2)
TOTAL	93,571	100	92,017	100	89,939	100
SAVINGS (PENALTIES)	(3,632)		(2,078)			

(1) Based on LUG Rate which includes GR&FT
(2) GR&FT is included in fuel price

TABLE 9-V

RANGE OF CAPITAL COSTS USED IN SENSITIVITY ANALYSIS
1981 $\$10^3$

	LOW ESTIMATE	BASE ESTIMATE
Package Boilers 50×10^6 Btu/hr	990 each	1,100 each
Package Boilers 60×10^6 Btu/hr	1,188 each	1,320 each
Total Cost of Boilers	47,520	52,800
Hudson Retrofit		
Stage 1 (Partial)	6,196	6,196
Stage 2	11,494	25,093
Stage 3	22,310	48,711
Total Cost of Hudson Retrofit	40,000	80,000
Kearny #12 Retrofit	8,000	10,000
Total Capacity Costs of Thermal Supplies	95,520	142,800

As shown in Table 9–VI for the district heating system using the reduced capital costs, the LAMRR for the case without landfill gas is nearly equal to that for the conventional system. Comparing Tables 9–IV and 9–VI, it can be seen that the LAMRR for district heating changes from a previous $3,632,000 penalty to a $1,048,000 savings, when the reduced capital costs are used in place of the original estimates. The LAMRR savings in this case for district heating is about 1%. If landfill gas is used, the LAMRR for district heating changes from a $2,078,000 penalty to a $2,601,000 savings, or about 3% of the LAMRR of the conventional system.

It can be concluded that uncertainties of the capital cost estimates for thermal supplies may change the magnitude of the savings or penalties but will not drastically change the basic economics of a district heating system compared to a conventional system.

The sensitivity of the Berry's Creek or the Berry's Creek plus Harmon Meadows scenarios to variations in the capital costs would be even smaller, since both scenarios are supplied primarily by package boilers and only a partial retrofit of Hudson #2.

A simplistic sensitivity analysis was performed in which the total system (3.7×10^9 BTU/hr) was considered, with the assumption that the Newark and Jersey City load areas were comprised entirely of new developments, with lower distribution system costs than normal urban areas and with 100% (displaced) new boilers in the conventional alternative. Transmission routing and costs were not modified, and potentially higher boiler efficiencies available to new construction were not included. The result showed district heating improved only about 5% relative to the conventional alternative, and still within the "error band" of the analysis. It does suggest, however, that limiting district heating to new developments may improve the overall economics.

The Gross Receipts and Franchise Tax (GR&FT) adds 13% to utility bills in New Jersey and, under present law, would do so to district heating.

TABLE 9-VI

LEVELIZED ANNUAL MINIMUM REVENUE REQUIREMENTS
FOR FULLY DEVELOPED DISTRICT HEATING SYSTEM
BASED ON LOW RANGE OF ESTIMATES
(1983 $X10³)

CAPITAL RELATED	District Heating Without Landfill Gas $	%	District Heating With Landfill Gas $	%	Conventional $	%
Boilers	4,933	6	4,933	6	3,978	4
Hudson #2 Retrofit	4,068	4	4,068	5	-	
Kearny Retrofit #12	688	1	688	1	-	
Natural Gas Service	61	-	61	-	1,622	2
Customer Heat Exchangers	1,590	2	1,590	2	-	
Metering	42	-	42	-	-	
Transmission	5,415	6	5,415	6	-	
Distribution	20,274	23	20,274	23	-	
Landfill Collection and Transmission			788	1	-	
FUEL RELATED						
Increased Electric System Production Costs	15,279	17	12,973	15		
Natural Gas	13,394	15	10,454	12	67,407(1)	75
Landfill Gas Royalties			1,846	2		
O&M Costs						
Manpower	8,245	9(2)	8,245	9	16,932(2)	19
Pumping Energy	2,988	3	2,988	3		
Materials	1,688	2	1,688	2		
Additional Costs Associated With Landfill			1,237	1		
GROSS RECEIPTS AND FRANCHISE TAXES	10,226	12	10 048	12	0(3)	0
TOTAL	88,391	100	87,338	100	89,939	100
SAVINGS (PENALTIES)	1,048		2,601		-	

(1) Based on LVG Rate which includes GR&FT
(2) District heating system requires 105 men when fully developed. Conventional system requires 400 men when fully developed.
(3) GR&FT is included in fuel price.

The situation of district heating is however different from that of other utilities in that it is a new service in New Jersey, striving to compete with entrenched competitive (conventional heating) systems, while other utilities are subject to a much smaller degree of competition (or none).

The last two columns of Table DS–I show that the removal of the GR&FT charge makes all district heating scenarios attractive, with savings over the conventional alternative ranging from 8% to 41%. In some cases, GR&FT can tip the balance in the decision whether to building a district heating system. In such cases, discussions with State regulatory and legislative bodies might be appropriate to find a way to maximize potential benefits to the State and its citizens, since a district heating system that is not built, provides no economic benefits or tax revenues. In the case of the Trenton (TDEC) system now under construction, regulatory accommodations were a facilitating factor. TDEC does not charge its customers GR&FT, and is not currently subject to regulation.

While the district heating system is capital intensive, the conventional system is fuel cost intensive. Fuel accounts for 75% of the conventional system LAMRR compared to only 31% for the fully developed district heating system. Recent drops in fuel price estimates for the future are indicative of the uncertainties that exist, and they are generally beyond the influence of a utility. Political effects, OPEC pricing policy, the extent of conservation impact, etc. are only a few of the items that could alter fuel prices.

Since the trend in the past year or two has been toward lower price escalation projections, a sensitivity analysis was performed using a 1% per year reduction in all fuel price projections starting in 1985. In effect, the 1984 fuel prices were held constant, 1985 price projections were reduced by 1%, 1986 price projections by 2%, etc. through the endpoint of 2011.

Secondary effects of lower fuel prices, such as reduced inflation, were not considered althrough the cost of hot water pumping energy was reduced to account for

TABLE DS-I

MINIMUM REVENUE
REQUIREMENTS
1983 \$ X 10^3

SCENARIO	Base Conventional \$	Savings (penalty) over base incl. GR&FT \$	%	w/o GR&FT \$	%
Berry's Creek	12447	2744	22.0	3860	31.0
Berry's Creek w/landfill gas	12447	4195	33.7	5144	41.3
Berry's Creek w/partial Hudson retrofit	12447	(459)	(3.7)	1026	8.2
Berry's Crrek & Harmon Meadows					
- w/Hudson #2 retrofit	26060	2259	8.7	4997	19.2
- w/Hudson #2 retrofit & landfill gas	26060	4528	17.4	7005	26.9
Fully developed system	89939	(3632)	(4.0)	7133	7.9
- w/landfill gas	89939	(2078)	(2.3)	8508	9.5

the lower price of generating electricity that would result from reduced fuel prices.

Table 9-VII shows the LAMRR for the fully developed district heating system compared to the conventional alternate, using the reduced fuel prices.

A comparison of Tables 9-VII and 9-IV indicate the sensitivity of district heating and its conventional alternate to changes in fuel price escalation.

When the annual escalation rate for all fuels was reduced by 1%, the LAMRR for district heating dropped to about 95% of its previous value, a relatively modest change. The LAMRR for the conventional system drops to about 87% of its previous value, a more significant change.

With lower fuel escalation rates, the LAMRR penalty for district heating increases from $3,632,000 to $9,802,000. This represents an increase in penalty from about 4% to 12% over the conventional system.

The 4% LAMRR penalty, under the basic fuel price assumptions, is relatively small and the full district heating system could be considered as economically equivalent to a conventional heating alternate. If the fuel price escalation rates are reduced, the LAMRR penalty becomes large enough that the full district heating system would definitely be considered as not economically viable.

It can be concluded that the economic comparison of district heating with a conventional alternate is very sensitive to variations in fuel price escalation. Lower fuel cost escalations tend to reduce the viability of district heating while higher fuel prices increase its attractiveness.

TABLE 9-VII

LEVELIZED ANNUAL MINIMUM REVENUE REQUIREMENTS
FOR FULLY DEVELOPED DISTRICT HEATING SYSTEM
WITH A 1% REDUCTION IN ALL FUEL PRICE ANNUAL ESCALATION RATES
(1983 $X10^3)

Capital Related	District Heating Without Landfill Gas $	%	Conventional $	%
Boilers	5,426	6	3,978	5
Hudson #2 Retrofit	7,569	9		
Kearny Retrofit #12	835	1		
Natural Gas Service	61	-	1,622	2
Customer Heat Exchangers	1,590	2		
Metering	42	-		
Transmission	5,415	6		
Distribution	20,274	23		
Fuel Related				
Increased Electric System Production Costs	12,743	14		
Natural Gas	11,886	13	56,097	71
Landfill Gas Royalties				
O&M Costs				
Manpower	8,245	9	16,932	22
Pumping Energy	2,484	3		
Materials	1,688	2		
Additional Costs Associated With Landfill				
GROSS RECEIPTS AND FRANCHISE TAXES	10,173	12	0	0(2)
TOTAL	88,431	100	78,629	100
SAVINGS (PENALTIES)	(9,802)			

(1) Based on LVG Rate which includes GR&FT
(2) GR&FT is included in fuel price

RATES

Basic approaches to rate formulation were established and a Draft Hypothetical Tariff for Thermal Service was formulated by the PSE&G Rates and Load Management Department. This Draft Tariff was submitted to NJ BPU for comment, but no comments were received, despite repeated inquiries. BPU has expressed reluctance to issue hypothetical rulings in the absence of an actual rate case. Rate schedules for various classes of customers would be determined based on the load characteristics and cost of service of each customer class, in a manner analogous to gas and electric service.

The Draft Tariff considers fully metered service with demand and energy charges. Ownership of connecting equipment (customer interface) is not mentioned, but the Economic Evaluation (Section 9) considered it to be utility owned and rolled into the rates. The customer is offered a choice of billing for service as incurred or spread over the year under a "Budget Plan." (See Section 8.10 of Draft Tariff.) No provision was made for utilization of customer equipment, but this could be considered on a site-specific basis where practicable. A discussion of technical aspects of such utilization is given in Section 6.7.4 of this report.

As noted on page 3 of the Tariff, service will be offered to specifically defined areas. Section 2.1 of the Tariff provides that applications for service, where it is not available or where it might adversely affect the supply to other customers, may be rejected. Sections 13.1 through 13.3 of the Tariff provide for limitations or interruption of service due to emergency conditions, and a disclaimer of liability for direct or consequential damages due to such limitations or interruptions. Section 7.2 of the Tariff provides for up to 200 feet of service connection at no cost to the customer, but for customer payment of the cost of any service connection beyond 200 feet.

Cost of service is defined subject to the criterion that all costs associated with district heating shall be covered by revenues from the district heating customers, and no such costs shall be passed on to existing electric and gas customers. Capital costs of the Hudson and Kearny plant retrofits and all specifically district heating-related capital costs are charged to district heating. Fuel costs for district heating local heating plants, replacement electric power, labor, pumping energy and materials are similarly charged to district heating. The following is a list of these expenses.

ALLOCATION OF DISTRICT HEATING COSTS

Capital Related
- Boilers
- Hudson #2 Retrofit
- Kearny #12 Retrofit
- Natural Gas Service
- Conversion Packages
- Metering
- Transmission
- Distribution

Fuel Related
- Increased Electric System Production Costs
- Natural Gas

O & M Costs
- Manpower
- Pumping Energy
- Materials

Gross Receipts and Franchise Taxes

IMPACT ON FUEL USE & ON THE ENVIRONMENT

Fuel Utilization

A major advantage of district heating is the ability to reduce the required amount of fuel to supply the same demand and to substitute low cost fuel such as coal for oil and natural gas. The retrofit of Hudson #2 could supply a significant portion of the thermal demand of a district heating system. The heat supplied by Hudson #2 would come from increased coal consumption at the station, higher overall efficiency and a diversion of energy from electric to thermal production. The reduction in electric generation at Hudson as a result of extracting steam for district heating would require increased output from other generating units, fueled primarily by oil. This increase in oil consumption offsets to a large degree any savings associated with using low cost thermal energy from Hudson #2. Retrofitting Kearny #12 for the recovery of waste heat would have a minimal effect on the electric capability of the unit but could change the number of hours the unit operates. If the unit is required to operate more hours in order to supply thermal energy when it would not operate based on economic dispatch to supply electric demand, there would be some increase in ~~oil~~ fuel consumption at Kearny and some overall operating cost penalties.

PSE&G is a member of the Pennsylvania–New Jersey–Maryland Interconnection (PJM), a power pool covering most of New Jersey, Pennsylvania, Maryland and Delaware, plus the District of Columbia. When conditions permit, the electric output within the pool is normally dispatched based on using the lowest cost generation available without regard to the individual company ownership. The electric energy required to make up for the capacity reduction at Hudson when supplying thermal energy would be the lowest cost energy available over a broad geographic area and not limited to generating units owned by PSE&G. Similarly any generating unit output reductions required to offset increased operation of Kearny #12 to supply thermal load would be the highest cost energy over the same geographic area.

The package boilers are fueled by either natural gas or landfill gas with efficiencies of 83% and 82% respectively for these fuels. These efficiencies compare with a 65% efficiency assumed for individually owned boilers in the conventional system.

The higher efficiency of district heating boilers, due to higher load-factor operation, reduces their fuel consumption as compared to a conventional system.

Although fuel consumption accounts for a major portion of the costs associated with supplying heat, it must be kept in mind that it is the overall economics as well as other considerations and not fuel requirements alone that will determine utility involvement in a district heating system.

Berry's Creek without a Hudson #2 retrofit, Figure 10.1 shows the total natural gas consumption for Berry's Creek district heating system with neither landfill gas nor a Hudson #2 retrofit. compared to a conventional customer owned heating system. The district heating system uses approximately 21% less fuel than a comparable conventional system. The fuel savings is due to the higher efficiency of the district heating boilers compared to customer owned boilers. Thermal distribution system losses are relatively small for the Berry's Creek district heating system and account for only about 1% of the annual energy supplied.

Figure 10.2 shows fuel consumption by type if landfill gas is utilized as a supplemental district heating fuel source. The decrease in landfill gas beginning in 1995 is due to the limited life of this fuel source. Landfill gas has a limited life whether or not it is used, and unless additional new sources can be developed, natural gas will eventually supply the entire load.

Figure 10.3 shows the thermal supplies for the Berry's Creek scenario including a limited retrofit of Hudson #2. The Hudson #2 retrofit is capable of supplying the entire thermal load at Berry's Creek. The boilers are used only for back-up in the event of the unavailability of Hudson #2 due to either forced or planned outages.

BERRYS CREEK FUEL CONSUMPTION WITHOUT LANDFILL GAS

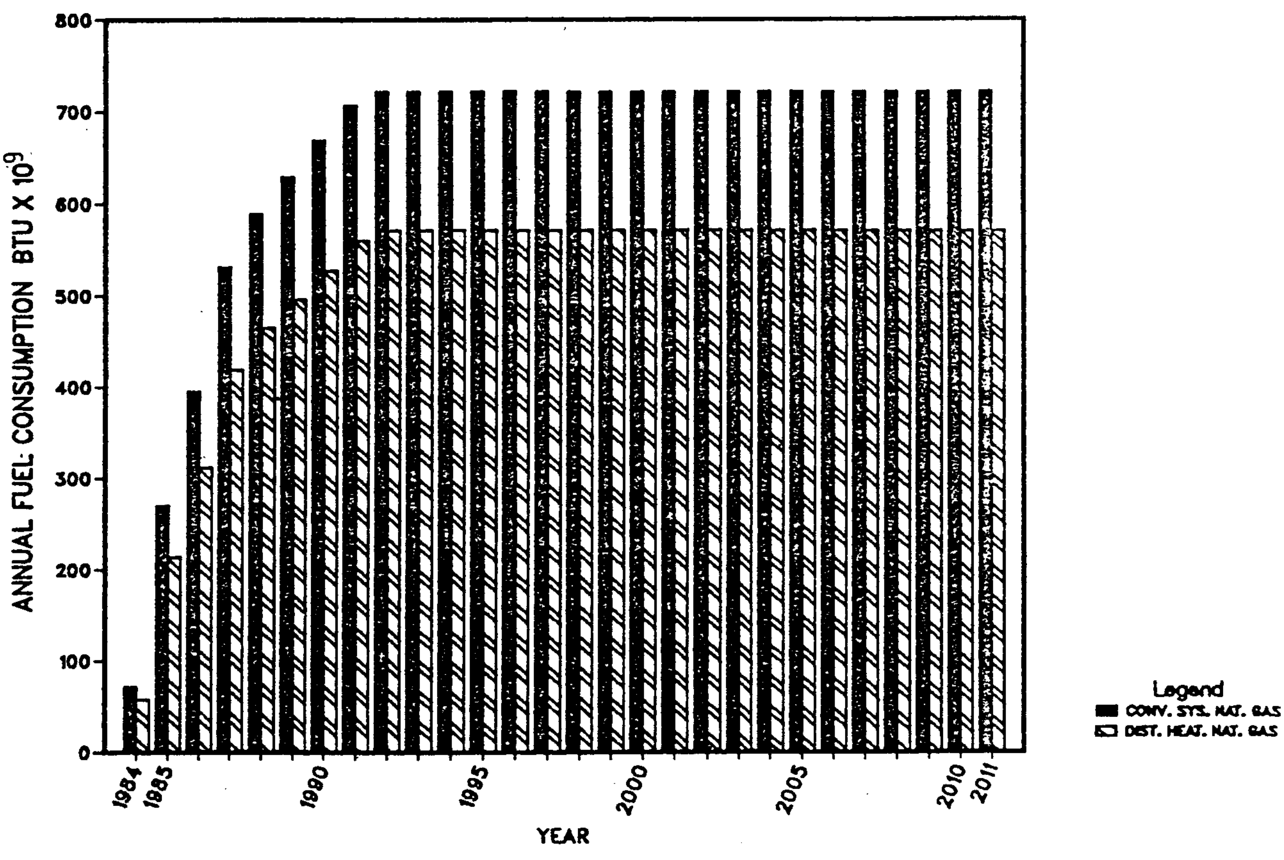


FIG. 10.1

BERRYS CREEK FUEL CONSUMPTION WITH LANDFILL GAS

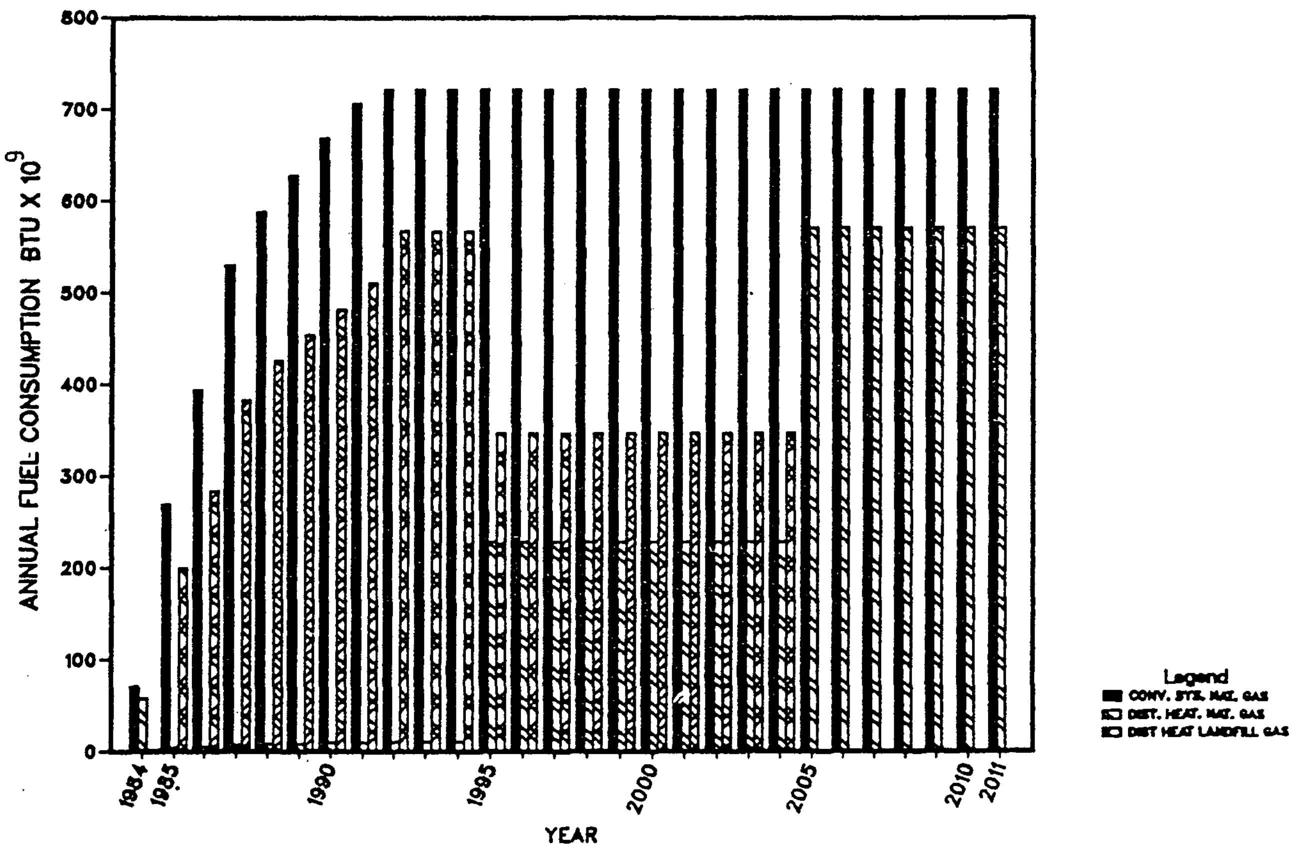


FIG. 10.2

BERRYS CREEK FUEL CONSUMPTION WITH A HUDSON #2 RETROFIT

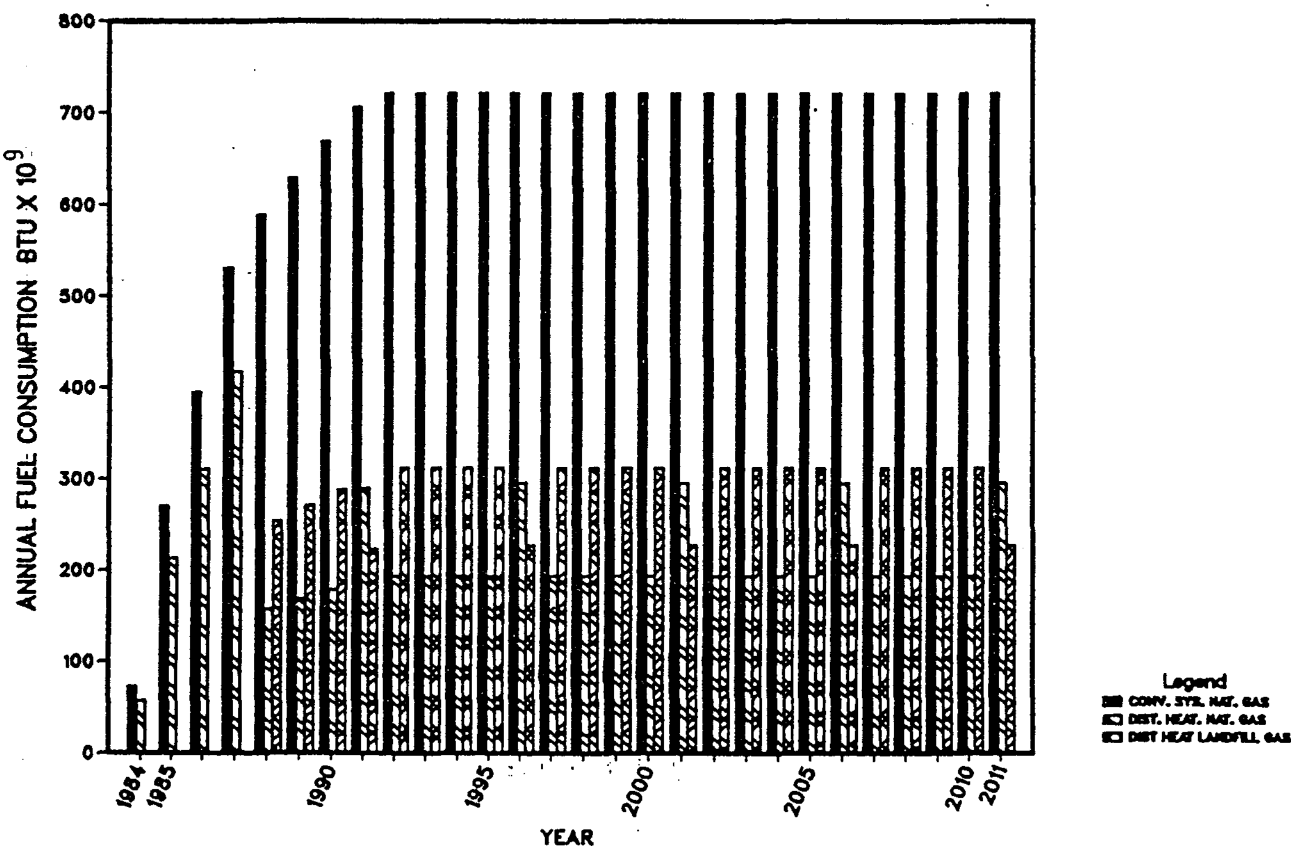


FIG. 10.3

It must be recognized that the thermal energy supplied by Hudson #2 comes, in part, from a reduction in electric capacity that must be made up using other generating units supplied primarily by oil.

Supplying Berry's Creek and Harmon Meadows with centralized package boilers results in fuel requirements as shown on Figure 10.4. If landfill gas is included as a potential district heating fuel source, the fuel requirements will be those shown in Figure 10.5.

The fuel consumption with a partial retrofit of Hudson #2 to supply the thermal energy is shown in Figure 10.6. Again it should be remembered that the thermal energy supplied by Hudson #2 will require a reduction in electric generation that must be replaced by other units fueled primarily by oil.

Figure 10.7 illustrates the various thermal energy sources of the district heating system. The total energy supplied by direct sources in the 1984–2011 period is shown in Figure 10.8. Hudson #2 supplies an impressive 52.7% and Kearny #12 15.9%, giving a total of 68.6% supplied by cogeneration. Considering the fuel required to replace the reduced electric output of Hudson #2, due to district heating, and any fuel use changes associated with operation of Kearny #12, based on district heating demand, the overall fuel consumption by type for district heating is shown on Figure 10.9. It can be seen that better than 75% of the district heating energy is provided directly or indirectly by oil or natural gas, and less than 25% by coal.

These results are for the site specific study based on the PSE&G and PJM planned systems and may not be interpreted for other utilities.

Environmental Impact

Potential environmental effects of district heating are (1) air quality impact due to change in the type and quantity of fuel burned and (2) reduction in thermal discharge to waterways. Heating of the ground by heat losses from district heating

BERRYS CREEK AND HARMON MEADOWS FUEL CONSUMPTION WITH NATURAL GAS

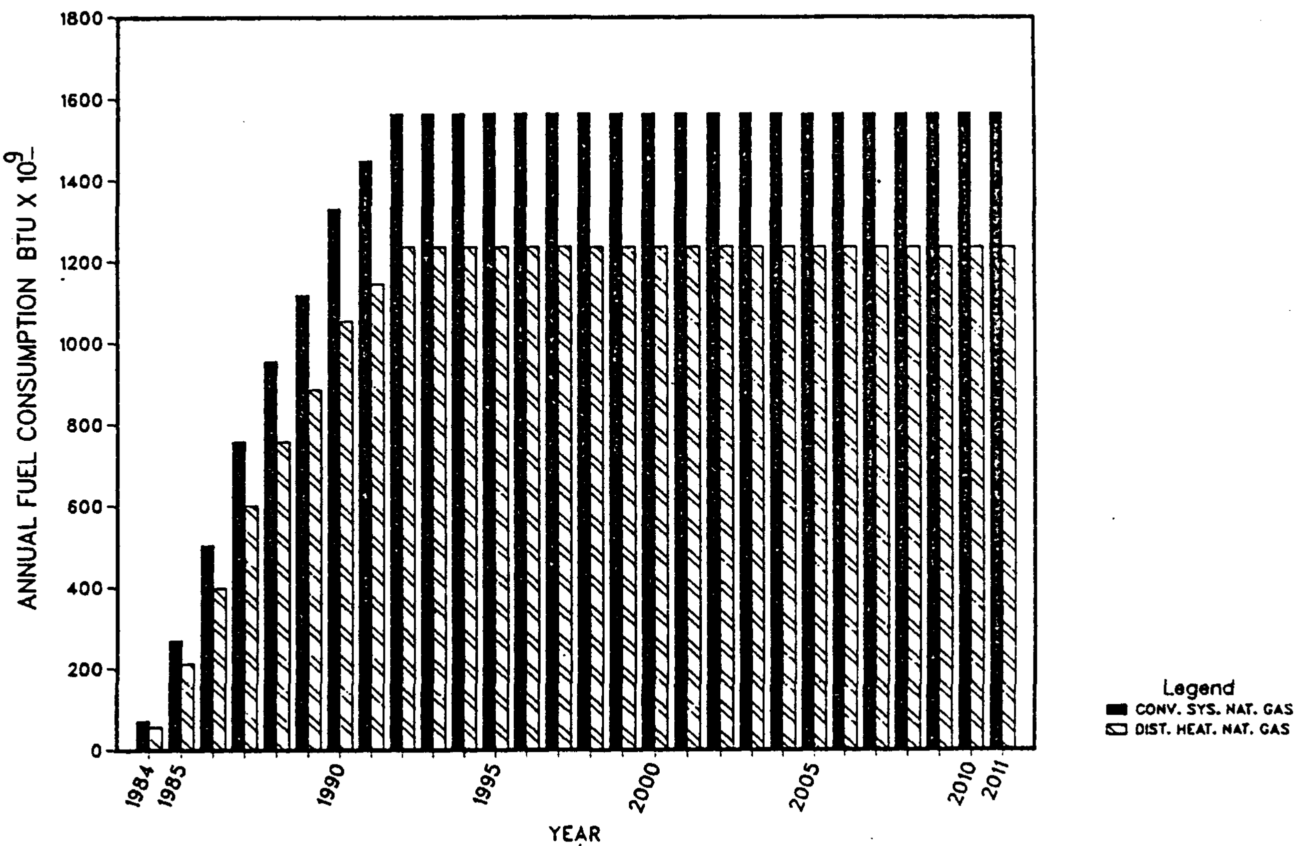


FIG. 10.4

BERRYS CREEK AND HARMON MEADOWS FUEL CONSUMPTION WITH LANDFILL GAS

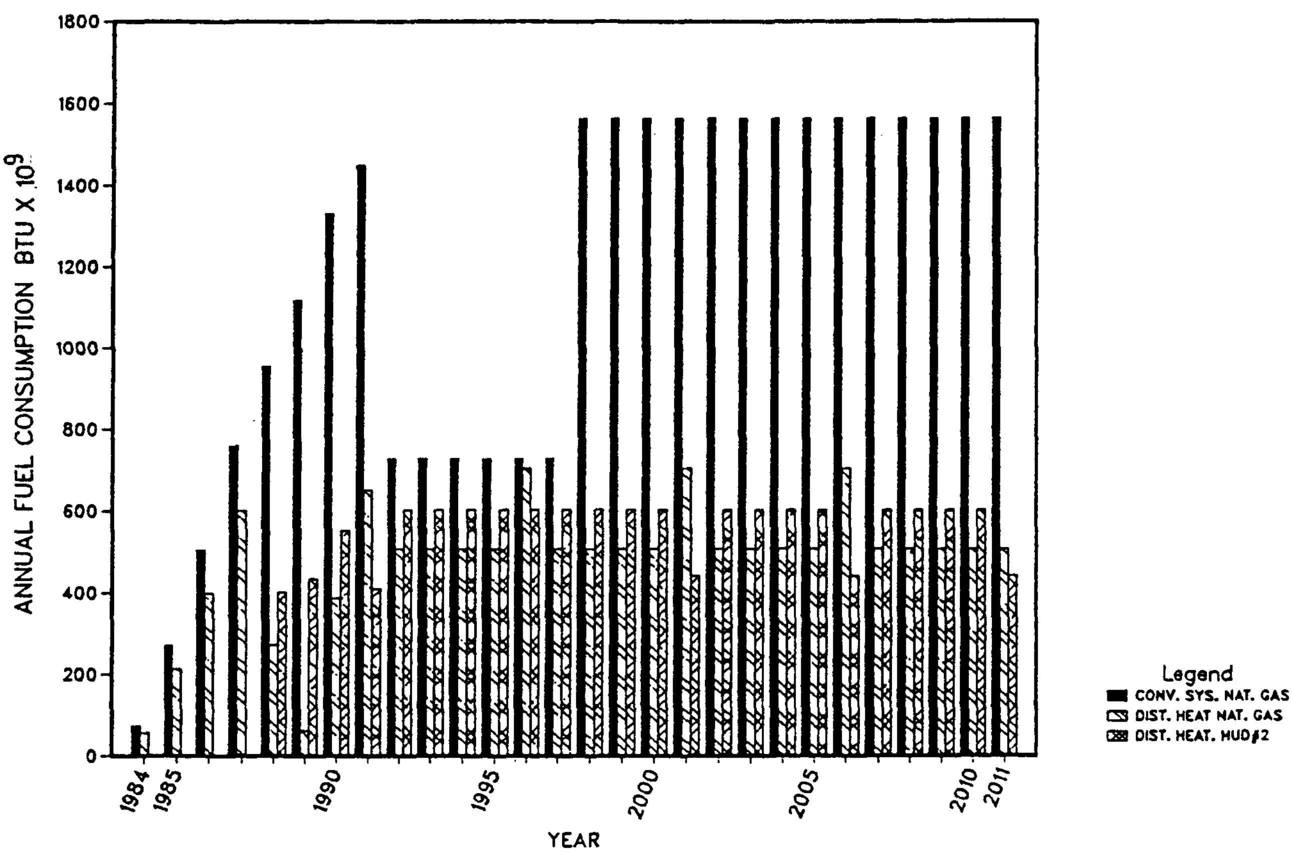
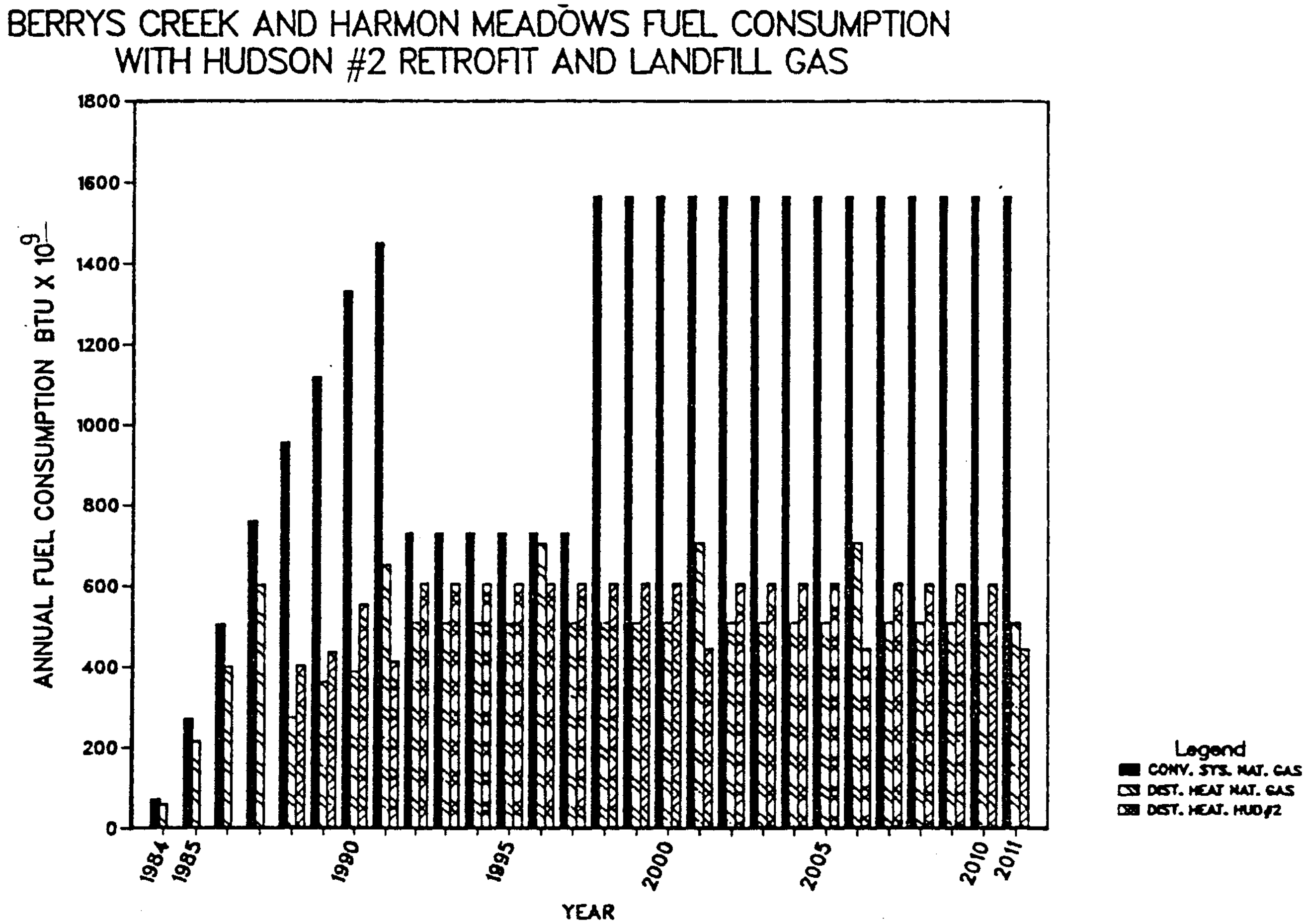


FIG. 10.5



BERRYS CREEK AND HARMON MEADOWS FUEL CONSUMPTION
WITH HUDSON #2 RETROFIT AND LANDFILL GAS
ANNUAL FUEL CONSUMPTION BTU X 10^9
1800
1600
1400
1200
1000
800
600
400
200
0
1984
1985
1990
1995
2000
2005
2010
2011
YEAR
Legend
CONV. SYS. NAT. GAS
DIST. HEAT NAT. GAS
DIST. HEAT. HUD#2

FIG. 10.6

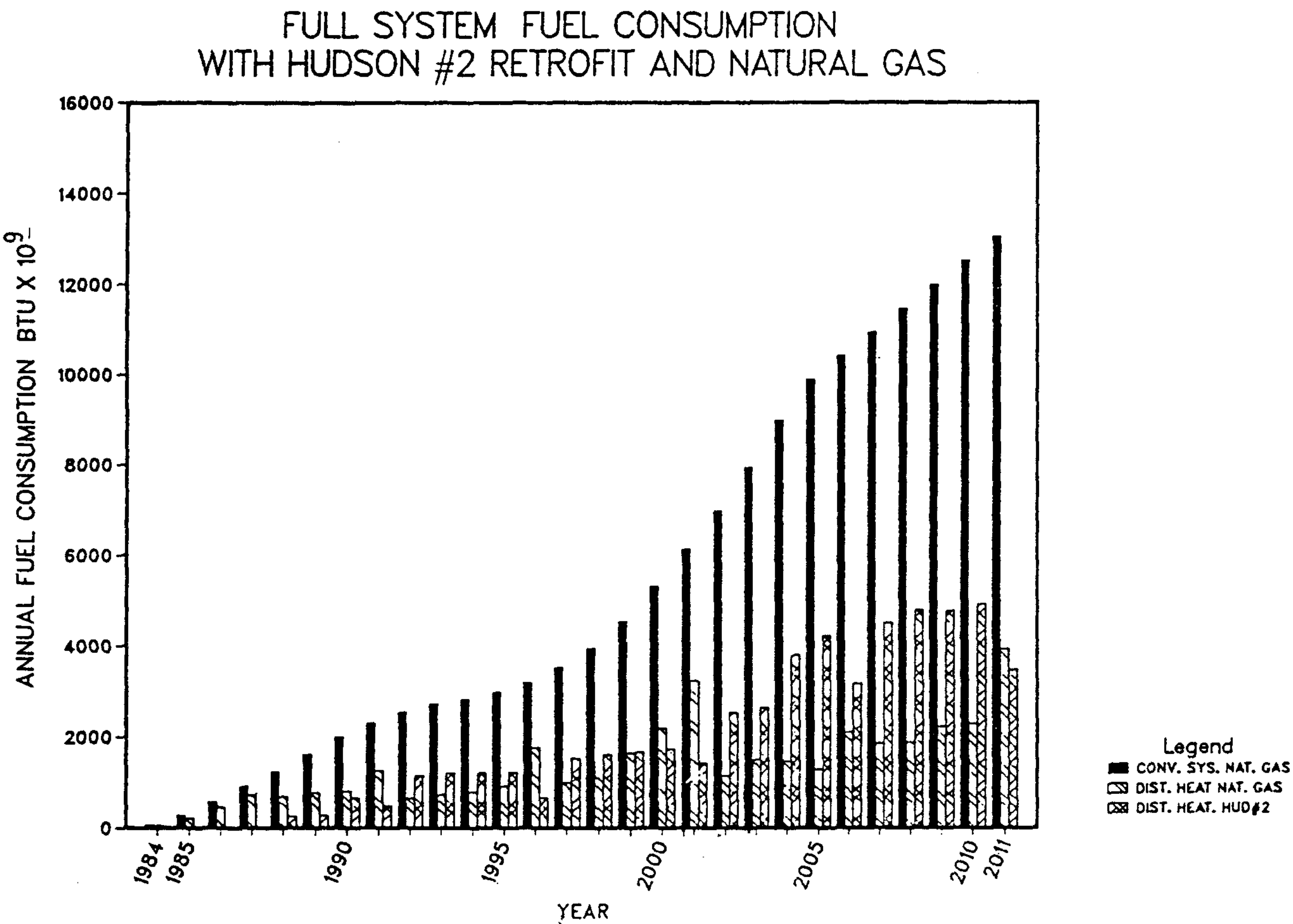
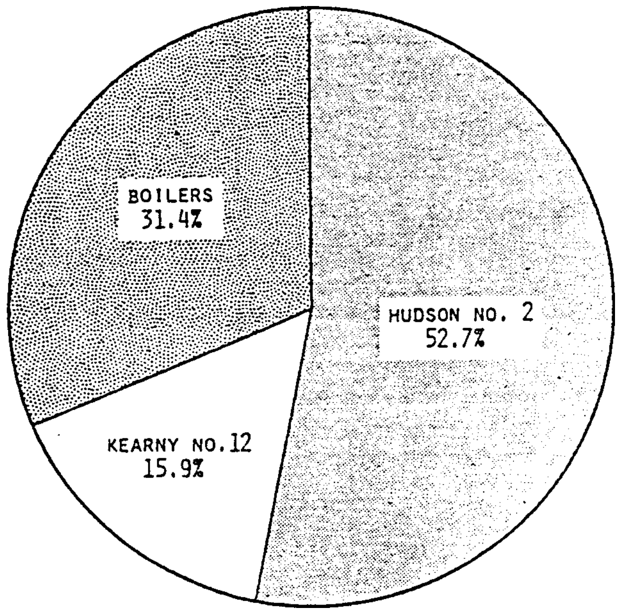

FULL SYSTEM FUEL CONSUMPTION
WITH HUDSON #2 RETROFIT AND NATURAL GAS
ANNUAL FUEL CONSUMPTION BTU X 10^9
16000
14000
12000
10000
8000
6000
4000
2000
0
1984
1985
1990
1995
2000
2005
2010
2011
YEAR
Legend
CONV. SYS. NAT. GAS
DIST. HEAT NAT. GAS
DIST. HEAT. HUD#2

FIG. 10.7

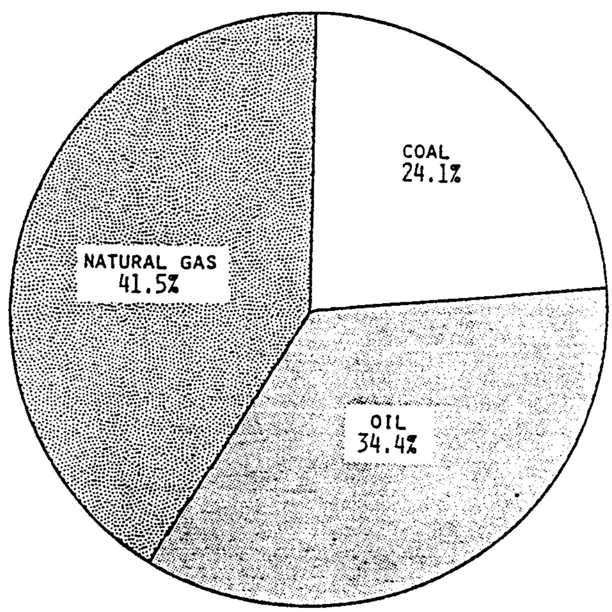
FULL DISTRICT HEATING SYSTEM
THERMAL ENERGY SUPPLIED-BY DIRECT SOURCE
1984-2011



JS/Nov.24,1982

FIG. 10.8

FULL DISTRICT HEATING SYSTEM
THERMAL ENERGY SUPPLIED-BY FUEL TYPE
(INCLUDING EFFECT ON ELECTRIC SYSTEM OPERATION)
1984-2011



JS/Dec.1, 1982

FIG. 10.9

pipes is minimal for well insulated pipes, and the recovery and utilization of landfill gas for fuel has been found environmentally acceptable in New Jersey (Cinnaminson, N.J. PSE&G/Hoegaenes) and elsewhere.

Although the extraction of 1.6×10^6 lb/hr of steam from Hudson #2 for district heating would reduce thermal discharges to the river by about 1.5×10^9 BTU/hr, this improvement would occur mainly during the winter heating season. However, themal discharges to waterways are of environmental concern during the summer because of the consequent reduction in dissolved oxygen. Thus the reduction in thermal discharge has minimal environmental significance.

District heating may impact air quality through (1) increase in fuel burned at Hudson #2 and Kearny #12 for district heating; (2) fuel burned at (new) local heater plants of the district heating system and (3) reduction/elimination of fuel which would have been burned by district heating customers in their own boilers.

Because Hudson #2 is at maximum load ("base-loaded") except for a few hours each night, the fuel burned at Hudson increases only slightly due to district heating. The natural gas burned at Kearny #12 and the local heater plants (and the landfill gas burned at the Meadowlands) produce minimal particulate emissions, no SO_2 emissions, but NO_x emissions could be significant.

First, modeling was done for an annual period for particulates, NO_x and SO_2 without taking credit for the displacement of customer fuel use by district heating (Section 10.6.1). The increments in SO_2 and particulates due to district heating wee found to be zero. Increments in NO_x ranged from 0–3 micrograms per cubic meter. This is negligible compared to the Federal Ambient Air Quality Standard of 100 micograms/cubic meter for NO_2 (not NO_x which is only partly NO_2) and a maximum annual average observed level of NO_2 of 78 micrograms per cubic meter. There is no chance that district heating would cause the standard to be exceeded. When "worst-case" NO_x modeling was done for the month of January (very stable meteorological conditions and maximum heating load), but including the effect of customer fuel use reduction (Section 10.6.2), the NO_x increment ranged from +1 to −3 micrograms per cubic meter, with the exception of two points immediately downwind of heater plants (+4 and +5 micograms per cubic meter). Thus the NO_x impact of district heating is essentially negligible, ranging from minor increases to minor reductions.

Section 10.6.3 shows "worst-case" SO_2 modeling results for January. These range from increases of 0 to 1 micrograms per cubic meter without customer fuel displacement credit to reduction of 0 to 2 micrograms per cubic meter with credit for reduced emissions due to reductions in customer fuel burning (except for one point with a 1 microgram per cubic meter increase). Again the air impact of district heating is negligible. This differs from the situation in Europe where the heating fuel displaced is high sulfur oil instead of 0.2% No. 2 oil or natural gas with no sulfur.

Two sets of month-by-month district heating system fuel use were input to the computer model, one (8 week Hudson No. 2 outage) for a normal year and one (18 week outage) reflecting the periodic longer outage (one every five years) for steam turbine rebuilding.

In summary, the proposed total system district heating scenario was found to have negligible environmental impact. The smaller scenarios would have even less impact.

INSTITUTIONAL QUESTIONS

Meetings and discussions were held, at staff level, with State regulatory agencies relevant to district heating, including the New Jersey Board of Public Utilities (NJBPU), the New Jersey Department of Environmental Protection (NJDEP), the New Jersey Department of Labor & Industry (NJDL&I). Personnel of the New Jersey Department of Energy (NJDOE) were assigned to liaison with this study, and also assisted with tasks in the area of energy and fuel use assessment. However, statements and opinions expressed by staff members of these agencies are not binding on the agencies, which have refused to issue "hypothetical rulings" on district heating. Their attitude has been, "We will rule when you come to us with an actual rate case or licensing request to decide." A "Hypothetical Draft Tariff for Thermal Service" (Section 4) was sent to NJBPU for review and comment, but despite repeated inquiries, no response was forthcoming. With this qualification, the results of discussions with regulatory bodies will be summarized below.

There are currently no regulations "on the book" on district heating in New Jersey primarily because there is no district heating other than military bases and college campuses. Since these do not cross property lines, they would not be regulated, in any event. However, there is little doubt that district heating which did cross property lines would be regulated under current N.J. law, whether or not it was owned by PSE&G (a "utility"). The New Jersey Statute specifically gives the N.J. Board of Public Utilities the right to regulate "sales of heat." (This is unlike the situation in some other States where sales of steam are specified in the statute, but sales of hot water might escape regulation.) Excepted from regulation would be situations (like college campuses and military bases) where no property lines are crossed and municipal utilities operating entirely within their own borders. Industrial parks and shopping centers might be exempt as long as the developer retains ownership of all streets and buildings, and if the energy source were within the property. However, once buildings are sold to individual owners and/or streets become public areas, there would be crossing of property lines and regulation could impinge.

Whether district heating is "regulated," or "a public utility" has important implications to its viability. The Federal tax aspects of "utility" vs. "non-utility" status are discussed in Section 5 "Financial Considerations." The implications of "regulation" will be discussed here. The Gross Receipts and Franchise Tax (GR&FT) of about 13% added to all utility bills would, in effect, raise the price of district heating by 13% and make an otherwise viable project marginal, while killing already marginal projects. However, it would be within the power of the State Legislature to change this, if they were convinced that a lower GR&FT rate on a viable district heating system would provide higher revenues to the State than 13% on a district heating system that is never built.

Another regulation-related problem is the traditional utility "rate-of-return" rate setting process, whereby a utility's rates are set on the basis of an "allowed rate of return on investment" (rate base), typically 16% at present. As noted below (Sections 4, 5, 9), because district heating is heavily front-end capital loaded, rate of return regulation could result in the first few years' heat prices to the customer being much higher than the conventional alternative heat source (individual gas-fired boilers in each building), which would mean no customers at all! Conversely, in subsequent years, as fuel prices escalate, rate of return regulation would set heat prices far below the customers' alternative heat price, and there would be no way of recovering the initial years' losses at a later time (Figure 3.1). Some way of leveling out earlier and later heat prices, such as by long-term contracts with customers, thus seems essential.

Federal regulations which might impact district heating include PURPA and the Public Utility Holding Company Act (PUHCA). PUHCA restricts the type of activities that existing public utilities can engage in and the manner in which they may be organized, including the use of subsidiaries. Proposed revisions to PUHCA are currently before Congress and may affect this situation. PURPA limits certain tax and regulatory benefits to cogenerators to facilities not more than 50% owned by electric utilities. This limits the participation of electric utilities in cogeneration/district heating projects to "third party" arrangements if the benefits of

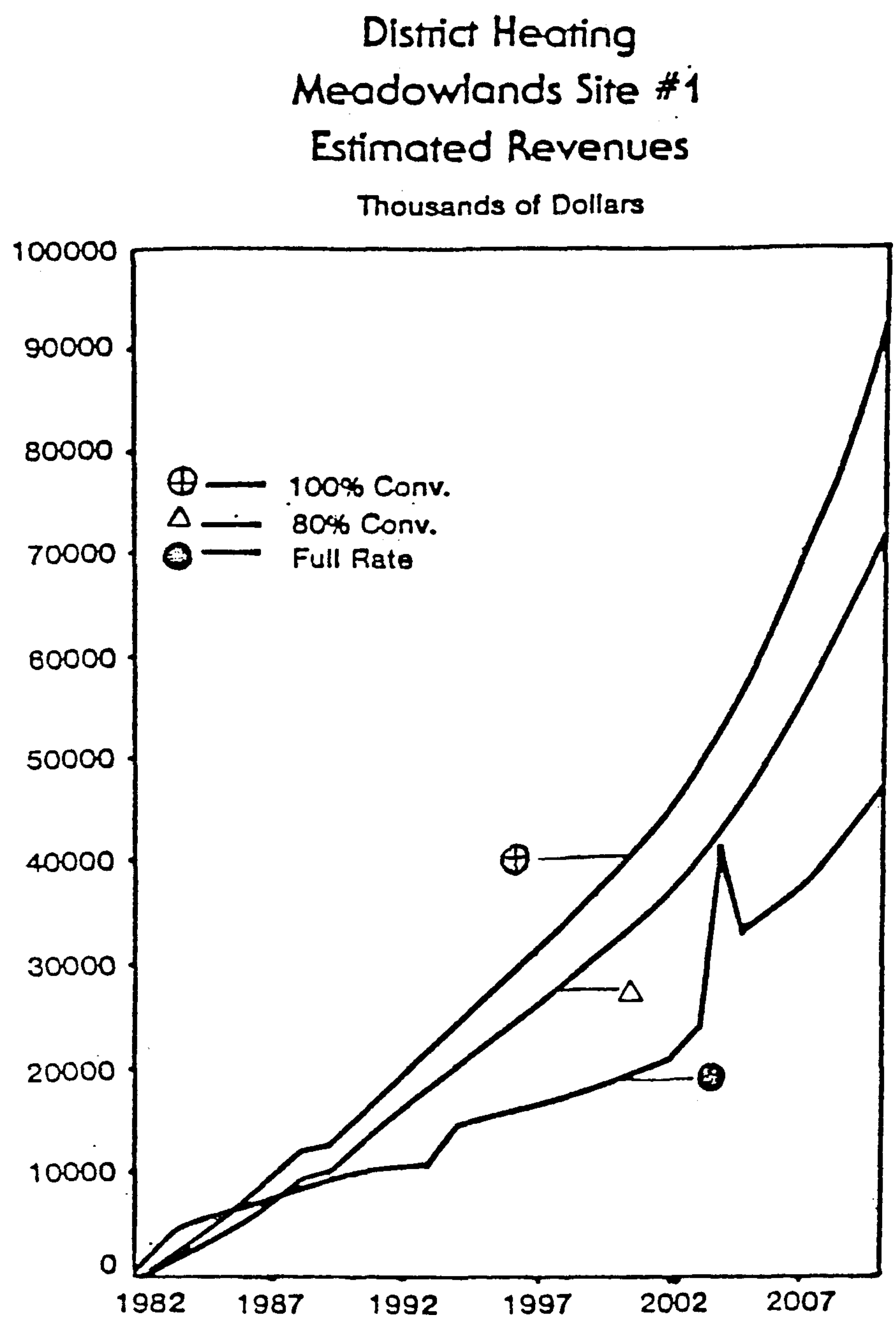

District Heating
Meadowlands Site #1
Estimated Revenues
Thousands of Dollars
100000
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
100% Conv.
80% Conv.
Full Rate
1982
1987
1992
1997
2002
2007

FIG. 3.1

PURPA are desired. Proposals to remove this 50% utility ownership restriction on cogeneration facilities are being advanced.

Federal Fuel Use Act (FUA) restrictions on natural gas use have been eased during the course of this project and are no longer a problem to district heating.

The regulations of the New Jersey Department of Labor and Industry Office of Boiler and Pressure Vessel Compliance (NJDL&I) require a full time operator on-site at all steam boilers. After several meetings with NJDL&I they agreed that fired hot water heating units were different enough from steam boilers to allow remote control and operation, with a central remote control operator monitoring each plant and shutting it down remotely if needed, and a "roving boiler operator" in radio contact with the central remote operator, and visiting each plant once each day (Figure 3.2). This reduces the number of boiler operators needed for 11 local heating plants and considerably improves the economics of the district heating system. It was also agreed by NJDL&I that if hot water from the district heating system were used to generate low pressure steam at a customer's facility, these steam generators, being unfired, would not require a boiler operator.

By utilizing an existing coal-fired central generating unit (Hudson), an existing gas turbine plant (Kearny) and gas-fired local boiler plants, environmental impact of the proposed district heating system has been minimized. In discussions with NJDEP, no insurmountable licensing barriers or environmental impact was found. The time scale for required environmental licenses are short enough (1 – 1-1/2 years) not to be the limiting factor in construction of a district heating system.

There are expected to be no insurmountable land-use or noise abatement problems associated with the proposed district heating system. The local heating plants are gas-fired. It was found that sites are available suitably located with respect to gas and electric supply and thermal load. There are no separate pumping stations. All pumps are contained within the central (Hudson), intermediate (Kearny) and local heating plants. The fired water heaters (50-60 million BTU/hr each) are of a type

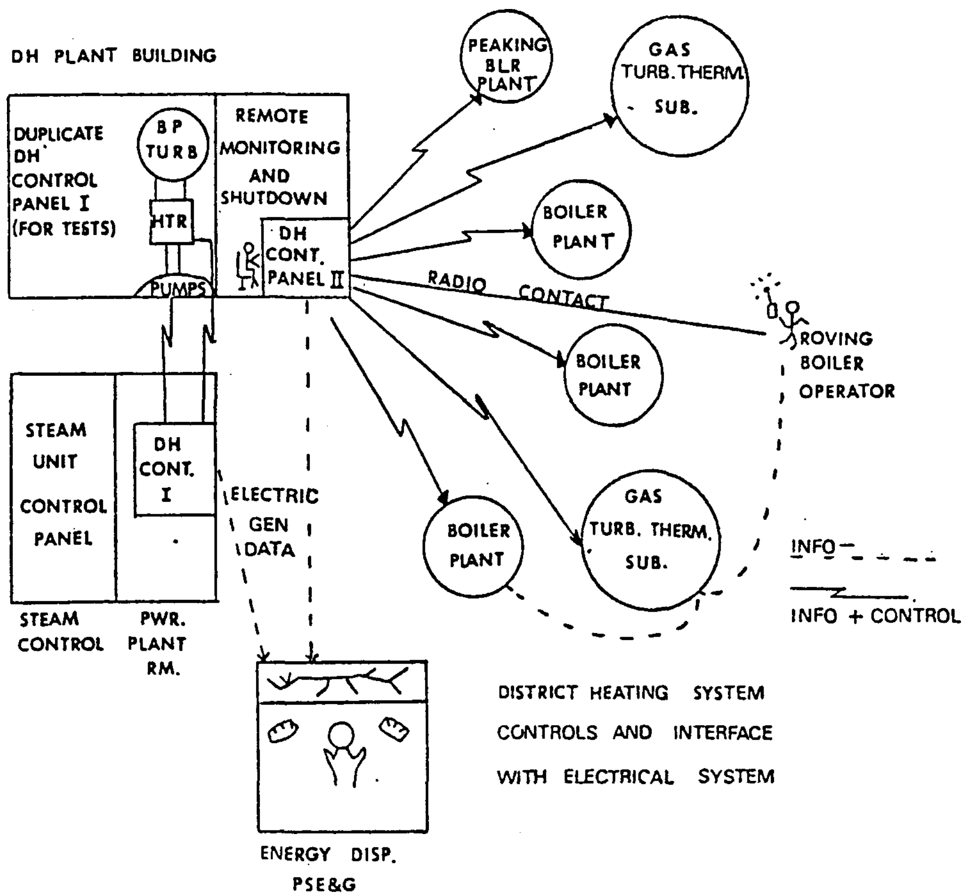

DH PLANT BUILDING
DUPLICATE DH CONTROL PANEL I (FOR TESTS)
B P TURB
HTR
PUMPS
REMOTE MONITORING AND SHUTDOWN
DH CONT. PANEL II
PEAKING BLR PLANT
GAS TURB. THERM. SUB.
BOILER PLANT
RADIO CONTACT
ROVING BOILER OPERATOR
BOILER PLANT
BOILER PLANT
GAS TURB. THERM. SUB.
INFO
INFO + CONTROL
STEAM UNIT CONTROL PANEL
DH CONT. I
ELECTRIC GEN DATA
STEAM CONTROL
PWR. PLANT RM.
ENERGY DISP. PSE&G
DISTRICT HEATING SYSTEM CONTROLS AND INTERFACE WITH ELECTRICAL SYSTEM

FIG. 3.2

common in commercial/industrial service and pose no noise abatement problem. The Trenton District Energy Company (see below) has obtained all needed approvals despite the higher noise associated with its diesel engines (compared with gas boilers in our proposed system).

The proposed district heating system has been designed to minimize right-of-way problems. Maximum use is made of existing PSE&G electric and gas rights-of-way. This also reduces construction cost through reduction of interferences with existing underground utilities, paving, etc. One river crossing is made through an existing minimally used gas transmission line tunnel to reduce costs. Other river crossings are made along the river bottom, without using existing bridges or other structures. Costs for this crossing were based on recent PSE&G experience with gas transmission line river crossings. It was decided not to use railroad rights-of-way because of the unfavorable experience the Gas Department has had regarding charges for such usage. Permission to use city streets, where needed, must be obtained on a site-specific basis once street routing is definite, but no problems are expected. (A district heating system is currently under construction by the Trenton District Energy Corporation (TDEC) in the center of Trenton, and has received all necessary approvals.) The portions of our proposed district heating system in new developments in the Hackensack Meadowlands and elsewhere would be installed at the same time as other underground utilities (water, sewage, electricity, telephone) and thus require no additional street opening.

At the inception of a district heating system, all the heat comes from the local heating plants. If this is all natural gas, the cost can be high, but would decrease once the retrofitted central powerplant is in service and the local plants revert to peaking/backup duty. However, in the event that a larger, central powerplant-based district heating system never materialized, the district heating company would be left with high-operating-cost heating plants and connected customers it was committed to serve. This could be avoided if the initial, isolated heating plants were made self-sufficient, or as nearly so as possible, through use of waste fuels (including landfill gas, where available), coal (using fluidized bed combustion) and cogeneration.

In contacts with developers of industrial parks and shopping centers and other potential large district heating customers, little psychological inertia or bias against district heating was found, if it would be priced below competing fuels. However, prospective customers wanted definite price and delivery date commitments. (Recent fuel price oscillations have also caused many prospective customers to distrust economic analyses based on fuel price projections.) However, definite commitments on district heating cost of heat and delivery date are difficult to make without knowing definitely the number, location and loads of customers, i.e. without signed-up customers. This is also impacted by expected regulatory treatment, and regulatory agencies are reluctant to give any binding opinions in advance of an actual case. This "vicious circle" might be broken by: (1) Starting with small systems which reduce exposure. Smaller risks require less certainty. (2) Get contingent commitments from customers based on their own estimated cost of alternative supply. They agree to connect if district heating is competitive.

Another "uncertainty" from the standpoint of the district heating entity is the default or departure of customers leaving the district heating system with under-utilized facilities. This might be alleviated by concentrating on governmental and institutional customers as was done by TDEC in Trenton, or by some sort of insurance/bonding arrangement.

Because of budget cycle and long term advance planning requirements, a number of presentations on district heating have been made to PSE&G Senior Management prior to completion of the present study, and approval has been requested for inclusion of funds in the budget for district heating implementation.

On October 5, 1981, a presentation was made to the PSE&G Management Council, which consists of the PSE&G Chairman of the Board, President, Executive Vice President–Corporate Planning and all Senior Vice Presidents of PSE&G of a conceptual $17.2 million district heating project over a 10–year span.

On August 24, 1982, district heating was included in a presentation directed to a group consisting of the PSE&G President, Executive Vice President–Finance, Senior

Vice President–Corporate Planning, Senior Vice President–Planning and Research, Vice President and Controller, Vice President–Production and Vice President–Transmission and Distribution. A conceptual district heating system was presented, based on a 200 x 10^6BTU/hr (peak) initial stage in the Hackensack Meadowlands, using landfill gas, as the beginning of a 3.7 x 10^9BTU/hr (peak) system developing over 30 years, and costing over $29.7 million over the first 10 years.

On March 18, 1983, Messrs. John Millhone (USDOE) and Floyd Collins (USDOE) visited PSE&G, received a project briefing and met with the President of PSE&G.

On May 17, 1983, a District Heating Review was given to the New Jersey Board of Public Utilities and on May 25, 1983, a Project Review was given at USDOE in Washington, D.C. Prior to the BPU presentation, project status and preliminary results were reviewed with the Senior Vice President–Planning and Research.

On August 16, 1983, district heating/cogeneration development prospects were reviewed with the President and the Senior Vice President–Planning and Research of PSE&G.

Review of the final results, conclusions and recommendations of this project was conducted with the Senior Vice President–Planning and Research and the PSE&G District Heating Coordinating Team (see Table 1–I). A presentation to the Management Council of the attractive small and intermedite scale scensarios was recommended for early 1984. Site specific studies of district heating/cogeneration opportunities are planned for 1984, and recommendations to Management will follow. Management has specifically requested recommendations regarding district heating for the post–1986 period when the company financial situation is expected to improve.

CONCLUSIONS

(1) Small localized district heating systems in new developments, each with a peak demand in the order of 200 x 10^6BTU/hr and supplied by centralized package boilers appear economically preferable to conventional natural gas-fueled individual-building heating systems. The Levelized Annual Minimum Revenue Requirements (LAMRR) advantage of district heating ranges from 22% (natural gas) to 34% (landfill gas) savings over the conventional system (Table 9-II).* Table 5-VI shows the projected cost of heat from district heating of such a new development (using landfill gas) compared with conventional heating. District heating is initially more expensive due to front-end capital loading, but shows a growing cost advantage after the fourth year. Site specific analyses will however be required to confirm these findings.

(2) A small, localized district heating system (200 x 10^6BTU/hr peak) supplied by a limited retrofit of coal-fired Hudson No. 2 seems economically equivalent to the package boiler alternative described above. It would thus be difficult to justify the higher capital investment of a limited retrofit of Hudson No. 2 relative to the package boiler option (Table 9-I).

(3) A combination of district heating supplies from package boilers and limited retrofit of Hudson No. 2 into one system (400 x 10^6BTU/hr load) results in averaging their performance providing an advantage of 9% with natural gas and 17% with landfill gas (Table 9-III). This is less than for two smaller district heating systems fueled totally by natural gas as in (1) above. Thus, the retrofit of Hudson No. 2 and associated transmission piping cannot be justified in this case.

* References correspond to main body of report.

(4) There is no real economic incentive to accelerate the development of a regional (3.7 x 10^9BTU/hr) district heating system based on retrofitting coal-fired Hudson No. 2 and constructing associated thermal transmission facilities (Fig. 9–IV) over what a gradual market penetration (using package boilers) would dictate. This is shown in Table 9–IV (levelized analysis) and Table 5–IV (price of heat).

(5) Distribution piping facilities account for the largest item (16%) of the Levelized Annual Minimum Revenue Requirements for the fully developed system, due primarily to the urban locations for the pipe installations. Concentrating on new developments, with one–third less the distribution piping cost of established areas, could significantly improve district heating economics. Use of innovative technology to reduce piping installation costs could have a similar effect.

(6) The economic viability of district heating is heavily dependent on fuel prices. Higher fuel price escalations would favor district heating and lower price escalations tend to favor a conventional system (see Tables 9–IV and 9–VII).

(7) Because of landfill gas supply limitations (several hundred million BTU/hr) in the study area, landfill gas could have only a small but positive effect on the economics of a regional district heating system (3.7 x 10^9BTU/hr peak), by reducing the natural gas consumption required for such a system (Table 9–IV). The effect of landfill gas becomes quite significant for smaller systems (see (1) above).

(8) Reasonable variations in capital costs of thermal energy supply facilities (i.e., district heating plant) have a minimal effect (about 5%) on the overall economics (see Tables 9–IV and 9–VI).

(9) The alternative financing ownership options evaluated in the study do not greatly affect the levelized economics of district heating. They do, however, affect cash flow, breakeven period, internal generation of capital and competitive pricing (see Tables 5–III and 5–IV).

(10) The small, localized, 200 x 10^6BTU/hr district heating system described above in (1) has a higher capital requirement than the conventional alternative. However, its 71% internal generation of capital meets the minimum corporate requirement of 50% (see Table 5–V).

(11) The 13% Gross Receipts and Franchise Tax (GR&FT) significantly affects the viability of district heating. If this charge were to be eliminated by legislation, all district heating alternatives would be viable with advantages over conventional systems of 10% (regional district heating system) to 41% (district heating of Berry's Creek with landfill gas). This is shown in Table ES–IV which summarize the (levelized) economic analysis of all scenarios, with and without GR&FT.

RECOMMENDATIONS

The major conclusion of this study was that small district heating systems in conjunction with new developments can be profitable, and these should be pursued by looking for specific opportunities in northeast New Jersey and other areas with similar characteristics. These dispersed, small systems could provide the underpinning of large regional district heating systems of the future.

A number of the major barriers to district heating implementation identified in the current study are listed in Table 13–I. Major recommendations derived from this study are listed below.

1. District heating development requires a utility to make a fundamental corporate decision and commitment as to whether it wishes to become involved in district heating as a new business area, if and where it is proven profitable.

If the answer is positive then the following steps are appropriate:

a. The utility should decide if it wishes to own and operate the entire system (including T&D), sell heat to another T&D entity or build and operate all or part of the system for another owner (e.g., the customer(s) or a third party).

b. Specific small (10×10^6BTU/hr) and intermediate (200×10^6BTU/hr) scale district heating opportunities should be identified. Consideration of large (3.7×10^9BTU/hr) systems should be deferred for the present.

c. A small-scale economically viable, district heating/cogeneration project (e.g., in a new development) should be identified and carried through study to demonstration in a cooperative effort between the Utility, the customer(s) the municipality and private investors. Contingent commitments based on cost estimates of gradually increasing accuracy should be utilized.

d. The use of transportable heater plants (as in Europe) to reduce district heating start-up costs and improve initial cash flow should be investigated.

e. The feasibility of reducing the generation loss resulting from the limited retrofit of a major generating station should be pursued with the manufacturer and the utility operating departments.

f. District heating distribution cost estimates for an urban site should be done on a "street-specific" basis due to large variations in costs from the interferences with other underground utilities.

2. R&D on the utilization and development of innovative technology to reduce the installed cost of district heating piping in the transmission and distribution sectors should be pursued.

3. Studies should be done of the potential of coal and waste-fired (fluidized bed) cogenerating heating plants to improve district heating economics.

4. New developments/redevelopments now being planned for urban areas in the nation (e.g., Meadowlands and River waterfronts of New Jersey) should be the focus of attention for district heating implementation because of their lower distribution system installation cost (about two–thirds of built–up areas).

5. Case specific studies of industrial development opportunities in conjunction with district heating should be considered.

TABLE 13-I

District Heating Barriers to Implementation and Suggestions for Resolution

Barrier	Actions Required
Marginal Economics	(1) Reduce costs, particularly T&D piping installed cost; (2) Negotiate resolution of taxation/regulatory issues with state government; (3) Reduce local heating plant operating costs by use of cogeneration and waste fuels.
Startup losses due to heavy capital loading	(1) Phase DH capital costs more gradually, use transportable heater plants as in Europe; (2) Rate adjustment to offset startup losses and repay later.
High capital costs of T&D piping	(1) Investigate cost reduction via European DH technology and development/ adaptation of advanced technologies including cost optimization via subsurface mapping using computer graphics, street-specific cost/routing optimization.
Uncertainties in Economic/ Financial conditions and fuel prices	(1) Minimize exposure by starting with small systems; (2) Obtain contingent commitments from customers based on estimated costs (customer supplies his cost projections of alternative supply and agrees to connect if DH is competitive.)
Cost of operating small local heating plants in isolation from central DH system	(1) Use of waste fuels (including landfill gas), coal (using AFBC) (2) Utilization of cogeneration to improve economics.
High total capital costs vs. utility capital constraints due to other construction	(1) Start with small initial system; (2) Seek outside (venture capital) financing (3) Municipality/customer group backing (4) Creative financing leasing, UDAG, Block Grants.

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