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

Final Report, Volume 1, Executive Summary

October 1979
Report Date

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

Public Service Electric and Gas Company
Newark, New Jersey

DEPARTMENT OF ENERGY · UNITED STATES OF AMERICA

U. S. DEPARTMENT OF ENERGY

Division of Buildings and Community Systems

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

Volume I

Executive Summary

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

Prime Contractor:

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

Subcontractors:

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

Report Date: October 1979

Prepared for the

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

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

FOREWORD

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

Volume I:	Executive Summary	
Volume II:	Task 1:	Demonstration Team
	Task 2:	Identify Thermal Energy Sources and Potential Service Areas
	Task 3:	Energy Market Analysis
Volume III:	Task 4:	Technical Review and Assessment
Volume IV:	Task 5:	Institutional Assessment
	Task 6:	Preliminary Economic Analysis
	Task 7:	Proposal for Further Work

ACKNOWLEDGEMENTS

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

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TABLE OF CONTENTS

Executive Summary

List of Figures

List of Tables

Executive Summary

Abstract:

The technical-economic feasibility and environmental acceptability of a district heating and cooling system serving communities by retrofit of existing intermediate and base-load electric generating stations has been studied. The study area was a densely populated area of New Jersey not being served by district heating.

A range of power plant retrofit concepts were examined. These included steam extraction (reheat or crossover) from a condensing turbine cycle, to supply a heat exchanger or back-pressure turbine and modification of condensing turbines to back-pressure operation. Conceptual designs for retrofitting power plants for cogenerative operation (electricity and district heating/cooling) were developed. Innovative adaptations of existing technology were investigated that could make delivery of thermal services from central stations a reasonable investment for private capital.

A market analysis was conducted to establish the extent and nature of the potential heating and cooling loads which are technically available within the proposed project areas. Both survey and simulation techniques were used. Potential for growth in thermal energy requirements was projected for each type of end-use consumer for periods ranging from 5 to 20 years beyond the study period.

The conclusions of Phase 1 may be summarized as follows:

- PSE&G Northern stations have best combination of heat supply capability and nearby high density thermal loads. District Heating offers greater near term potential than District Cooling. (Task 2)

- Market potential for District Heating/Cooling was found in new construction developments and in existing urban areas with high density industrial, commercial and high-rise residential thermal loads. (Task 3)

- Utilization of heat supply capability of plants would require only 20% market penetration of thermal load within 5 miles of plants. (Task 3)

- Hot water distribution system on European model appears best method of heat transmission. No technological barriers were found. (Task 4)

- Economics were marginally favorable. Considering uncertainties and that technical design was good but not optimized, more detailed study in Phase 2 is justified. (Task 6)

- Annual load factor was low (28%). To improve utilization of capital investment and reduce unit heat costs, Phase 2 must consider methods of raising load factor (cooling, industrial process load, storage, etc.). (Task 6)

- Optimized technical design is required in Phase 2 to minimize costs. (Tasks 4, 6)

- Refined costs and economic analysis are needed to reduce uncertainties. (Task 6)

- Staged system development is essential to keep capital outlays in step with load/revenue growth. (Task 6)

- Analysis of legal, tax, regulatory, environmental and other institutional factors revealed no major obstacles. (Task 5)

- PSE&G considers the project sufficiently promising to proceed to Phase 2 and share in the cost of this effort. (Task 7)

- The Phase 1 Demonstration Team is suitable for Phase 2, with the addition of the turbine manufacturers (G.E. and Westinghouse) and consultants on thermal storage, air emissions modeling (Trenton State College) and Institutional Factors (NJ Department of Energy. (Task 1)

I. INTRODUCTION

With the energy shortage and rise in fuel prices, the improved thermodynamic efficiency of combined heat and power production (cogeneration) has received renewed interest. PSE&G is participating in a U.S. Department of Energy (USDOE) sponsored Demonstration Program to determine the technical, economic and institutional feasibility of retrofitting existing base and/or intermediate load fossil-fired steam generating units to provide thermal services to communities through a distribution network. Subcontractors in this program are Stone & Webster Engineering Corporation, Stone & Webster Management Consultants Inc., and Transflux International, Ltd. The Swedish firm, A. B. EnergiKonsult has been a consultant to the project.

The PSE&G studies in Phase 1 of the Demonstration Program had as a goal to identify market areas which could be served with thermal services from central stations and the plant retrofit and hot water distribution schemes required to provide these services. The studies were also designed to examine institutional factors which need resolution, preliminary financial requirements and the economic prospects of developing a business in thermal services. On the basis of the results from Phase 1, certain areas in New Jersey appear to offer rather uniquely favorable conditions to the application of centralized thermal services.

II. TECHNICAL ASSESSMENT

This study began with an examination of PSE&G's eight fossil-fired steam generating stations: Bergen, Hudson, Kearny, Essex, Linden, Sewaren, Mercer, and Burlington. Based on European district heating experience, the potential service area was considered, conservatively, to extend to a 15 mile (24 km)* radius from each generating station. Figure 1 shows PSE&G's Gas and Electric territories, which cover the densely populated strip of New Jersey between New York City and Philadelphia. Superimposed on this map are areas within 5, 10, and 15 mile radii from each plant. These areas can be seen to cover much of this densely populated strip, including a distribution of thermal load centers and generating stations uniquely suited to district heating. The PSE&G nuclear generating stations at Salem (1 operating, 1 ready for startup) and Hope Creek (2 under construction) were not included in the study because of the extremely small population and thermal load density in their vicinity.

*Throughout this report, SI metric units are given in parentheses following English System units.

Examination of European, Soviet, and Japanese district heating systems, as well as operating U.S. systems, led to the conclusion that a hot water distribution system has overwhelming advantages over a steam distribution system. It is difficult to transmit steam over distances above one mile, while hot water distribution systems may extend beyond the 15 miles considered in the study. Additional advantages of hot water over steam include lower transmission losses, less loss of electric generation capacity, high thermal inertia (providing some degree of inherent thermal storage and minimizing the effects of outages), lower corrosion and reduced makeup water requirements. Various heat carrying media were considered, but hot water appeared superior.

In order to select the best system to efficiently and economically transfer heat from the steam in the power cycle to water as the distribution medium, five sendout-return temperature ranges were considered for the district heating system: 390-270, 390-190, 290-230, 290-170, and 230-190^{o}F (199-132, 199-88, 143-110, 143-77, and 110-88^{o}C).

Possible steam extraction points considered included boiler main steam, hot reheat, cold reheat, I.P. (Intermediate Pressure) turbine, I.P./L.P. (Low Pressure) turbine crossover and low pressure extraction points (feedwater heater). The 290^{o}F/170^{o}F system with steam extraction from the I.P./L.P. turbine crossover was finally chosen.

The higher temperature systems required steam extraction from higher temperature points in the cycle with resultant greater loss in electric generation. Steam extraction from some of these points could lead to boiler operating problems (including inbalance of heat transfer between boiler sections). Higher supply temperature (and pressure) require more expensive materials for the distribution system. On the other hand, the lower temperature-difference schemes require much higher water flow rates (and larger pipes and/or pumping power) to transfer a given amount of heat.

Retrofit schemes were developed for the selected stations (Essex, Hudson, Bergen and Kearny), in which steam was extracted from the I.P./L.P. turbine crossover. In the case of Kearny Units 7 and 8, the crossover was physically inaccessible and the extraction point was a cross-under pipe between I.P. turbine stages. Later discussions with the turbine manufacturer indicated possible thrust bearing problems due to inbalance and further consideration of Kearny was deferred.

For Bergen Units 1 and 2 and Hudson Units 1 and 2, the crossover steam pressure is 75-81 psia (517-558 kPa), at zero extraction. The steam pressure is therefore dropped through back pressure turbines, allowing the replacement of some lost electric generation. An economic analyses showed that the value of the electricity generated justified the use of a back pressure turbine rather than a (less expensive) pressure-reducing station.

In the case of Essex Unit 1, the nominal crossover pressure is lower, about 50 psia (344 kPa) - therefore, no back pressure turbine was considered.

Estimates of seasonal heating loads based on historical New Jersey outdoor temperature data indicated that peak district heating system load would occur on a 0 ^{o}F (-17.78^{o}C) day, while average load (about 2/3 the peak) would occur on a 30^{o}F (-1.11^{o}C) day. Plant retrofit heat balances were done for three design points zero district heating, 30^{o}F ambient and 0^{o}F ambient.

Figures 2, 3 and 4 show heat balances for the retrofitted Essex No. 1, Hudson No. 2 and Bergen No. 1 Units, for a 0^{o}F ambient day. Auxiliary boilers are used at Essex to supply peaking and backup capabilities. The Bergen No. 2 unit crossover is manifolded with that of Bergen No. 1, to provide backup capability in the event of unit outage. Similarly, oil-fired Hudson No. 1 Unit is manifolded with coal-fired Hudson No. 2 to provide backup. Additional auxiliary boilers, not shown in the heat balance, provide backup against dual unit outage.

Table I shows the original electric generation capabil-ilities of the units examined, the electric generation reduction through retrofitting, and the thermal output available from them. It should be noted that since no turbine reblading or condenser modifications are considered, the original, full electric capability can be restored instantly by ceasing to extract steam. The units listed represent a variety of turbine arrangements. Essex 1 is a 100 MW_e unit with tandem-compound double-flow turbines. Kearny 7 and 8 are 144 MW_e units with tandem-compound triple-flow turbines. Bergen 1 and 2 are 297 MW_e units with cross-compound four-flow turbines. Hudson 1 is a 410 MW_e unit with tandem-compound four-flow turbines. Hudson 2 is a 652 MW_e unit with tandem-compound six-flow turbines.

Visits were made to the generating stations to determine the space available for retrofit equipment and controls. Preliminary equipment and piping layouts were made and used to estimate plant retrofit costs.

The transmission and distribution (T&D) studies involved an examination of the topography and major load centers around and between the four selected stations, a preliminary identification of transmission rights-of-way and the development of generalized distribution grids. The highlights are as follows:

- Limited and isolated thermal supply pipeline grids do not require river crossings. The interconnection of the power plants will, however, require river crossings, possibly along existing bridge structures.

- The thermal supply transmission right-of-way could benefit from siting along an existing electric transmission right-of-way, an oil pipeline, major roads (New Jersey Turnpike) and even along major utility lines in populated areas.

- The transmission lines would use dual 18-36 inch (0.46-0.91 m) diameter welded carbon steel pipe with insulation of polyurethane foam and PVC jacket. Hot water would be kept pressurized at 500 psia (3.4 MPa) in the transmission segments and will move at flows of up to 28,770 gallons/minute (1.82 m^3/sec). Conventional construction (aboveground and underground) is envisioned with the exception of areas involving marshlands.

- The distribution lines would commence at thermal supply substations. Dual welded carbon steel pipes of diameters ranging from 8 inches (0.20 m) to 16 inches (0.41 m) would be used with polyurethene foam for insulation and PVC jacket. Expected pressures and flows are 5,000 gallons/min (0.32 m^3/sec) and 300 psia (2.1 MPa), respectively.

Schematic diagrams of conversion systems for adapting customer domestic hot water and space heating equipment (using hot air, hot water and steam) were prepared and used in estimating conversion system costs. A heat pump package to convert hot water to low pressure steam is expected to be commercially available by the early 1980's, and might be used to adopt customers' steam equipment to a district heating system using hot water.

Thermal storage and district cooling were briefly examined in this Phase 1 study and compared with alternatives. They will be examined in more detail in Phase 2 in an effort to improve system load factor and economic performance.

III. MARKET ANALYSIS

A preliminary estimate of potential thermal load was made using 1970 U.S Census data, published tabulations of office space, housing types and fuel use, and energy use data from the PSE&G Company files. Diagrams were prepared showing the location of communities and density of thermal load around the PSE&G generating stations. Table II shows the number of housing units in northern New Jersey and three of its major cities including the fuels used for space heating and domestic hot water.

Other tabulations were prepared to ascertain the breakdown of fuel use per demand sector (residential, commercial, institutional and industrial) and the directional patterns of thermal load distribution in relation to the power plants being considered for retrofitting to supply thermal services. It became evident that certain regions around the PSE&G generating stations in northern New Jersey have load densities 2-3 times those around the other stations in the PSE&G system. For this reason, the Essex, Kearny, Hudson and Bergen generating stations were selected for further, more detailed study.

Data on type, age and fuel of customer heating system were gathered from PSE&G Company files and from an annual Appliance Saturation field survey conducted by PSE&G (about 1% of all customers). Typical data are given in Tables III and IV. A field survey of large and small commercial and industrial customers and high-rise apartment buildings was performed. Data on fuel and energy use, temperature of heat required, expansion plans and required payback period for investments were gathered. Data on the location of and fuel use by high-rise apartment buildings were also obtained from PSE&G Company files. Aerial photographs provided additional information on existing buildings location, new development areas, rights-of-way and potential service territories relative to the generating stations.

In the field survey, a carefully selected sample consisting of 384 PSE&G customers were interviewed, including owners of small and large commercial buildings, small and large industrial buildings, residential (large and medium) and multi-use buildings (Table V). Floor area totaled 23,815,000 square feet, averaging 152,000 square feet per customer (Table VI). The average annual heating bill per customer is shown in Table VII, where residential buildings have been included with the commercial, for convenience. The average payback period or return on investment for the building sample was 3.7 years.

The projected and current areas for space heating within five mile radii of the generating stations considered in this study are shown in Tables VIII and IX. By the year 2000 the area within the relevant 5-mile sector is expected to contain over 1.2 billion square feet of floor area, representing an annual growth rate of about 1.65%. The Meadowlands district accounts for the growth in high-rise residential units. The area outside the Meadowlands is expected to provide substantial growth of the non-residential type.

The results of the survey, combined with projections of future population changes and area development, suggest that the thermal services market penetration and evolution will be different depending on whether a locality offers load growth, with attendant new construction, or no load growth and is therefore restricted to building retrofit. In the PSE&G northern territory, most of the residential thermal load growth, and much of the commercial and industrial thermal load growth, is expected to occur in an area designated as the Hackensack Meadowlands, located northwest of Hudson Generating Station. On the other hand, the concentration of existing population and, in particular, high rise residences and offices suggest building retrofit opportunities in areas west of Essex Station (City of Newark) and southeast/northeast of Hudson Station (Jersey City, Hoboken and other communities along the Hudson River).

For these reasons, market areas and distribution systems to serve them were developed further on the basis of three scenarios outlined:

Scheme #1 - Retrofit Hudson Units 1 & 2 (by 1985) to supply thermal energy 469 MW_t (1.6 X 10^9 BTU/hr.) to the future development of the Hackensack Meadowlands and Jersey City (existing loads and urban redevelopment)

Scheme #2 - Retrofit Essex Unit 1 (by 1985) to supply thermal energy 226 MW_t (0.772 X 10^9 BTU/hr.) to the City of Newark (an area with existing thermal loads and redevelopment potential)

Scheme #3 - Retrofit Hudson Units 1 & 2 and Bergen Units 1 & 2 (by 1985) to supply thermal energy 821 MW_t (2.8 X 10^9 BTU.hr.), as well as as retrofit Essex Unit 1 (by 1995) to supply 226 MW_t (0.772 X 10^9 BTU/hr.) to combined communities mentioned above and neighboring areas.

Figures 5, 6A and 6B provide additional details on Scheme #3. Schemes #1 and #2 are proposed for further evaluation in Phase 2. Ultimately, the system might grow to the extent indicated in Scheme #3.

Figure 6B and Table X present the location and major characteristics of new construction developments in the Hackensack Meadowlands and Newark, New Jersey.

Table XI presents heating load projections for the Hackensack Meadowlands and the other communities mentioned above. Comparison of the available heat from the generating stations studied with the potential thermal loads shows that a 20% saturation of the available thermal loads within 5 miles of the stations would absorb all the available heat. Hence, one can be selective in choosing the buildings to be retrofitted for district heating.

Figure 7 shows monthly average and peak district heating loads compared with PSE&G gas sendout. The two sets of curves are similar since they are equally dependent on ambient temperature. Worth noting is the low utilization of the district heating system during the summer. Indeed, the system annual load factor is 28%. It is clear that raising this load factor by means of seasonal thermal storage, cooling and serving industrial process loads (low pressure steam or hot water) would improve the economics of the system.

IV. ECONOMIC EVALUATION

The economic evaluation required that estimates be made of capital expenditures, operating and maintenance costs and other expenses and credits associated with the construction and operation of a system to provide thermal services. A basic premise followed in allocating the costs and conducting the economic analysis was that the PSE&G electric and gas customers would not be penalized by the district heating and cooling operations.

The principal capital expenditures associated with the district heating and cooling system are:

- Power plant retrofit cost including backup and peaking boilers
- Transmission and distribution system including booster substations and storage facilities, as required
- Conversion and metering equipment at customer's end

- Electric capacity penalty from the decrease in electric generating from a retrofitted unit

- General overheads associated with the capital expenditures

Major operating and maintenance (O&M) costs include:

- O&M associated with the plant retrofit and any new equipment for thermal services

- O&M increase resulting from the increased operation and fuel use of the dual function plant

- O&M associated with the T&D network and customer equipment

- General and administrative charges associated with the O&M costs

Other expenses and credits include:

- Penalty for forced operations of the less efficient or retired electric generating units

- Capacity credit for reactivation of retired electric capacity

- Tax changes, depreciation, exemptions and benefits

Table XII presents the approximate costs of the principal elements of the district heating system schemes considered in the study.

The economic analysis involved the calculation of annual revenue requirements on the basis of conventional financing and pollution control bonds (tax free bonds), for the three commercialization schemes previously described.

The assumptions used in the economic analysis include:

- Oil escalation rates of 3% and 10% above general inflation rate

- Fuel costs based on PSE&G's economic dispatch of electric system with and without district heating. This assumes utility fuel prices per PSE&G experience and forecasts and alternate fuel prices according to customer survey results and accepted forecasts

- Capacity penalty costs provided by PSE&G based on cost of replacement capacity

- Capital, operating and maintenance costs as shown in Table XII
- Overhead costs calculated using 29.2% of total capital costs excluding Allowance for Funds Used During Construction (AFUDC) and working capital
- AFUDC based on 8% annual rate for an 18-month construction period compounded semiannually
- Working capital defined as 12.5% of fuel and other O&M plus 1% of distribution plant
- Administrative and General (A&G) expenses based on 46% of other O&M excluding fuel costs
- Customer expenses of $14.21/customer as for gas customers
- Book life: 33 years. Tax life: 22.5 years
- Income tax and deferred tax rates: 46%
- Depreciation for tax purposes: sum-of-years digits
- Deferred Federal Income Tax (FIT): normalized between Straight Line (SL), book and Acc. Tax Depreciation
- Gross Receipts Taxes (13.9%) excluded
- Investment Tax Credit (10%) normalized over 22.5 years
- Insurance rate: 0.1%
- Interest charged to construction: none
- Conventional Financing cost of capital:

Rate (%):	8.6 Debt/	8.87 Preferred/	13. Common
Ratio:	0.47 Debt/	0.13 Preferred/	0.4 Common

- Pollution Control Financing cost of capital:

Rate (%):	6.6 Debt/	0.0 Preferred/	0.0 Common
Ratio:	1. Debt/	0.0 Preferred/	0.0 Common

  Equity Penalty to compensate for departure from optimum corporate debt/equity ratio (See Appendix 2.6.2-4A for explanation and Appendix 2.6.2-4B for calculation.)

Table XIII shows the average district heating energy costs for the three schemes selected for this project, for the years 1985, 1990, and 1995. The results show that Scheme #1 has the lowest revenue requirement, Scheme #2 the highest and Scheme #3 is in-between. This outcome reflects the fact that Hudson #2 is an efficient coal-fired unit supplying an area with new building construction. Essex is a less efficient oil-fired unit supplying an area with established buildings which will need retrofitting of existing space and water heating equipment.

Especially when we consider the dramatic increase in fuel oil costs for home heating since the study began, these figures indicate, to the first approximation accuracy justified by the Phase 1 study, that there is a distinct possibility that district heating could be successful as a competitive form of heating for buildings, and provide an adequate rate of return to the utility.

Cost allocation methods of utilities with operating district heating and cooling systems were reviewed. The tariff conditions and rate design philosophy for district heating and cooling were examined in a preliminary way and will be developed further in Phase 2 of this study.

V. INSTITUTIONAL ASSESSMENT

District Heating and Cooling (DH/C) has not been previously practiced either in the PSE&G territory or in the State of New Jersey. Accordingly, a number of institutional questions were explored with the results outlined:

1. <u>Extent and effects of state and/or local utility commission regulation.</u>

   The New Jersey Board of Public Utilities (NJBPU) has statutory authority to regulate DH/C services as any other utility services. New codes or statutes may however be required, in particular, to promote market penetration of DH/C and to achieve a proper balance of its benefits vs. costs.

2. <u>Easements, Franchises and Zoning Ordinances</u>

   The installation and operation of a DH/C distribution network will require easements, franchises, street opening and building permits, as well as land acquisition and possibly zoning variances, involving local and state authorities and private owners.

   Statutes exist which allow support of NJBPU utility actions to obtain easements, condemnation and power of eminent domain to provide utility services. In general, the power to consent or to overrule rests with the NJBPU or municipality involved.

3. Plant Siting Laws

Power plant siting laws which apply to new plants do not apply to the plant retrofitting for DH/C. However, the New Jersey Department of Environmental Protection (NJDEP) and the New Jersey Department of Energy (NJDOE) may attempt to exercise siting jurisdiction when the retrofit involves a substantial change in the operation of the existing plant. New plants for DH/C, including substations, will be governed by the New Jersey Coastal Area Facility Review Act, the NJDOE Act and local zoning ordinances.

4. Environmental Regulations

The power plants considered for retrofitting to provide DH/C services are located in an area where the following regulations are applicable.

Water

- Wetlands Act -- concerns the disturbance of mapped coastal wetlands
- Riparian Statutes -- concern the construction in lands subjected to tide action
- Waterfront Development Law -- concerns any development along waterfront areas
- Water Quality Programs -- concern permits involving discharges and water quality
- Others -- concern stream encroachment, flood hazards, wild and scenic rivers and recreational areas

Air

- New Jersey Air Code -- requires the application for a permit to use certain combustion equipment and possibly retrofit power plants for DH/C
- Federal Air Quality Regulations -- concern the prevention of significant deterioration in "clean-air areas" and trade-offs in emissions from contiguous sources in "violating areas"
- Fuel Use Act -- concern the use of oil vs. coal for certain units

In general, the implementation of district heating and cooling is thought to be environmentally beneficial but local and far field effects will need careful examination.

5. Intra Company Factors

Under the New Jersey Business Corporation Act, PSE&G finds itself empowered to engage in the construction, ownership, and/or operation of a DH/C system. Existing statutes suggest that the DH/C service would have to be provided to all who desire it and are located within the designated DH/C territory.

In general, a decision by PSE&G to own and operate a DH/C system would require that the DH/C project meet the normal Company criteria in investment decision-making. These criteria include: engineering soundness and acceptable impact on existing operations, economic advantages demonstrated by the expected return on investment, availability of capital, legal and regulatory acceptability, compatibility with labor unions and satisfactory agreements with customers. The latter factor will require a detailed analysis of costs and structure of appropriate thermal energy supply rates.

VI. SUMMARY

Statistical load estimates were made, based on U.S. Census and other tabulated data and PSE&G information, of potential thermal loads within 10 miles of each of 8 PSE&G fossil-fired steam generating stations. Based on examinat of generating unit heat balances and other engineering dat preliminary retrofit schemes were devised and estimates made of the available steam which would be extracted. It was determined that sufficient load existed within 5 miles of most stations to far exceed the stations' heat supply supply capability. Based on this information and plant visits, four stations (Essex, Kearny, Hudson, and Bergen Generating Stations) were selected for more detailed study.

An examination of alternate heat transport media indicated that hot water at a 290°F sendout and 170°F return temperature was the preferred method. Detailed retrofit schemes and costs were developed for the four selected generating stations. A field survey of potential industrial, commercial and high-rise residential customers was made. Data were gathered on heating and air air conditioning plant type, fuel usage and prices, thermal needs, growth plans and preferred payback period for capital investments.

Because of certain unknowns concerning the feasibility of retrofitting Kearny Generating Station, three distributions schemes were further developed:

Scheme #1 - Hudson Units 1 & 2 supplying thermal services to the Hackensack Meadowlands Area and Jersey City, New Jersey.

Scheme #2 - Essex Unit 1 - supplying thermal services to the City of Newark, New Jersey

Scheme #3 - Hudson Units 1 & 2 and Bergen Units 1 & 2, supplying the entire Hackensack Meadowlands Area, Jersey City, and Hoboken, New Jersey. Essex 1 supplying the City of Newark

Detailed schematics of the proposed distribution systems were drawn and costs estimated for the power plant retrofit, piping distribution schemes and the conversion schemes at the consumer's end. The results from previous tasks were then used in economic analyses to determine the cost of District Heating/Cooling to customers, its competitiveness with alternate fuels and the potential the potential scarce fuel saving of the Demonstration Project. A PSE&G load dispatch computer program was used to predict the effect of district heating on fuel burned by the utility and thermal customers over a typical annual operating cycle.

VII. CONCLUSIONS

Preliminary cost estimates indicated that high density loads (industrial, commercial, high-rise apartments) were the most economically favorable. Multiple dwellings showed higher per-unit capital costs than high-rise apartment buildings, and single family homes showed the highest cost. For single family homes, the carrying charges on the branch distribution portion of the district heating system (not including plant retrofit, long distance transmission or customer conversion system) would exceed current heating bills, bills, thus removing single family homes from further consideration. The economics of district heating services for concentrated load centers appears to be competitive enough to warrant further detailed analysis.

In summary, results of Phase 1 show that new construction developments offer the most favorable conditions for implementation of district heating and cooling services. However, communities with a high concentration of population and, in particular, high rise residences and offices offer the potential of building retrofitting to accept thermal services from centralized sources.

A preliminary assessment of institutional factors, related to a District Heating/Cooling Project was conducted through contacts with regulatory agencies, municipalities, potential customers and internal Company departments. The factors examined include: rates and utility commission regulation, legal requirements for project implementation, tax laws, environmental regulations, construction permits, corporate charter restrictions and the effect of a statutory mandate to serve all demands. No major obstacles associated with institutional factors have been found.

A number of important technical economic and institutional issues will require further examination and a clearer resolution in Phase 2 of the Demonstration Program. Because PSE&G is a summer peaking utility and member of of the Pennsylvania-Jersey-Maryland (PJM) power pool, the selected units derating, production costs, operation and maintenance schedules will receive particular attention.

These conclusions may be summarized briefly as follows:

- PSE&G Northern stations have best combination of heat supply capability and nearby high density thermal loads. District Heating offers greater near term potential than District Cooling.
- Market potential for district heating/cooling was found in new construction developments and in existing urban areas with high density industrial, commercial and high-rise residnetial thermal loads.
- Utilization of heat supply capability of plants would require only 20% market penetration of thermal load within 5 miles of plants.
- Hot water distribution system on European model appears best method of heat transmission.
- Economics were marginally favorable. Considering uncertainties and that technical design was good but not optimized, more detailed study in Phase 2 is justified.
- Annual load factor was low (28%). To improve utilization of capital investment and reduce unit heat costs, Phase 2 must consider methods of raising load factor (cooling, industrial process load, storage, etc.)
- Optimized technical design is required in Phase 2 to minimize costs

- Refined costs and economic analysis are needed to reduce uncertainties
- Staged system development is essential to keep capital outlays in step with load/revenue growth
- Analysis of legal, tax, regulatory, environmental and other institutional factors revealed no major obstacles
- PSE&G is sufficiently confident in the Demonstration Project to proceed to Phase 2 and share in the costs of that effort.

LIST OF PRINCIPAL ABBREVIATIONS

AFUDC:	Allowance for Funds Used During Construction
BTU/hr:	British Thermal Units/hr.
^{o}C:	Degrees Celsius
DH/C:	District Heating and Cooling
^{o}F:	Degrees Fahrenheit
GW:	Giga (10^9) Watts
km:	kilometer
kW:	kilo (10^3) Watts
m:	meter
MJ:	Mega (10^6) Joules
MW_e:	Mega (10^6) Watts (electrical)
MW_t:	Mega (10^6) Watts (thermal)
NJDEP:	New Jersey (State) Department of Environmental Protection
NJDOE:	New Jersey (State) Department of Energy
O&M:	Operating and Maintenance
Pa:	Pascals (Newtons/square meter)
PSE&G Co.:	Public Service Electric and Gas Company
psia:	Pounds (force)/square inch (absolute)
PVC:	Polyvinyl Chloride
sec:	second
T&D:	Transmission and Distribution
USDOE:	United States Department of Energy
W:	Watts

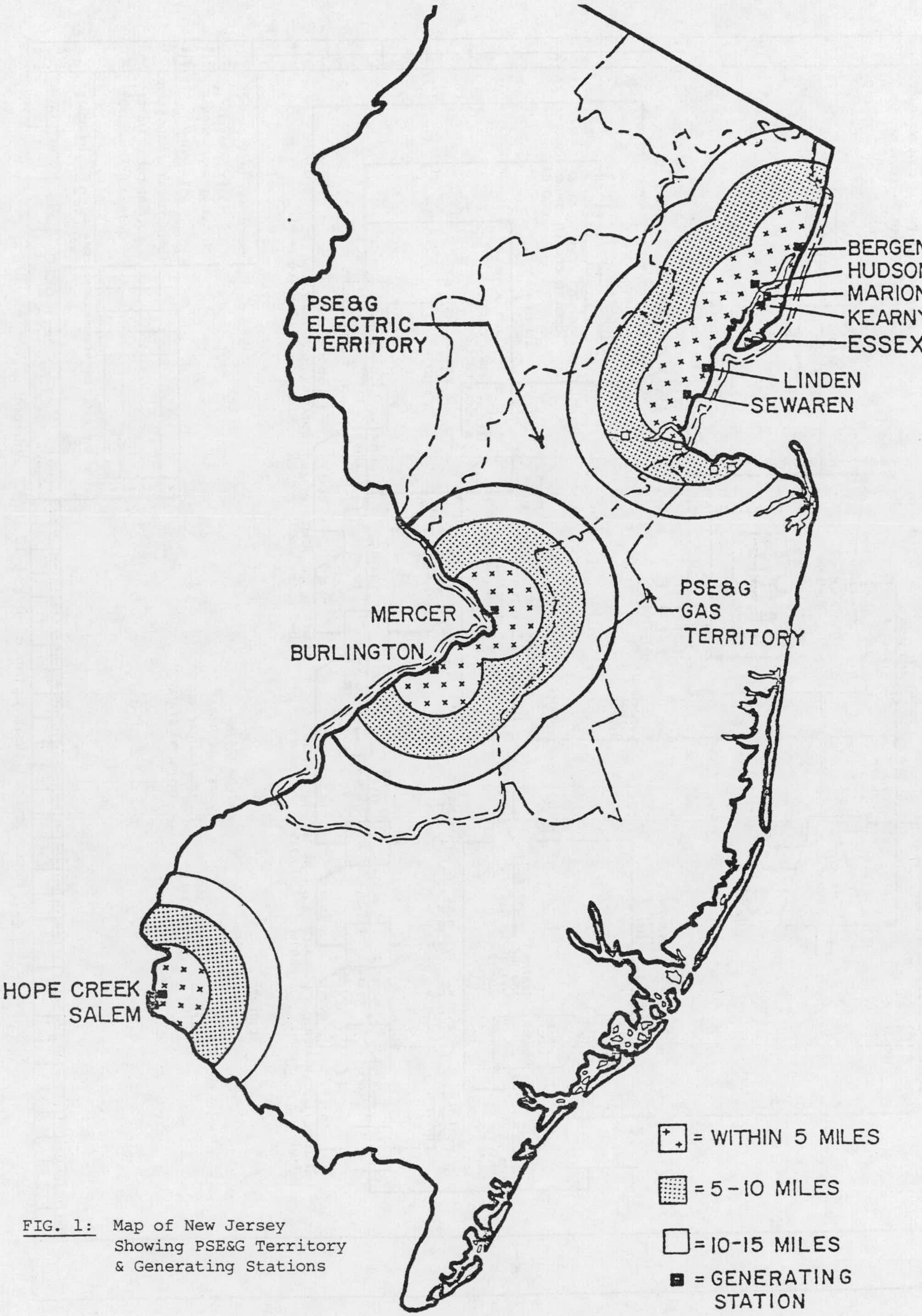


FIG. 1: Map of New Jersey Showing PSE&G Territory & Generating Stations

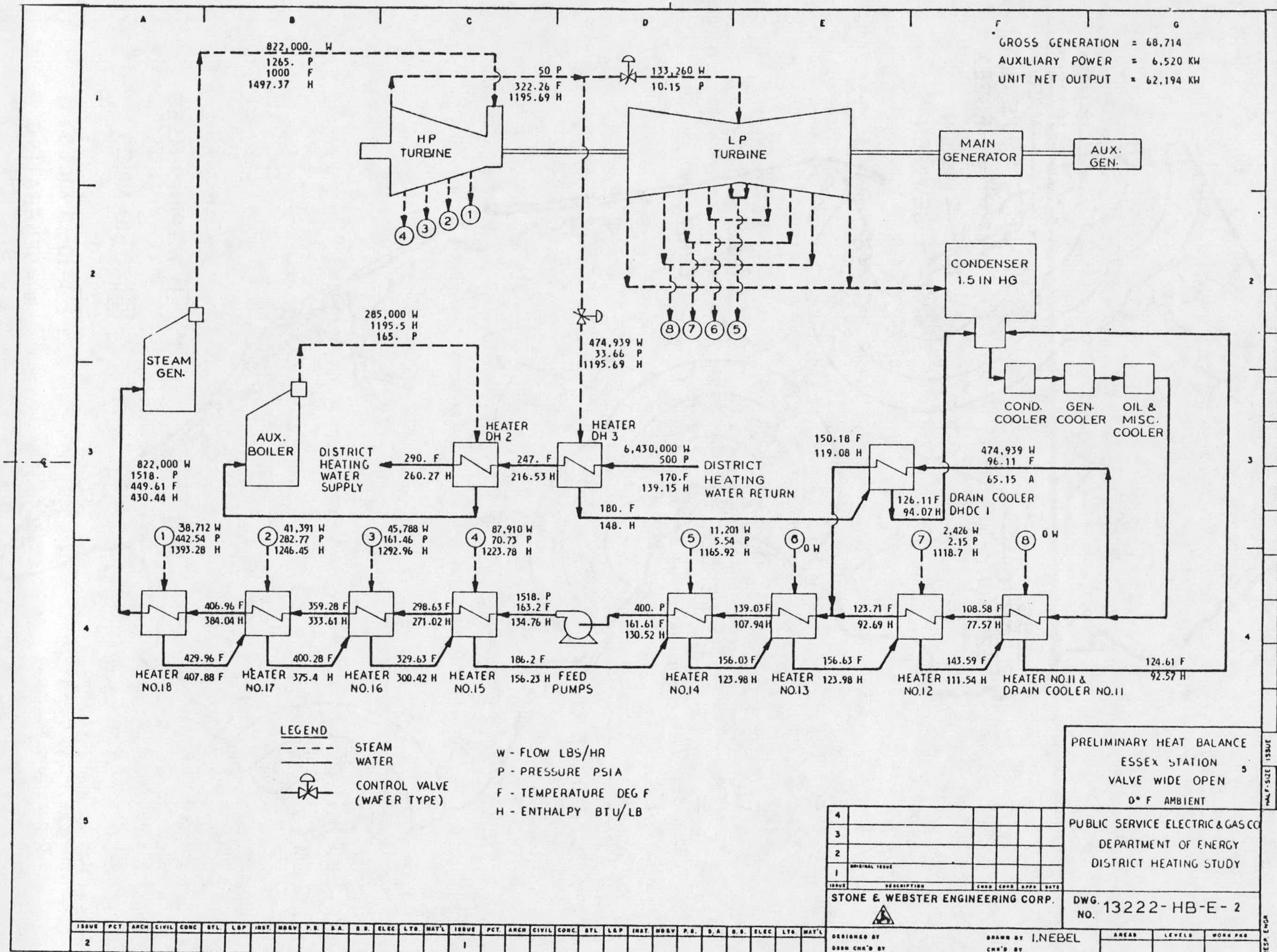


FIG. 2: Essex Unit 1 Heat Balance -0°F (-17.78°C) Ambient

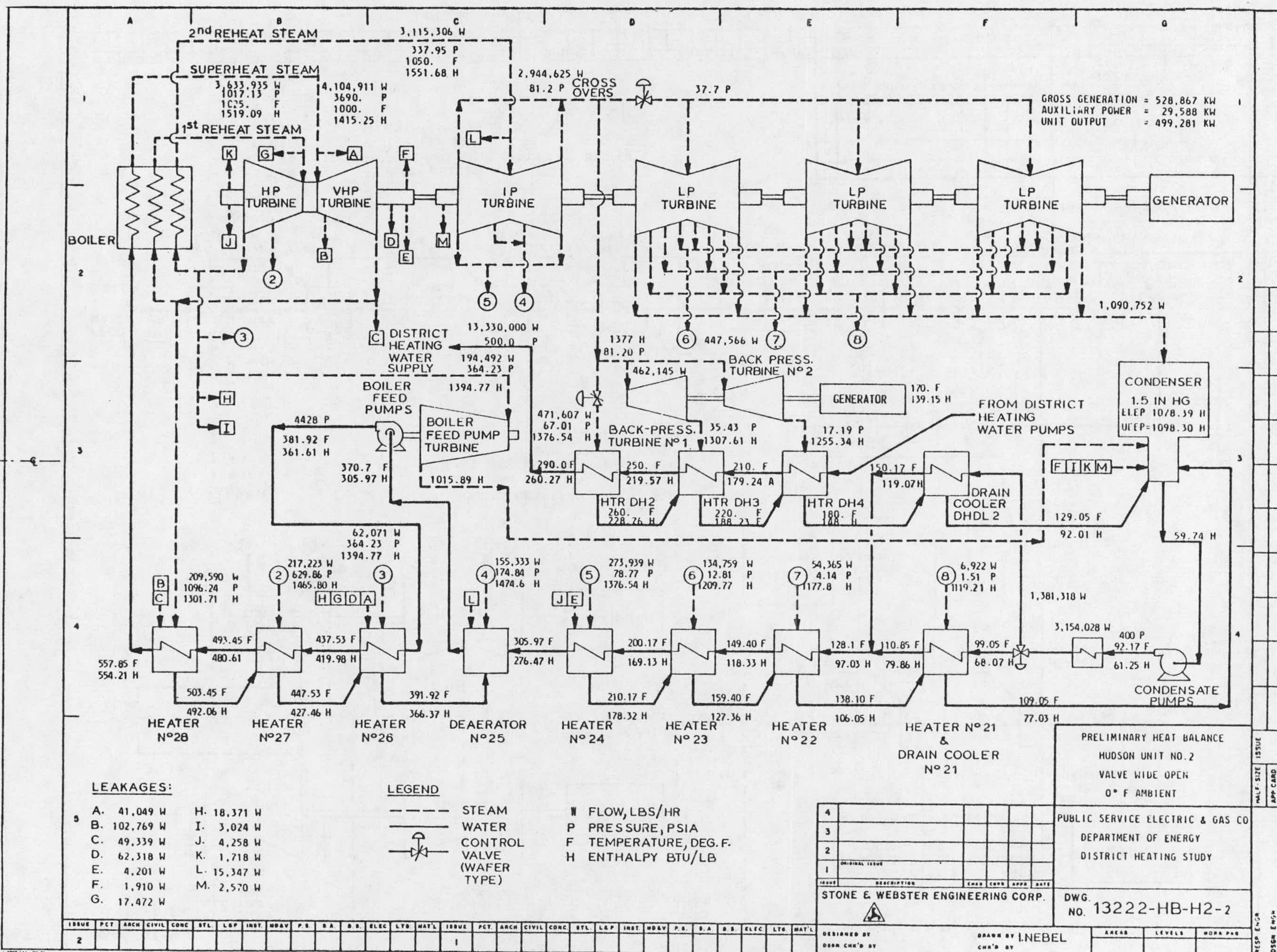


FIG. 3: Hudson Unit 2 Heat Balance -0°F (-17.78°C) Ambient

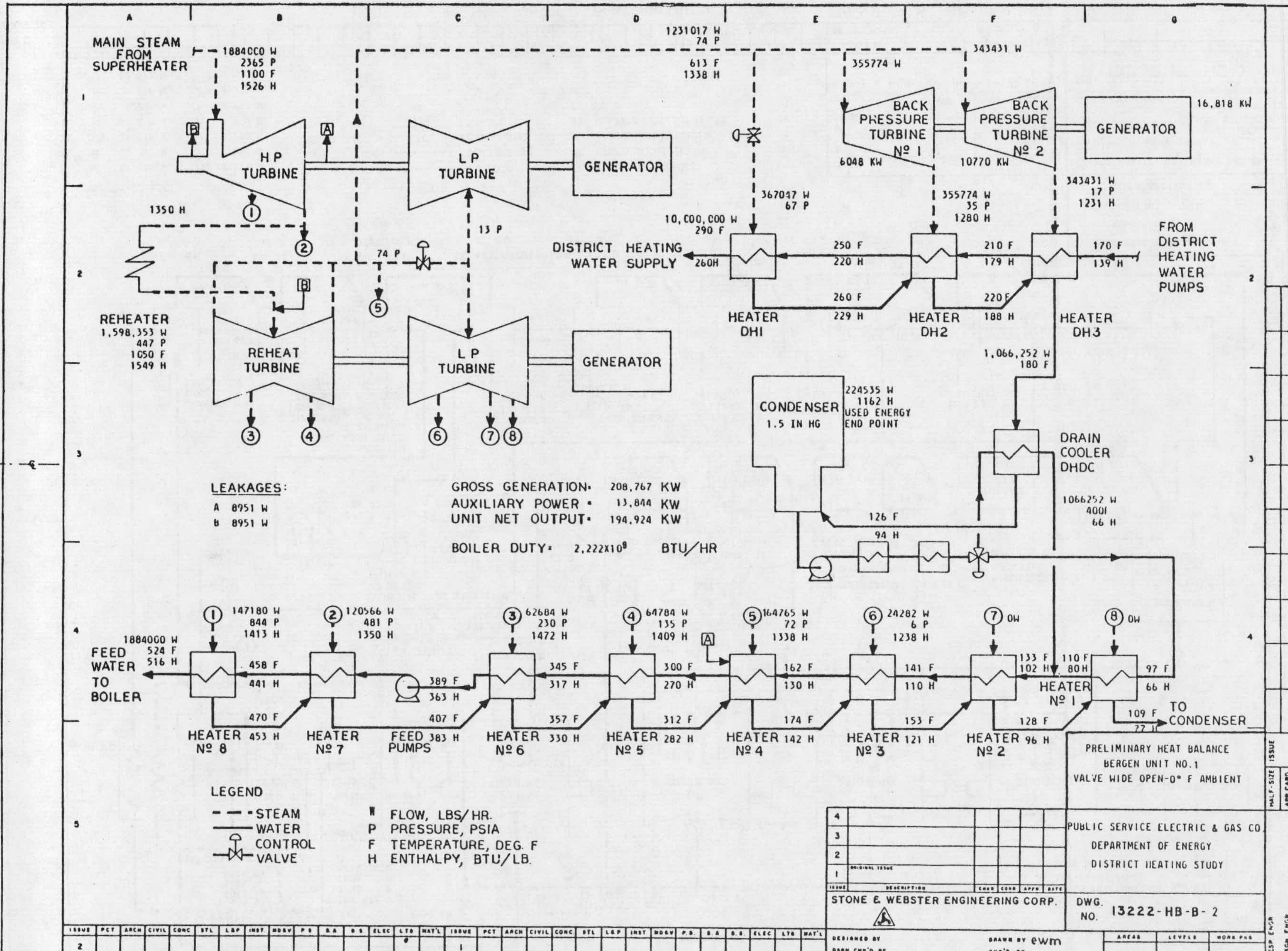


FIG. 4: Bergen Unit 1 Heat Balance -0°F (-17.78°C) Ambient

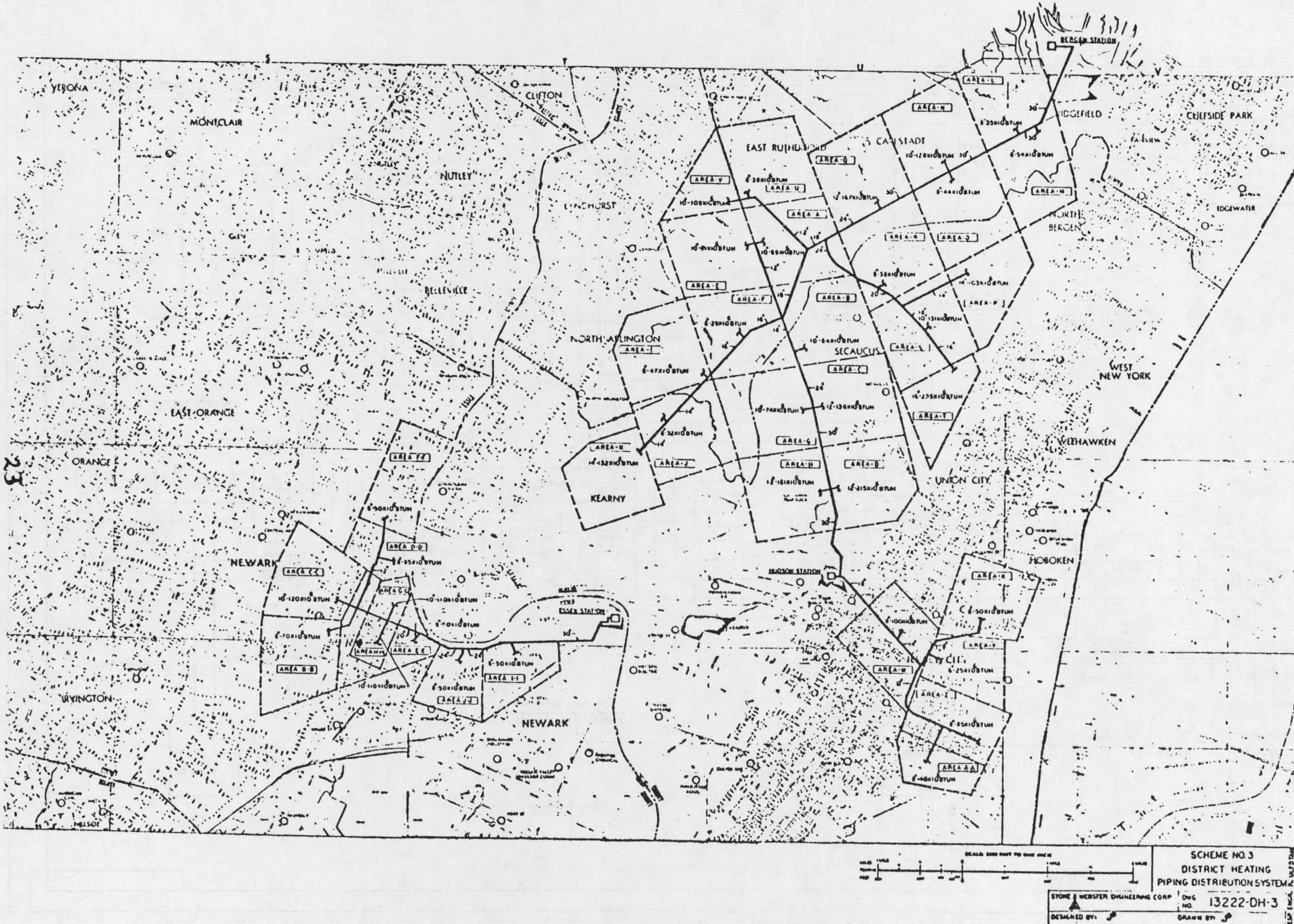


FIG. 5: District Heating Distribution System - Scheme #3

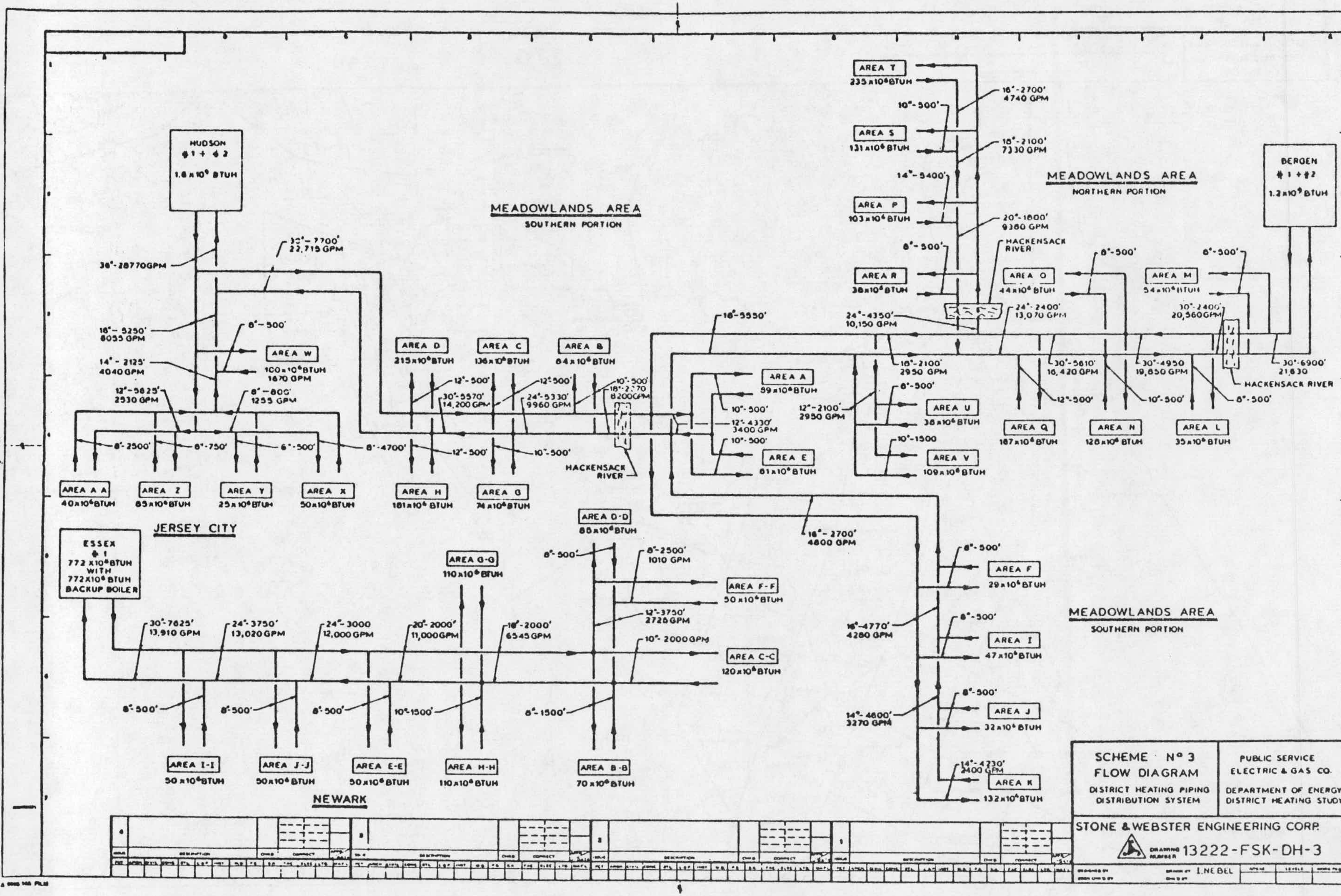


FIG. 6A: District Heating Flow Diagram - Scheme #3

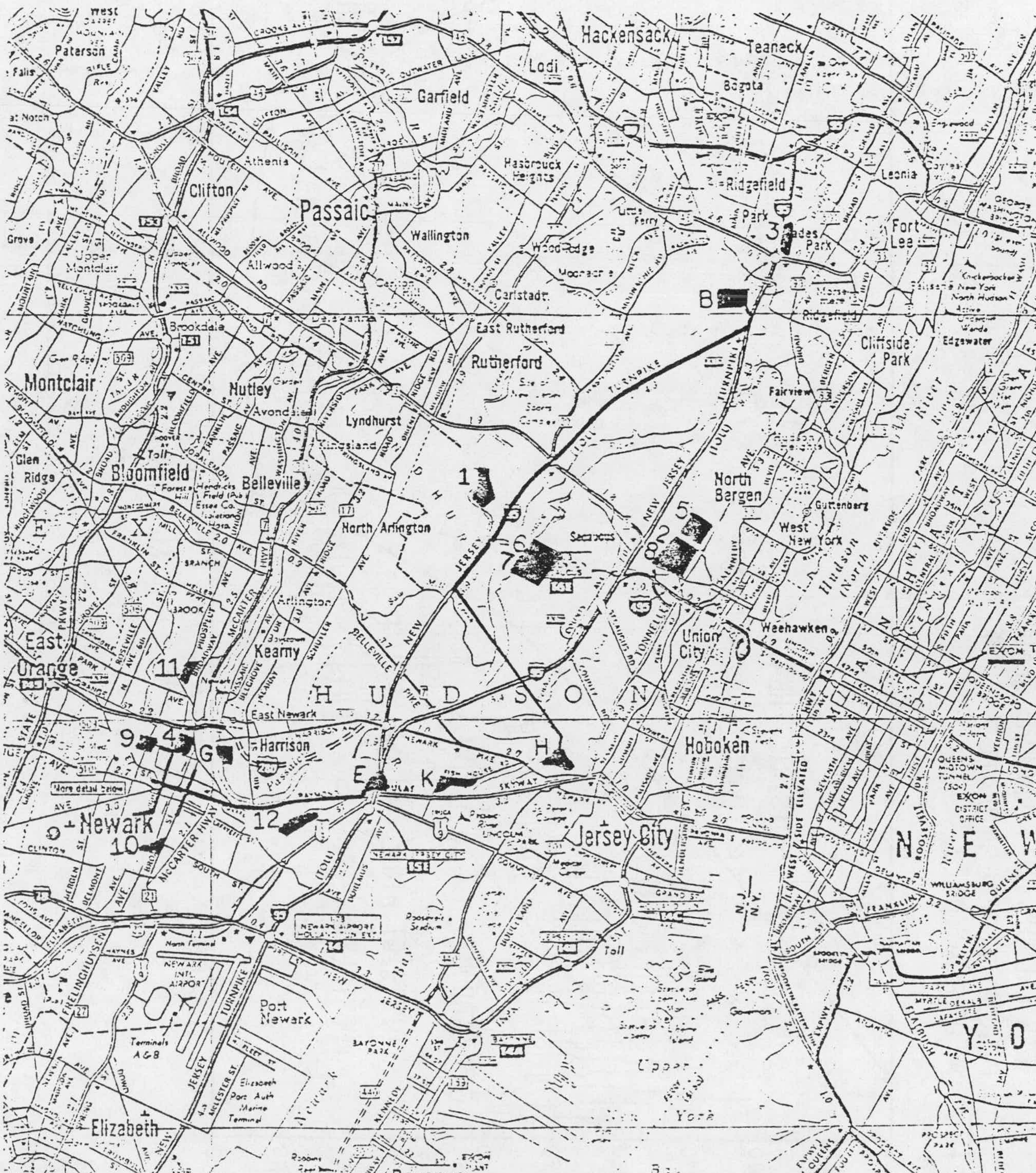
FIG. 6B: Preliminary Schematic - Candidate Plants for Retrofitting and Principal Mains for Thermal Supplies: Assumes Emphasis on New Developments at the Hackensack Meadowlands and the City of Newark

LEGEND:

1. Squitieri Assoc.
2. Sterns Dpt. Store
3. Ridgefield Park
4. One Wash. Park Assoc. (UDAG)
5. Hartz Mtn. Ind.
6. Hartz Mtn. Ind.
7. Hartz Mtn. Ind. (Harmon Cove III)
8. Hartz Mtn. Ind.
9. Pruco, Inc./Aspen Group
10. UDAG New Newark
11. St. Lucy's Dev. Corp.
12. Ironbound River Plaza

E. Essex Station
K. Kearny Station
H. Hudson Station
B. Bergen Station
G. Harrison Gas Plant

SCALE 1" ≃ 2 Miles



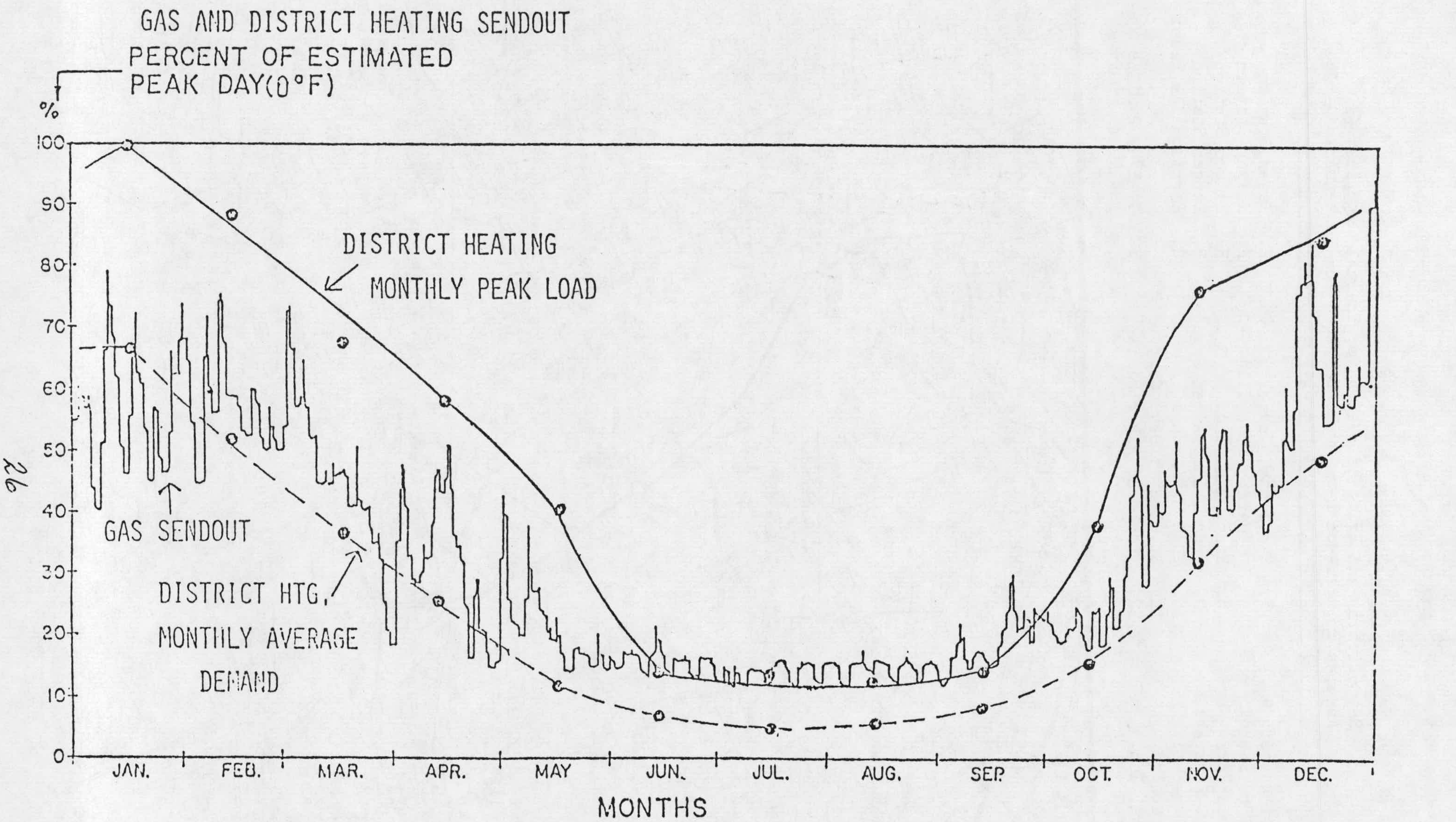


FIG. 7: Gas Sendout Vs. District Heating Load

Table I

ELECTRIC AND THERMAL CAPACITY OF
GENERATING STATIONS CONSIDERED FOR RETROFITTING

	Essex #1	Kearny #7,8	Bergen #1,2	Hudson #1	Hudson #2
Unit Type	Non Reheat	Reheat	Reheat	Reheat	Reheat
Date in Service	1947	1953	1959/60	1964	1968
Base Fuel	Oil	Oil	Oil	Oil	Coal
Gross generation (MW_e) No District Heating	100	144	297	410	652
Gross generation (MW_e) With District Heating[a]					
0°F (-17.78°C)	69.9	92	209	288	529
30°F (-1.11°C)	69.6	117	246	340	585
50°F (10°C)	82.4	128	267	369	612
New electric generation (MW_e) by back pressure turbine					
0°F	--	18.1	16.8	26	26
30°F	--	20.0	19.7	29	29
50°F	--	12.0	12.0	17	17
District Heating Capacity 10^6 BTU/hr (MW_t)					
0°F	772(226)[b]	588(172)	1200(352)	1596(468)	1596(468)
30°F	495(145)	377(110)	770(226)	1024(300)	1024(300)
50°F	292(86)	222(65)	454(133)	604(177)	604(177)
Ratio: Thermal Energy Gain (MW_t) / Electric Energy Loss (MW_e)					
0°F	7.4[b]	3.3	4.0	3.8	3.8
30°F	4.7	4.1	4.4	4.3	4.5
50°F	4.7	4.1	4.4	4.3	4.5

[a] Includes new electrical generation by back pressure turbines

[b] Includes auxiliary steam boilers at Essex

Table II

FUEL USE PATTERNS FOR HEATING AND DOMESTIC HOT WATER OF SELECTED CITIES IN NEW JERSEY[a]

	NY-NE-NJ NJ Portion[b]		Jersey City		Newark		Union City	
	No. of Units	%	No. of Units	%	No. of Units	%	No. of Units	%
All Year Housing Units	1,478,442	100	91,884	100	127,314	100	21,247	100
Heating Fuel -								
Utility Gas	618,999	41	37,747	41.1	38,938	30.6	6,631	31.2
Fuel Oil	755,018	51.1	45,650	49.7	73,422	57.7	13,138	61.8
Coal	18,292	1.2	1,094	1.2	2,909	2.3	106	.5
Electric	30,576	2.1	1,159	1.3	1,837	1.4	450	2.1
Other	20,527	1.4	2,152	2.3	3,879	3.1	475	2.2
Water Heating -								
Utility Gas	804,659	54.4	44,564	48.5	48,935	38.4	8,197	38.6
Fuel Oil	522,519	35.3	36,876	40.1	62,974	49.5	10,849	51.1
Coal	5,880	.4	689	.7	1,254	1.0	71	.3
Electric	69,408	4.7	953	1.0	2,567	2.0	620	2.9
Other	40,986	2.8	4,720	5.1	5,255	4.1	1,063	5.0
Washer & Mech. Dishwasher[c]	985,139	66.6	46,454	50.1	53,648	42.1	9,342	44.0

[a]Reference: Standard Metropolitan Statistical Areas (SSMA) Places of 50,000 Inhabitants or More.

[b]New Jersey portion of New York-Northeast-New Jersey SSMA.

[c]Number and % of population with clothes washer and mechanical dishwasher.

Table III

Type of Residential Living Unit in PSE&G Territory

	Electric[a]		Gas[b]	
	%	Number	%	Number
Single Family House	59.3	860,764	64.9	744,330
Garden Apartment	11.9	172,733	7.6	87,163
High-Rise Apartment	4.6	66,771	3.9	44,729
Other (Two or more living units in one building)	24.2	351,273	23.6	270,666
TOTAL	100.0	1,451,541	100.0	1,146,888

[a]Based on 1,451,541 average number of residential electric customers billed monthly in the 12-month period ended December 1976.

[b]Based on 1,146,888 average number of residential gas customers billed monthly in the 12-month period ended December 1976.

Table IV

PSE&G Residential Customers' Survey (1976)

(Electric -- 18,000 responses)[a]
(Gas -- 15,000 responses)[a]

Type of Building	Single Family		Garden Apt.		Two or More Apts.		Hi-Rise	
	Elec.[b]	Gas[b]	Elec.	Gas	Elec.	Gas	Elec.	Gas
Age of building								
up to 2 yrs.	1.5	1.2	2.7	1.6	.9	.7	3.4	.7
3 to 5 yrs.	2.8	3.4	9.2	4.6	1.9	1.4	4.2	.3
6 to 10 yrs.	6.0	7.3	19.8	6.3	4.0	3.1	6.2	.9
11 to 20 yrs.	23.0	24.2	20.4	14.5	8.3	7.2	13.3	6.7
over 20 yrs.	58.5	56.0	29.2	48.3	56.1	57.5	44.5	56.4
Age of heating system								
up to 2 yrs.	6.4	5.8	4.2	3.4	5.0	4.2	4.6	2.9
3 to 5 yrs.	9.4	9.7	10.0	7.0	7.5	7.1	4.4	1.7
6 to 10 yrs.	15.4	16.8	16.3	7.4	12.9	13.0	6.4	2.9
11 to 20 yrs.	32.6	33.6	13.5	11.7	19.6	18.2	9.5	5.7
over 20 yrs.	26.1	24.3	9.7	17.0	16.2	16.6	14.8	19.0
Type of heating system								
Forced warm air	43.4	46.0	13.0	9.5	9.9	8.7	4.4	1.9
Hot water/steam	50.8	48.8	68.9	74.4	76.1	76.8	72.8	80.6
Other	3.4	2.8	10.0	7.5	7.4	7.5	9.6	6.7
Space heating by gas	56.4	67.8	25.9	23.6	38.2	39.2	9.7	10.6
oil	41.5	31.0	53.3	64.3	55.7	55.1	71.7	77.8
electric	1.1	.3	7.4	.7	1.4	.5	5.1	.6
Water heating by gas	74.7	85.9	16.7	22.0	45.7	47.3	5.7	6.7
oil	18.6	11.1	13.9	17.1	24.6	23.8	19.0	21.3
electric	4.5	1.2	5.5	.7	1.2	.3	2.2	.2
none	.9	.6	.6	.4	.6	.6	1.0	.7
landlord	.3	.3	59.1	.6	24.6	24.6	64.2	63.5

[a]Where a group does not add up to 100%, data was not received from that portion of total respondents.

[b]Type of PSE&G customer (electric or gas)

Table V

SURVEY SAMPLE SIZE

Customer	Sample Size Number	Sample Size Percent of Total
Commercial - Small	115	30
Commercial - Large	36	9
Industrial - Small	145	38
Industrial - Large	82	21
Residential	4	1
Multiuse	2	1
Total	384	100

Table VI

BUILDING FLOOR AREA

Customer	Size of Floor Area Total	Size of Floor Area Per Customer
	(1,000 ft^2)	
Commercial - Small	4,998	75
Commercial - Large	9,627	506
Industrial - Small	4,968	87
Industrial - Large	4,222	302
All Customers	23,815	152

Table VII

ANNUAL AVERAGE HEATING FUEL BILL PER CUSTOMER
($000)

	Oil #2	Oil #4 & #5	Oil #6	Natural Gas	Average
Commercial - Small	16.0	36.6	56.3	18.3	23.6
Commercial - Large	40.7	95.7	-	73.2	66.5
Industrial - Small	16.3	43.1	16.5	24.2	24.6
Industrial - Large	79.0	110.3	37.5	.72.3	77.9

Table VIII

Tri-State Regional Planning Commission
1970 Housing Units and Square Footage Estimates Within Five-Mile Radii of Given Generating Station

Generation Station (1)	Housing Units (2)	Floor Area (00 sq. ft.) Non-Residential (3)	Residential (4)	Other (5)	Total (6)
North Bergen	195,898	1,838,640	2,077,707	23,309	3,939,726
Essex	326,617	3,849,661	3,468,107	149,970	7,467,738
Linden	166,568	1,922,154	1,759,807	37,514	3,719,475
Sewaren	83,803	1,001,039	880,531	15,634	1,897,204
Total*	772,886	8,611,494	8,181,952	226,427	17,024,143
Total#	649,927	6,815,001	6,753,044	192,095	13,730,733

* Includes area of double counting.
# Avoids double counting.

Table IX

Floor Area Projections For Non-Residential and "Other" Structures (000,000 sq. ft.)

Development Type	1975	1980	1985	1990	1995	2000
Non-Residential*	727.8	777.2	830.0	886.4	946.6	1010.9
"Other" #	19.5	19.8	20.1	20.4	20.7	21.0
Total	747.3	797.0	850.1	906.8	967.3	1031.9

* Assumes growth rate of 1.323% annually.

Assumes growth rate of 0.301% annually.

Table X

District Heating and Cooling - New Developments in Area Considered for Thermal Services

Page 1

	Developer	Description (Qnty)	Value of Project Location (ACRES)	Area (Sq. Ft.)	Project Schedule
1.	Squitieri Assoc.	Hotels (2-300 Rm) Condominium (1000) Shopping Center	$300 million HMDC Rutherford (299)	2,400,000 S.F.	Begin 1980 (Stages)
2.	Sterns Dpt. Store	Department Store	HMDC No. Bergen	150,000 S.F.	-
3.	Ridgefield Park	Hotel/Conv. Ctr. (1000) Office Bldgs. (6)	$100 million/ Ridgefield Park (60)	-	-
4.	(UDAG) One Wash. Park Assoc.	Office Bldg.	$39 million Newark (1)	-	-
5.	Hartz Mtn. Ind.	Movie & TV Complex	multi-million HMDC No. Berg./Sec. (40)	203,000 S.F.	-
6.	Hartz Mtn. Ind.	Apt. Units (1480)	HMDC Secaucus	-	-
7.	(Harmon Cove III) Hartz Mtn. Ind.	Hi-Rise Condos (1380)	$80 million HMDC Secaucus (22)	-	Begin Oct. 1979 (482 Units) 3 stages total
8.	Hartz Mtn. Ind.	Alexanders, Inc. R. H. Macy & Co.	HMDC No. Bergen	200,000 S.F. 225,000 S.F.	-
9.	Aruco, Inc./ Aspen Group	Housing (200)	$5 million Newark	-	-
10.	UDAG New Newark	Shopping Center	$1.3 million Newark (2)	-	-
11.	St. Lucy's Dev. Corp.	Housing (194)	$10.3 million Newark	-	-
12.	Ironbound River Plaza	Condominiums (125) Shopping Ctr.	$17.2 million Newark (41)	-	-

E Essex Station

K Kearny Station

H Hudson Station

B Bergen Station

G Harrison Gas Plant

NOTE: Other developments located in Fort Lee (Fort Lee Executive Park, Century Center), Teaneck (Glenwood Park) and Sports Arena are not considered potential customers of thermal services.

Table XI

Annual Heating Load Projections[1]

(A) Meadowlands only

Annual Heating Load (10^{12} x Btu) Customer:	1985	1990	1995	2000
Residential	0.14	0.28	0.41	0.55
Commercial and Office	0.69	1.29	1.90	2.51
Industrial Small	1.76	2.16	2.88	3.61
Industrial Large	0.12	0.14	0.19	0.24
Total	2.71	3.87	5.38	6.91
Peak (10^6 x Btu/hr)	1,112	1,595	2,220	2,842

(B) Meadowlands excluded

Customer:	1975	1980	1985	1990	1995	2000
			(10^{12} x Btu)			
Commercial - Small	15.56	16.59	17.70	18.67	20.14	21.47
Commercial - Large	1.28	1.36	1.46	1.55	1.66	1.77
Industrial - Small	19.87	21.19	22.62	24.12	25.73	27.45
Industrial - Large	2.82	3.01	3.21	3.42	3.65	3.89
Residential[2]	1.14	1.14	1.14	1.14	1.14	1.14
Total	40.67	43.29	46.13	48.90	52.32	55.72
Peak Load (10^9 x Btu/hr)[3]	16.76	17.84	19.01	20.15	21.56	22.96

Notes:
(1) Weather normalized and based on 65% efficiency factor.
(2) 50,000 Btu/ft^2 is used.
(3) Using 27.7% Load Factor.

Table XII

District Heating System Approximate Costs (1978 $)

	Capital 10^6 $					O&M 10^3 \$/Year[a]				
Thermal Plant										
Hudson 1 & 2	33					280				
Essex 1		15					105			
Bergen 1 & 2				19					160	
Kearny 7 & 8					10					55
Transmission/Distribution										
Hudson (Scheme 1)	46					523				
Essex (Scheme 2)		27					292			
Hudson/Bergen/ Essex (Scheme 3)			109					1,210		
Totals										
Hudson (Scheme 1)[c]	79					803				
Essex (Scheme 2)[b]		42					397			
Hudson/Bergen/ Essex (Scheme 3)[d]			176					1,755		

	Capital 10^3 \$/dwelling		O&M \$/year/dwelling
	Hot Water	Hot Air	
Customer Conversion			
Single Family House[e]	2.3	2.5	Not Available
Four Family House[f]	1	1.3	Not Available
100-Apartment House[g]	.21		53
Commercial[h]	Not Available		52 - 210
Industrial[i]	Variable		52 - 160

a Fuel, storage and pumping costs excluded
b 226 MW_t (772 X 10^6 BTU/hr) Peak Load
c 469 MW_t (1600 X 10^6 BTU/hr) Peak Load
d 821 MW_t (2800 X 10^6 BTU/hr) Peak Load
e 17.6 kW_t (60,000 BTU/hr) /dwelling
f 11.7 kW_t (40,000 BTU/hr) /dwelling
g 5.86 kW_t (20,000 BTU/hr) /dwelling
h 126-79 W_t/m^2 (40 to 25 BTU/hr) / ft^2
i 110 W_t/m^2 (35 BTU/hr/ft^2)

Table XIII

Average District Heating Energy Costs
For the Three Schemes
All Values in 1978 $ per Million Btu[c]

Scheme #1

	1985 3%	1985 10%	1990 3%	1990 10%	1995 3%	1995 10%
C F	11.66[a]	13.59	10.39	16.60	9.83	21.91
T F	9.21[b]	11.12	9.02	15.19	8.99	20.97

Scheme #2

	1985 3%	1985 10%	1990 3%	1990 10%	1995 3%	1995 10%
C F	17.78	20.66	15.06	21.58	14.33	27.28
T F	14.70	17.55	13.33	19.81	13.25	26.12

Scheme #3

	1985 3%	1985 10%	1990 3%	1990 10%	1995 3%	1995 10%
C F	11.66	13.59	11.80	18.67	12.49	25.76
T F	9.21	11.12	9.99	16.80	11.02	24.20

C F = Conventional Financing

T F = Tax Free Financing

[a] Cost breakdown: Plant retrofit 25%, T&D 34%, Fuel 27%, Customer and other 10%, O&M and other 4%

[b] Cost breakdown: Plant retrofit 16%, T&D 22%, Fuel 35%, Customer and other 7%, O&M and other 20%

[c] 1×10^6 BTU = 1.055×10^9 Joules