ENERGY CONSERVATION

COO/4212-1/1

MASTER

# TRENTON ICES

Volume 1. Phase I, Final Report

July 14, 1977

Work Performed Under Contract No. EC-77-C-02-4212

Department of Planning and Development
City of Trenton
Trenton, New Jersey

## ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

### Division of Buildings and Community Systems

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Microfiche $3.00 (domestic)
$4.50 (foreign)

Printed in the United States of America
USDOE Technical Information Center, Oak Ridge, Tennessee

COO/4212-1/1

Distribution Category UC-95d

Trenton ICES
Phase I Report - Volume 1

US ERDA Contract EC-77-C-02-4212

The City of Trenton

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Turner Construction Company
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14 July 1977

ABSTRACT

Phase I Preliminary Design and Evaluation for a Grid Connected Thermally Controlled Integrated Community Energy System (ICES) for the City of Trenton, New Jersey has been carried out. The findings of the study are:

It is technically feasible, utilizing commercially available hardware.

It is economically competitive with conventional alternatives for heating and cooling buildings.

It will produce an overall reduction in fuel consumed of 32 to 43 percent when compared with conventional alternatives for heating and cooling buildings.

It will consume 4 to 9 percent more oil than will conventional alternatives for heating and cooling buildings.

It should be owned and operated by PSE & G. No major institutional impediments have been discovered under this arrangement.

It can provide thermal energy 21 months after the start of Phase II and electrical energy 32 months after the start of Phase II.

This study is site-specific and of a small size project. Its installation will not alter the planned PSE & G capacity expansion program. The econimic evaluation results of the report cannot be extrapolated for numerous co-generation installations that would affect the PSE & G planned capacity expansion program.

On the basis of the above findings, the members of the Phase I Demonstration Team for Trenton ICES analysis are positively disposed toward proceeding with the Phase II design of the plant in order to conclusively test system viability with the ultimate goal of plant construction.

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## BACKGROUND

The Trenton Integrated Community Energy System (ICES) study grows from the national concern to extract the greatest possible useful energy form each unit of scarce fuel consumed. Modern large (thousand megawatt) fossil fuel generating plants have achieved efficiencies as high as 40 percent (useful energy output/fuel energy input). The remaining 60 percent of the heat produced by burning the fuel is released as thermal energy into the environment which serves as a low temperature sink.

The Trenton ICES will generate electricity at lower efficiencies than the large central plant; however, a large portion of the heat discharged by the generating equipment will be captured and used for heating, cooling and domestic hot water. The result of this is that the useful energy output from the ICES plant is about 63 percent of the fuel energy input, representing almost a doubling of fuel utilization.

The trenton ICES plant falls into a general category referred to as co-generation, that is, thermal and electric energy are generated in one complex process. The heat produced by burning fuel is utilized at different temperatures for different uses. Typically, co-generation plants are "electric-controlled," that is, the output of the plant is based on the demand for electrical energy, and the resulting lower temperature heat is utilized to the degree to which there is a demand. However, in most cases, more waste heat is produced than can be used and the excess "waste" heat is simply discharged to the atmosphere.

The Trenton ICES plant is "thermal-controlled," that is, the demand for thermal energy controls the output of the plant and, in turn, the quantity of electricity produced. Since the system is connected to the utility electrical grid, any electricity produced in excess of the demands of the community will be utilized by other customers in the grid, thereby assuring that the total "useful" output of the plant is, in fact, serving some demand. This approach promotes an annual fuel utilization efficiency which much more closely approaches the peak operating efficiency.

The Trenton ICES Phase I work has identified and modeled the energy characteristics of the community which will place the thermal demand on the ICES system; evaluated the technological feasibility of such a plant; examined the institutional mechanisms required to build and operate the plant; compared the economic and energy costs of the ICES plant to those associated with "conventional" approaches to delivering the same services; further firmed commitments from ICES participants and regulating agencies; and proposed a work management plan to implement the ICES demonstration system.

This document summarizes the findings and conclusions of the Trenton ICES Phase I study. The complete results are found in Volume II of this report.

# task I

## preliminary energy assessment

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## 1.1 SITE LAYOUT

Community

The community served by the Trenton Integrated Community Energy System (ICES) plant is shown in Figures 1 and 12. It is comprised of 1,884,025 square feet of floor area in existing buildings, and 1,251,500 square feet floor area of new construction is projected for completion by 1982. This results in a demonstration community of 3,135,525 square feet floor area which the ICES will serve.

There are 18 existing buildings which would be served by the ICES plant. However, since these buildings share several common boiler plants, only four connections to the ICES plant are required. The longest of these connections is approximately 2,000 feet to the Statehouse complex. The total distribution distance to all existing buildings is approximately 3,400 feet.

DEMONSTRATION COMMUNITY

| Existing Buildings | SQ FT |
|---|---|
| Kingsbury I Towers | 280,000 |
| Kingsbury I Lowrise | 74,500 |
| Mercer Co. Detention Center | 160,000 |
| Mercer Co. Courthouse | 130,000 |
| Labor and Industry | 300,000 |
| Health and Agriculture | 144,000 |
| Statehouse Complex | 795,525 |
| | 1,884,025 |

| Proposed Buildings | SQ FT | Construction Start | Construction Completion |
|---|---|---|---|
| Lutheran Arms | 91,500 | 1977 | 1978 |
| Capital Place | 155,000 | 1977 | 1979 |
| Capital Place Commercial | 50,000 | 1978 | 1979 |
| Justice Department | 350,000 | 1978 | 1979 |
| Justice Commercial | 50,000 | 1978 | 1979 |
| Firehouse | 5,000 | 1978 | 1979 |
| Kingsbury II | 200,000 | 1980 | 1981 |
| Civic Center | 100,000 | 1981 | 1982 |
| Dept of Env. Protection | 250,000 | 1981 | 1982 |
| | 1,251,500 | | |

Total: 3,135,525 SQ FT

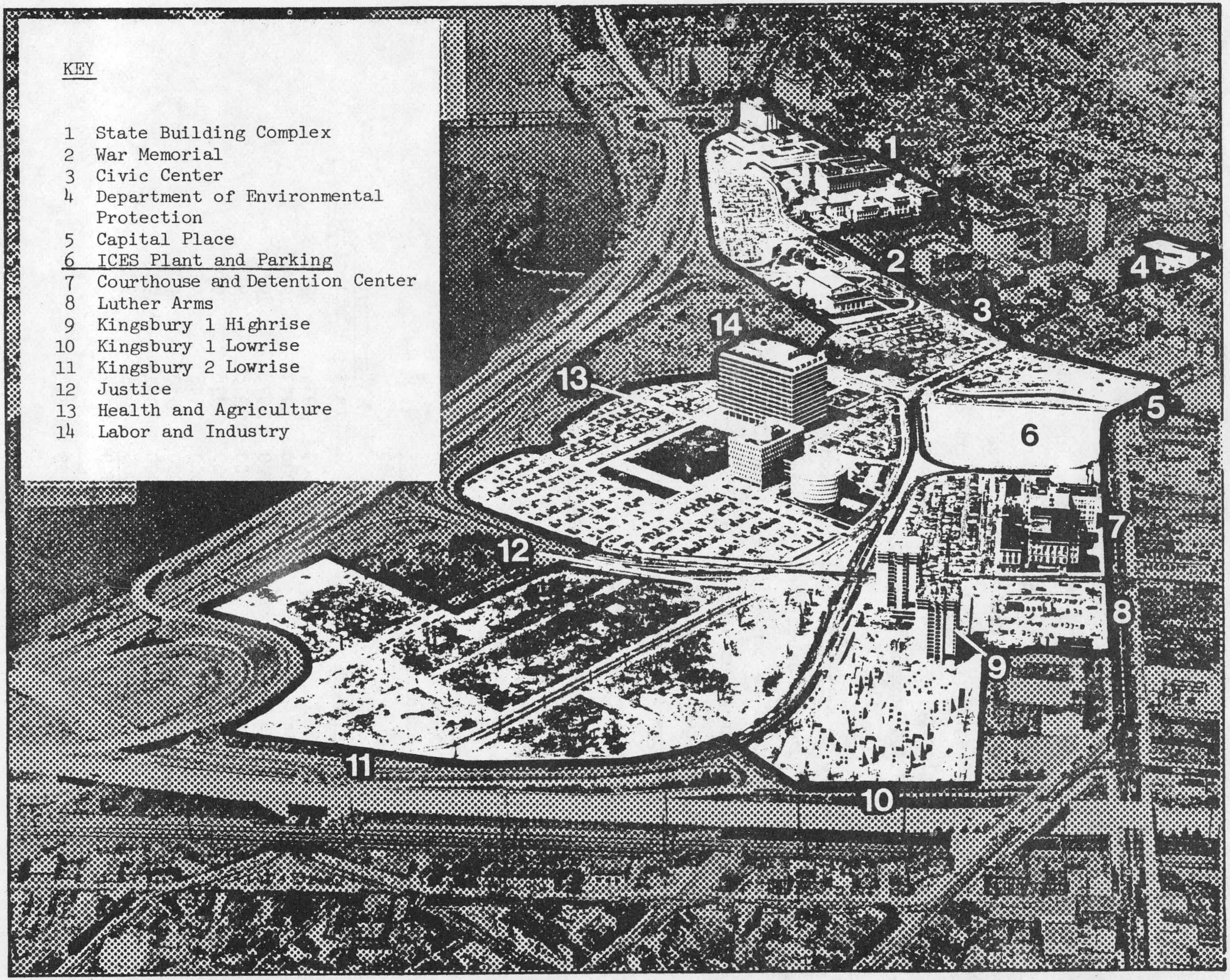

KEY
1 State Building Complex
2 War Memorial
3 Civic Center
4 Department of Environmental Protection
5 Capital Place
6 ICES Plant and Parking
7 Courthouse and Detention Center
8 Luther Arms
9 Kingsbury 1 Highrise
10 Kingsbury 1 Lowrise
11 Kingsbury 2 Lowrise
12 Justice
13 Health and Agriculture
14 Labor and Industry
1
2
3
4
5
6
7
8
9
10
11
12
13
14

FIGURE 1

- Existing Systems

A major criterion for the ICES System is to minimize disruption resulting from the connection of existing buildings to the system.

Since the primary approach includes electric supply by the existing utility, Public Service Electric and Gas (PSE & G) through its existing grid, the only existing systems which affect ICES decisions are those with thermal demands. The Statehouse Complex and the Labor and Industry and Health and Agriculture buildings are served by boilers providing 125 psig steam. In order to permit direct connection to these buildings, an ICES system delivering 125 psig steam was selected. The adoption of this approach requires the provision of high temperature heat and therefore limits available technologies. It was decided that since these building complexes represent 40 percent of the total Demonstration Community and additionally demonstrate the State's commitment to a co-generation approach, their inclusion represents a net benefit to the ICES project when weighed against the limitations imposed on the system.

## 1.2 DEMAND PROFILES

Three sets of hour-by-hour annual profiles were developed for the ICES project. The first of these is the thermal gain for the 15 buildings or groups of buildings which form the Demonstration Community. This profile represents the thermodynamic performance of the buildings in response to exterior temperatures, solar gain, and interior heat sources other than the heating or cooling systems. It is this thermal gain (shown as a negative figure in the case of winter heat loss) which must be offset by the use of building heating or cooling systems. A graphic printout of a typical month is shown on Figure 2. A typical day within that month has been expanded to indicate the hour-by-hour pattern.

The electric demand of the Demonstration Community was not modeled. This is because the entire electric output of the ICES plant is

FIGURE 2

Sample
Building Thermal Gain
Profiles

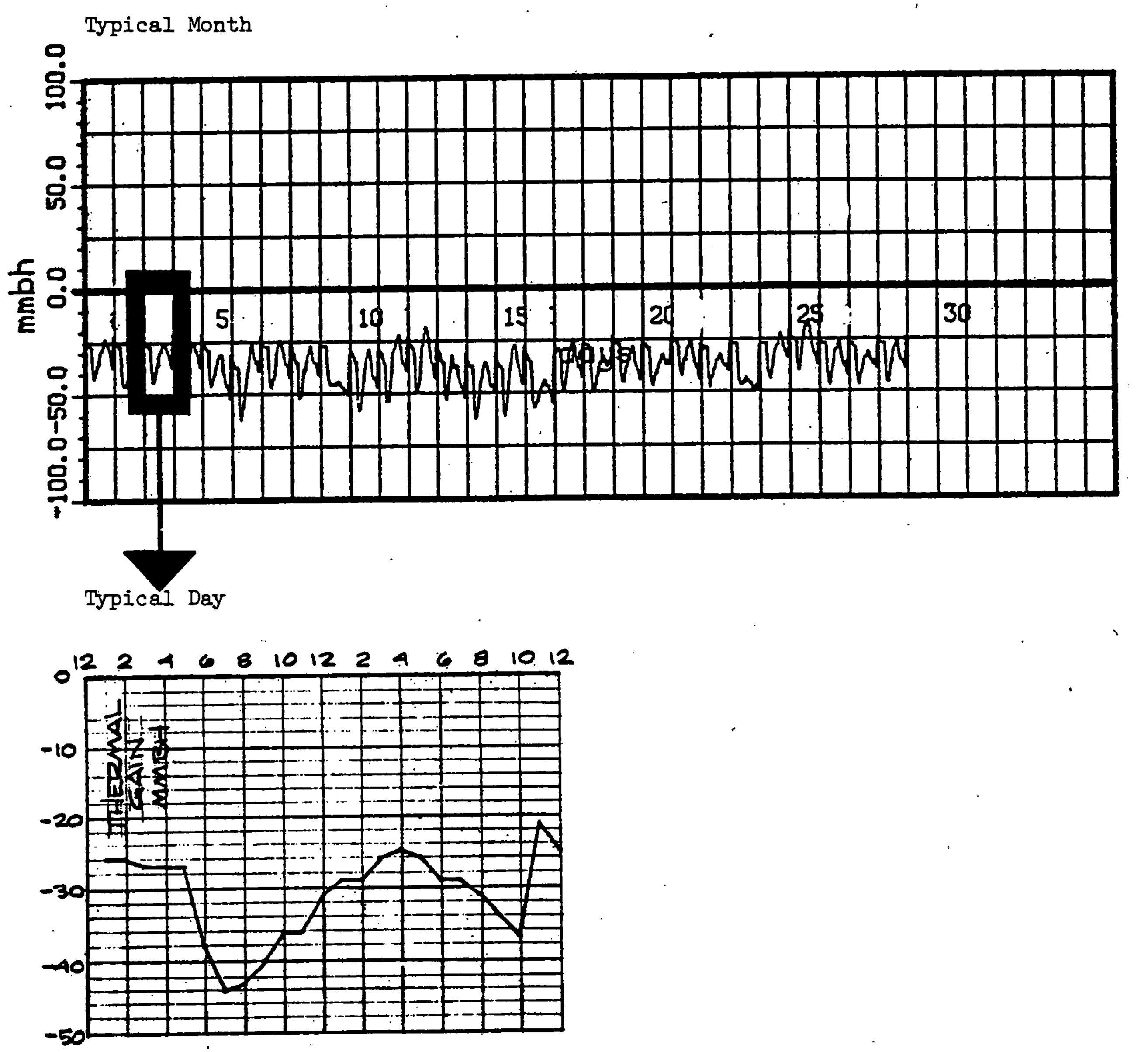
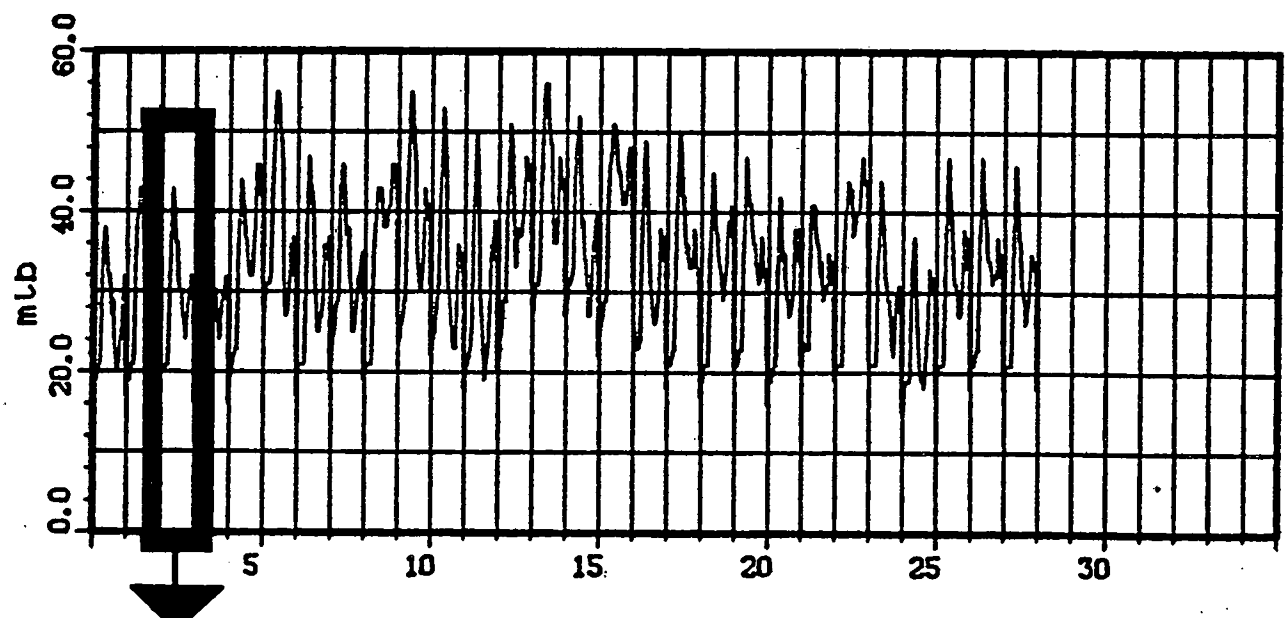


FIGURE 3

Sample
Building Steam Demand
Profiles

Typical Month




Typical Day

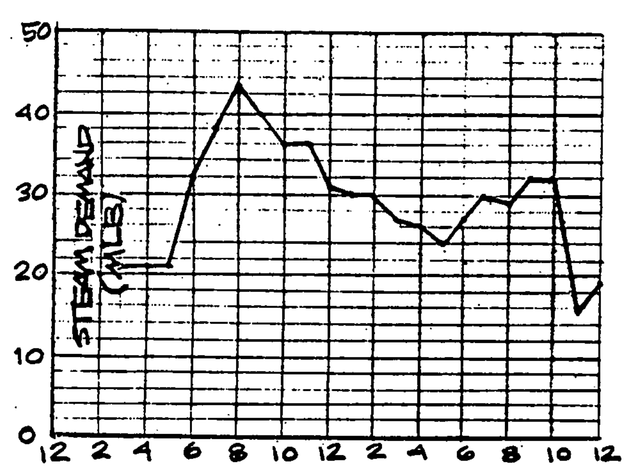
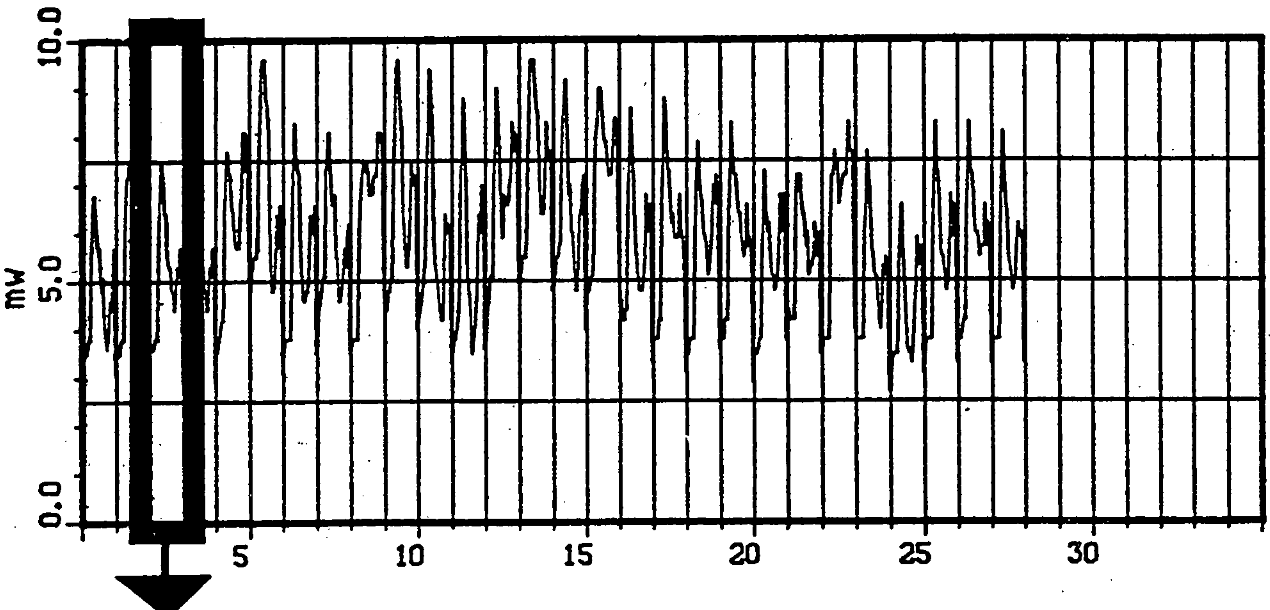


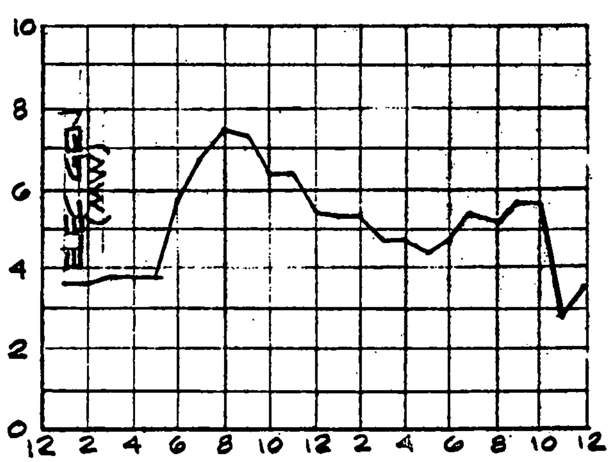
FIGURE 4

Sample
Building Electrical Generation
Profiles

Typical Month




Typical Day



This is because the entire electric output of the ICES plant is fed into the PSE & G grid and the electric needs of the community are served from this grid. Since the purpose of the analysis is to compare the ICES system with the conventional system and since the supply to the community of electrical energy is essentially the same in both cases, the simulation was not performed.

The thermal demand of the community provides the basis for the sizing of the ICES plant.

The second is the community's demand for steam from the ICES plant. This is the building heat gain characteristics as modified by thermal storage systems and by the performance characteristics of the absorption chillers which convert the steam into "cooling."

The third set of profiles is the electric output of the ICES plant resulting from the demand for steam. This was necessary so that the energy and dollar value of the electric output of the ICES plant can be compared against that of a conventional system. The results of these simulations and the uses to which they were put are described under Task 3.

## 1.3 PROJECTED GROWTH

The Phase I feasibility analysis is based on an evaluation of the community as it is projected in 1982. A refinement of this analysis requires that the characteristics of the community prior to its reaching this size as well as with potential growth after 1982 must be considered. A set of profiles for each significant stage of development will be generated during Phase 2.

It is not possible at this time to detail the post 1982 growth patterns; however, this situation can be accommodated in the basic ICES conceptual design in several ways.

* The distribution system can accommodate a 25 percent increase without modification.
* Additional radial distribution arms can be extended from the central plant.
* Space in the plant has been allowed for an additional turbine/boiler module.
* Space is provided in the existing module enclosures so that one or more of the 2.5 megawatt modules could be replaced with a 5 megawatt or 7.5 megawatt unit.
* It is anticipated that much of the existing Demonstration Community will undertake energy conservation procedures in the next 10-year period. This reduction in demand from the existing community will free capacity for an expanded service area.

## 1.4 CONVENTIONAL ENERGY SYSTEM

Two "conventional," that is, non-ICES systems for the provision of thermal energy to the demonstration community were evaluated. One system includes oil-fired boilers and electric chillers, the other uses electric heat pumps. These systems were subjected to the same type of analyses as the ICES.

The initial economic considerations require the establishment of a methodology for comparing the ICES to a conventional system. A "Total System" approach was utilized in which the overall annual costs to the users are compared. The following items were used in the comparison.

<u>ICES</u>

1. ICES Energy Production
   (a) Capital
   (b) Fuel
   (c) Operating and Maintenance
2. *Reduced Electrical Energy Demand (ICES versus Conventional)
3. *PSE & G Replacement Energy and Capacity Credit
4. *PSE & G Transmission and Distribution Savings Credit
   (a) Energy Loss Reduction
   (b) Long Range Investment Savings

<u>Conventional System</u>

1. Steam Production
   (a) Capital
   (b) Fuel
   (c) Operating and Maintenance

* It should be noted that under ICES, Items 2, 3, and 4 represent credits to this system. Item 2, reduced electrical energy, results from the fact that under ICES, new buildings utilize steam absorption chillers rather than electric chillers, thereby reducing their consumption of electric energy.

Item 3, replacement energy and capacity, represents the value of the electric energy produced plus the value of the ICES generating capacity to the PSE & G system.

Item 4 represents the savings in energy and in capital requirements for distribution equipment resulting from the proximity of the plant to the point of use.

The capital, fuel and replacement energy sections under ICES require that a considerably detailed study be done in order to determine with any degree of confidence the costs associated with these items. As these constitute the major portion of the ICES operating costs, it was decided to postpone the economic analysis until the schematic design of the plant is completed and a simulation of a year's operation can be performed. This analysis is to be carried out as part of Task III, Conceptual Design.

## 1.5 ICES CONDIDATE SYSTEM

Based on commercial availability of hardware and the size of the plant, diesel and gas turbine technologies were considered for the generating equipment of the plant. Of these, gas turbines were selected based on two factors. The first is that a large percentage of the waste heat from the turbines is at relatively high temperatures (±900 degrees F.). Since the plant must generate 150 psig steam for compatibility with existing buildings in the Demonstration Community, this characteristic permits the capture of a substantially higher portion of the waste than would be possible with the diesel. The second characteristic of the gas turbine which makes it desirable for this application is the fact that it will deliver 5.4 pounds of steam per net kilowatt hour as compared with 1.3 pounds of steam per net kilowatt hour with the diesel, thereby satisfying thermal demand of the community with a much smaller central plant. Since the plant is thermally controlled and will therefore have only seasonal operation, the minimization of capital cost is significant.

The heat recovery will be accomplished with a two stage boiler. The high temperature stage will produce the steam used for distribution to the community. A low temperature stage will generate 230 degree F. water. A portion of this energy will be used internally in the plant for combustion air preheating and space heating. The remainder will be used for preheating condensate return in the steam system and for heating a tennis facility immediately adjacent to the ICES plant. The net thermal efficiency (excluding that thermal output which is used internally by the plant) is approximately 65 percent. The cycle is shown on Figure 5.

## 1.6 THERMAL DISTRIBUTION

Thermal distribution will be carried out delivering 125 psig steam for compatibility with existing terminal equipment in the Statehouse, Health/Agriculture and Labor/Industry complexes. Buildings will be provided with heat exchangers to permit the conversion of the delivered steam to a form compatible with the local heating and hot water systems. Existing buildings will utilize the chillers which are presently installed. New buildings will be provided with two-stage absorption chillers, permitting the direct use of the 125 psig steam for the production of chilled water.

The distribution system is described in detail in Section III.

PROPOSED ICES PLANT CYCLE AT WINTER DESIGN CONDITIONS

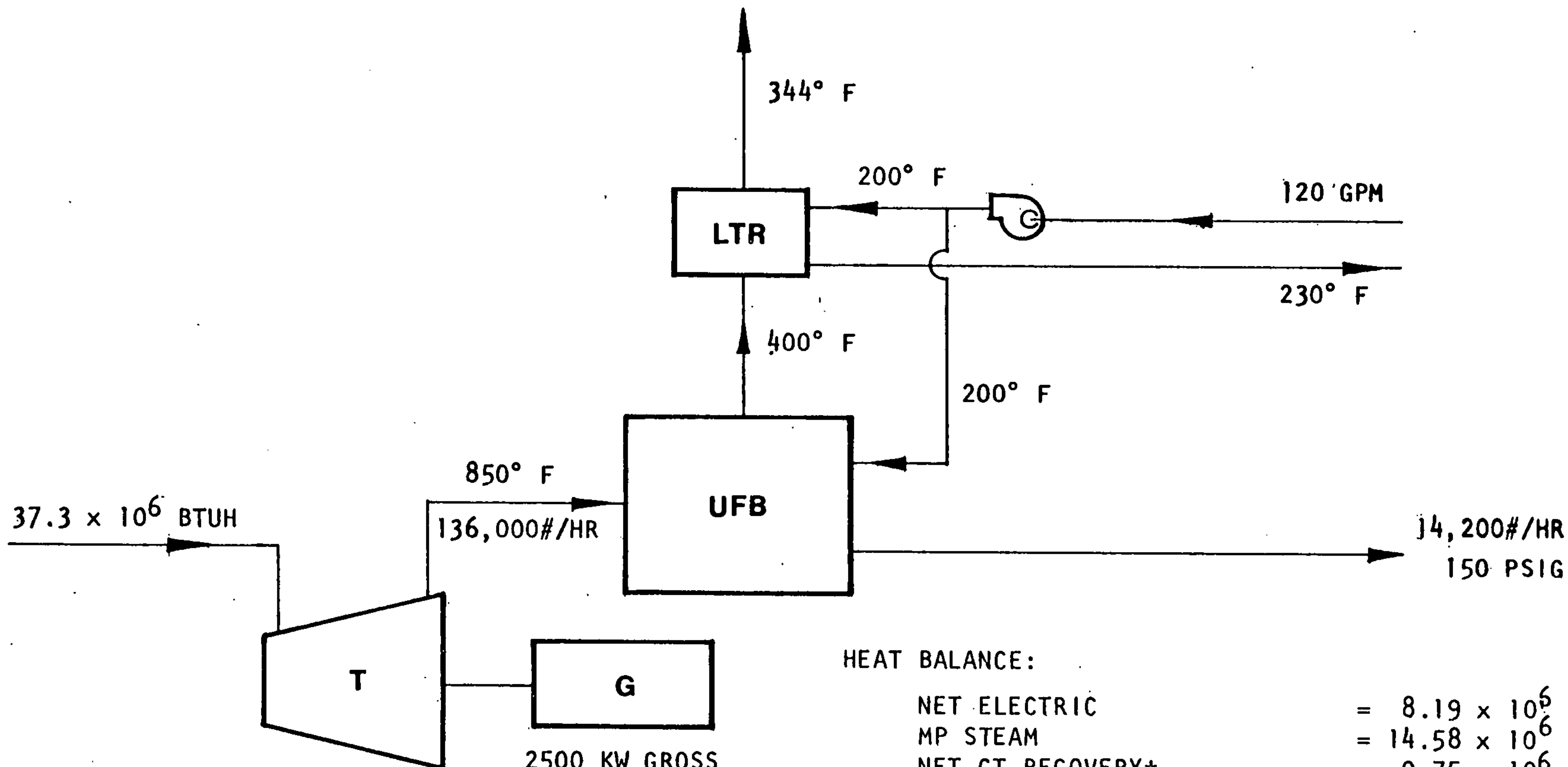



FIGURE 5

| | |
|---|---|
| **T** | TURBINE |
| **G** | GENERATOR |
| **UFB** | UNFIRED HEAT RECOVERY BOILER |
| **LTR** | LOW TEMPERATURE RECOVERY |

HEAT BALANCE:

| | |
|---|---|
| NET ELECTRIC | = 8.19 x $10^6$ BTUH |
| MP STEAM | = 14.58 x $10^6$ BTUH |
| NET CT RECOVERY* | = 0.75 x $10^6$ BTUH |
| | |
| TOTAL NET OUTPUT @ WINTER DESIGN | = 23.52 x $10^6$ BTUH |
| GROSS INPUT | = 37.30 x $10^6$ BTUH |
| PLANT EFFICIENCY | = 63.06% |

*GROSS LT RECOVERY = 2.75 x $10^6$ BTUH. HOWEVER AT WINTER DESIGN CONDITION, COMBUSTION AIR PREHEAT REQUIRES APPROXIMATELY 2.00 x $10^6$ BTUH

## 1.7 THERMAL STORAGE

Thermal storage will be insulated steel tanks buried adjacent to the buildings or terminal equipment which they service. They will store heated water during the winter and chilled water during the summer.

The installed cost for the storage system is estimated at $590,000 in 1977 dollars. The inclusion of this storage permits the plant to exist with one fewer generator/boiler module than would otherwise be the case.

The four-module plant is estimated at $6.6 million in 1977 dollars. On this basis the inclusion of the thermal storage facility reduces the central plant cost by more than $1 million.

The approach chosen for thermal storage has several distinct advantages over any others. The components are readily available and are used in conventional fashion, facilitiating installation and maintenance. The fact that storage is at the terminal rather than at the supply reduces the peak demand on the distribution system as well as on the generation equipment which, in turn, permits both of these systems to be reduced in size. In addition, the storage falls between the points of end use and the chillers which also reduces the size requirement for these units. While the initial decision to utilize remote thermal storage was based on a comparison between the cost of the thermal storage and the central plant equipment, its use also reduces distribution and terminal requirements which, in turn, show added benefits to ICES.

## 1.8 ELECTRIC POWER DISTRIBUTION

The Trenton ICES described in this report is based on PSE & G ownership and on the supply of electricity to the Demonstration Community from the PSE & G grid. Since electrical distribution remains unchanged in the ICES or conventional approaches, no special ICES electrical distribution system has been developed.

# task II

## institutional assessment

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## 2.1 INSTITUTIONAL ASSESSMENT

Three categories of institutional questions affecting the ICES plant were analyzed. These were: Legal and regulatory considerations controlling the plant regardless of ownership; Legal and regulatory considerations unique to each ownership option; and general acceptance of plant by its potential users and by the public at large.

## 2.2 GENERAL CONSIDERATIONS

### Environment

The effect of the Trenton ICES plant on the surrounding environment falls within the control of the New Jersey Department of Environmental Protection and the City of Trenton. The primary areas of environmental concern are: chemical and particulate discharge to the atmosphere and to surrounding water and the creation of noise.

In the case of the Trenton ICES, water pollution is not expected to pose any problem. There is no connection between the plant and any of the adjacent natural water systems. An initial review of the operation of the plant indicates that its discharge to the atmosphere can be kept within present Department of Environmental Protection Standards and that noise can be held to acceptable levels.

### New Jersey Public Utility Commission

The New Jersey Public Utility Commission (PUC) will have jurisdiction over the operation of the ICES plant regardless of ownership. The basic areas of PUC responsibility will be franchise approval of steam distribution (in the case of Public Service Electric and Gas ownership); electrical franchise territorial acquisition (in the case of municipal ownership); control of stocks, bonds, notes, etc.; and control of the general operation and administration of the plant once it is in service (in the case of either form of ownership).

Federal Power Commission

Federal Power Commission jurisdiction will apply based on the fact that the ICES plant, regardless of ownership, will be connected to the PSE & G grid and there will be energy interchange between them.

## 2.3 PUBLIC SERVICE ELECTRIC AND GAS COMPANY (PSE & G) OWNERSHIP AND OPERATION

There are no fundamental restrictions which would prohibit PSE & G from owning and operating the Trenton/ICES plant. The selling of steam is within the scope of PSE & G charter and no New Jersey laws or ordinances have been uncovered which would prohibit this activity. The question of the ability to refuse certain prospective steam customers due to plant and distribution limitations requires further study. Rate structuring is a matter for PUC review.

Other institutional questions analyzed for Public Service Electric and Gas ownership are zoning; the fact that the ICES site is in a designated urban renewal area; labor arrangements for plant construction and operation; taxation and finance; and the method of determining steam rates. In all of these issues there appear no unusual problems relating to ICES.

## 2.4 CITY OF TRENTON OWNERSHIP

Municipal ownership of the ICES plant was analyzed to determine whether any fundamental impediments existed to this approach. The state laws of New Jersey clearly permit municipal utilities; however, the decision as to whether the project should be undertaken would be subject to public referendum. Municipal ownership was further complicated by the intertwining of its services with those of Public Service Electric and Gas in the center city of Trenton.

Zoning questions are somewhat simplified as the municipality is not bound by local regulations; however, the impact of the urban renewal requirements remain the same for either ownership option. The operating labor arrangements may be complicated under municipal ownership, depending on whether plant operation is handled by contract for service or by civil service employees. The ICES plant would be tax exempt; however, it would also result in a loss of tax revenue to the City.

## 2.5 JOINT TRENTON/PSE & G OWNERSHIP

The general concept of joint private/municipal ownership was reviewed for institutional feasibility. Although no legal or regulatory restrictions were uncovered which would preclude such an arrangement, their remain some fundamental administrative and institutional difficulties which must be overcome to institute such an arrangement.

## 2.6 PUBLIC INFORMATION PROGRAM

The ICES Team has actively worked to gain support for the plant from potential customers and the community at large throughout the first phase of the project. Efforts in this area have included public meetings arranged by the City of Trenton Department of Planning and Development involving the Demonstration Team and potential customers and public agencies, press releases and updates to local news media, appearances at expositions and civic meetings, and the preparation of an explanatory brochure describing the concept and benefits of the ICES system. This brochure has been mailed to environmental groups, labor unions, politicians, members of the business community, civil servants, professional and trade associations and citizens groups.

The ICES team anticipates continuing strong efforts to obtain public awareness of the program, culminating in the creation of an energy information center as an integral part of the ICES plant (see Section III for details).

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# task III

## conceptual design

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## 3.1 ICES SYSTEM

### ICES Plant

The Conceptual Design of the ICES plant is based on the considerations outlined under Task 1. The primary generation technology is combustion turbine with the exhaust passing through unfired heat recovery boilers. These are two-stage boilers with the first (high temperature) stage, generating 150 psig steam and the second stage, producing 230-degree hot water. An auxiliary boiler provides thermal stand-by reserve equal to the output of two turbine/heat recovery boiler modules.

The basic module is a 2.5 megawatt gas turbine/generator set with a capacity to satisfy approximately 25 percent of the peak thermal demand. Four modules are provided. Redundancy and exceptional peak capacity are provided by the auxiliary boiler. This configuration permits a large degree of operational and expansion flexibility. The ability to function on fewer than four turbine/generator sets permits plant operation at less than peak demand while maintaining a high plant efficiency due to the heavy loading on those pieces of equipment which remain in operation.

The enclosure for the ICES plant is integrated into a parking garage for 1,200 vehicles to service the Capital Place Complex with capacity for Labor and Industry, Health and Agriculture, the Detention Center and commercial buildings adjacent to the Demonstration Community.

In addition, the ICES plant will serve a proposed Civic Center, primarily in the evenings. In order to facilitate pedestrian movement from the garage to these places, an elevated sidewalk system to the adjacent sites is provided. This system may allow the thermal distribution from the ICES plant to these adjacent sites to be run in chases provided beneath these walkways, thereby minimizing the excavation of public streets and facilitating future maintenance.

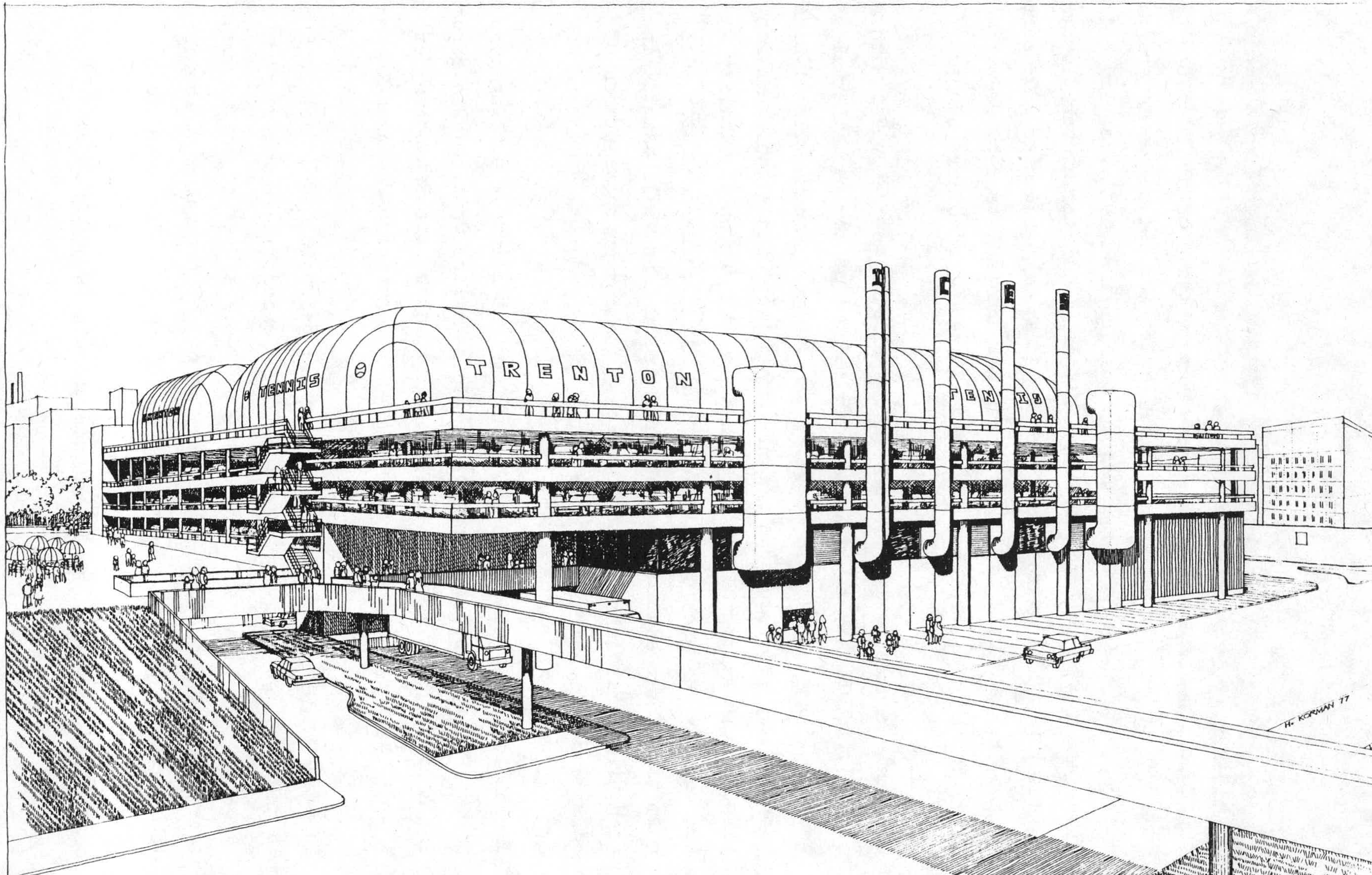
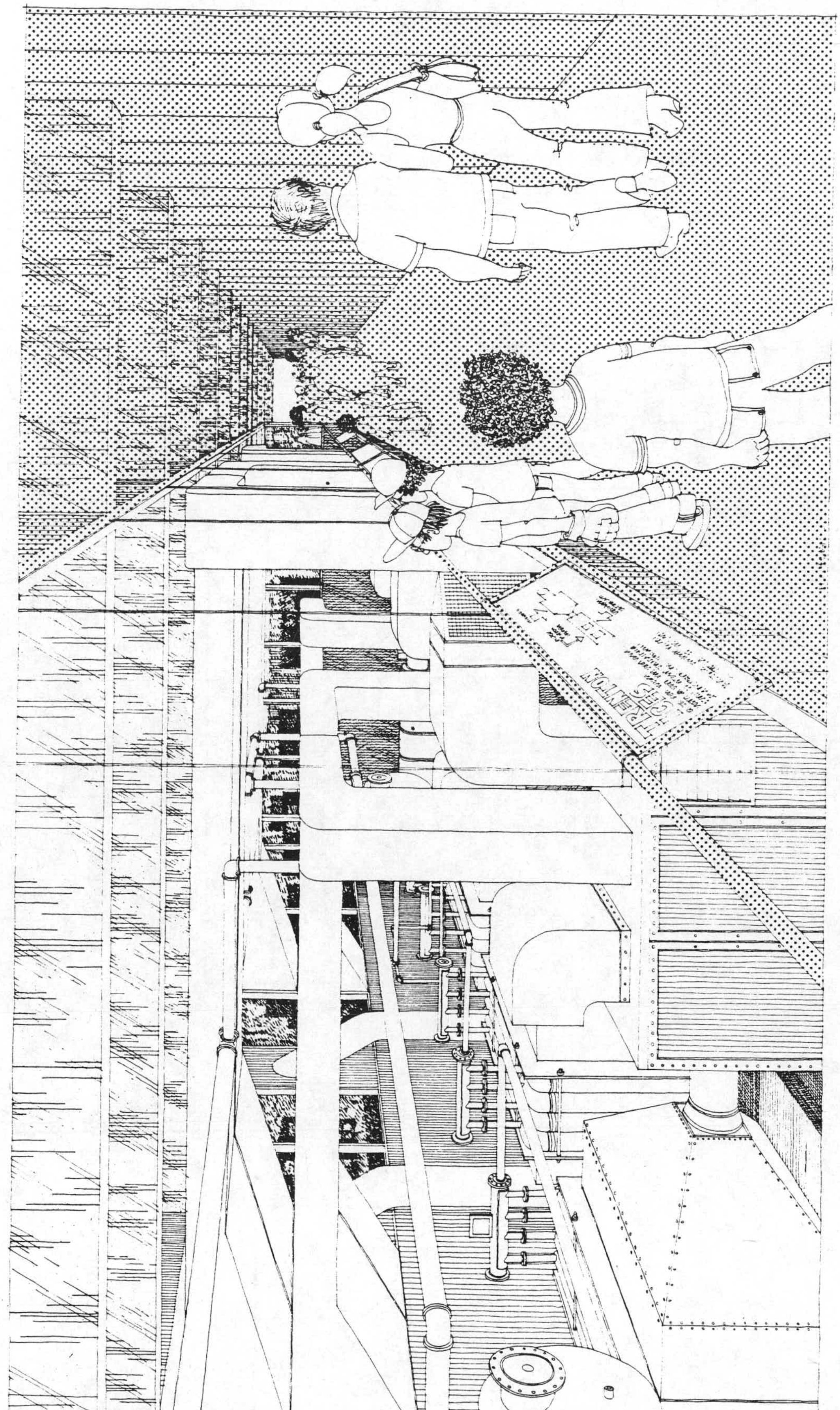



FIGURE 6

FIGURE 7



ICES PLANT & DISTRIBUTION SCHEMATIC

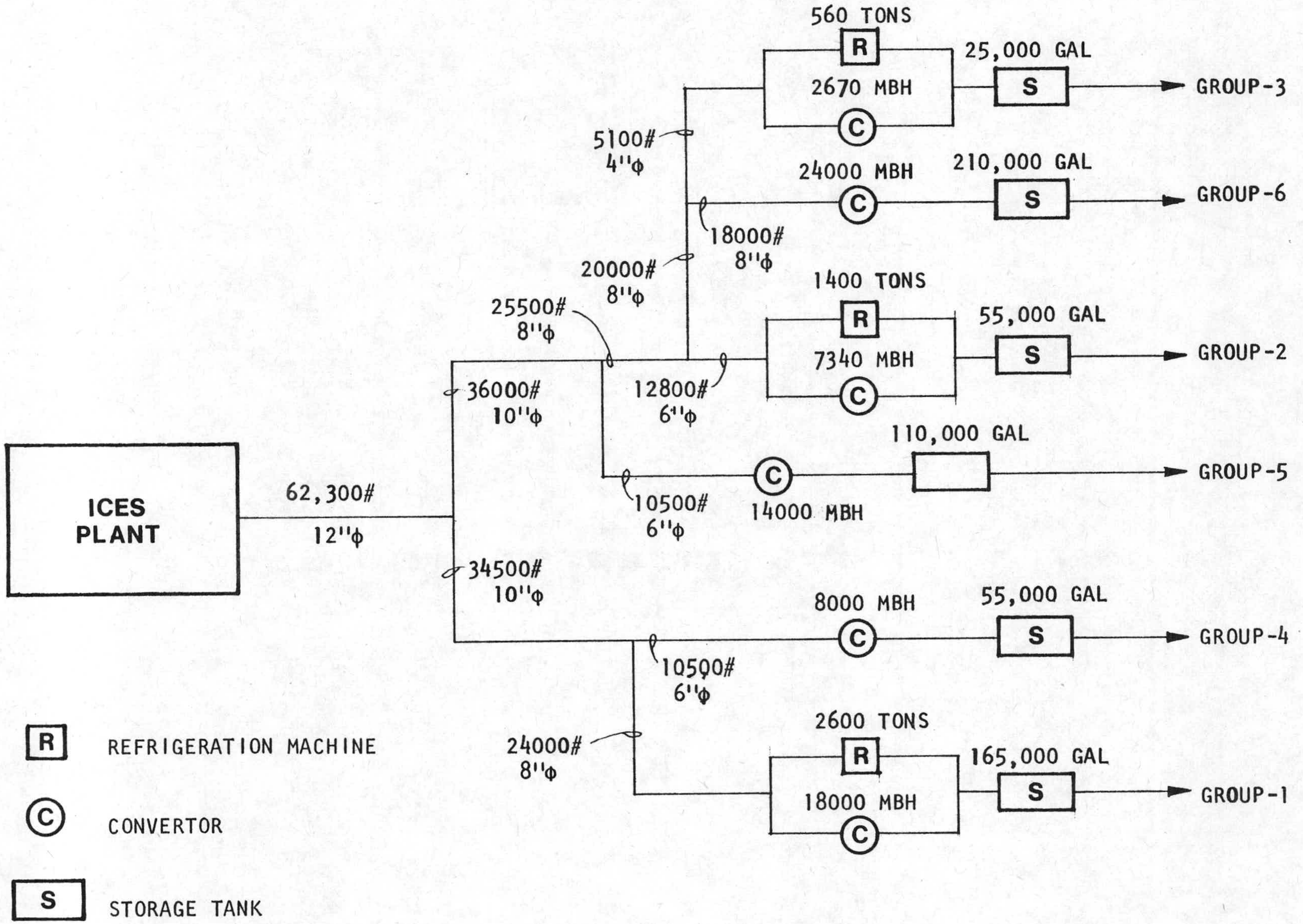
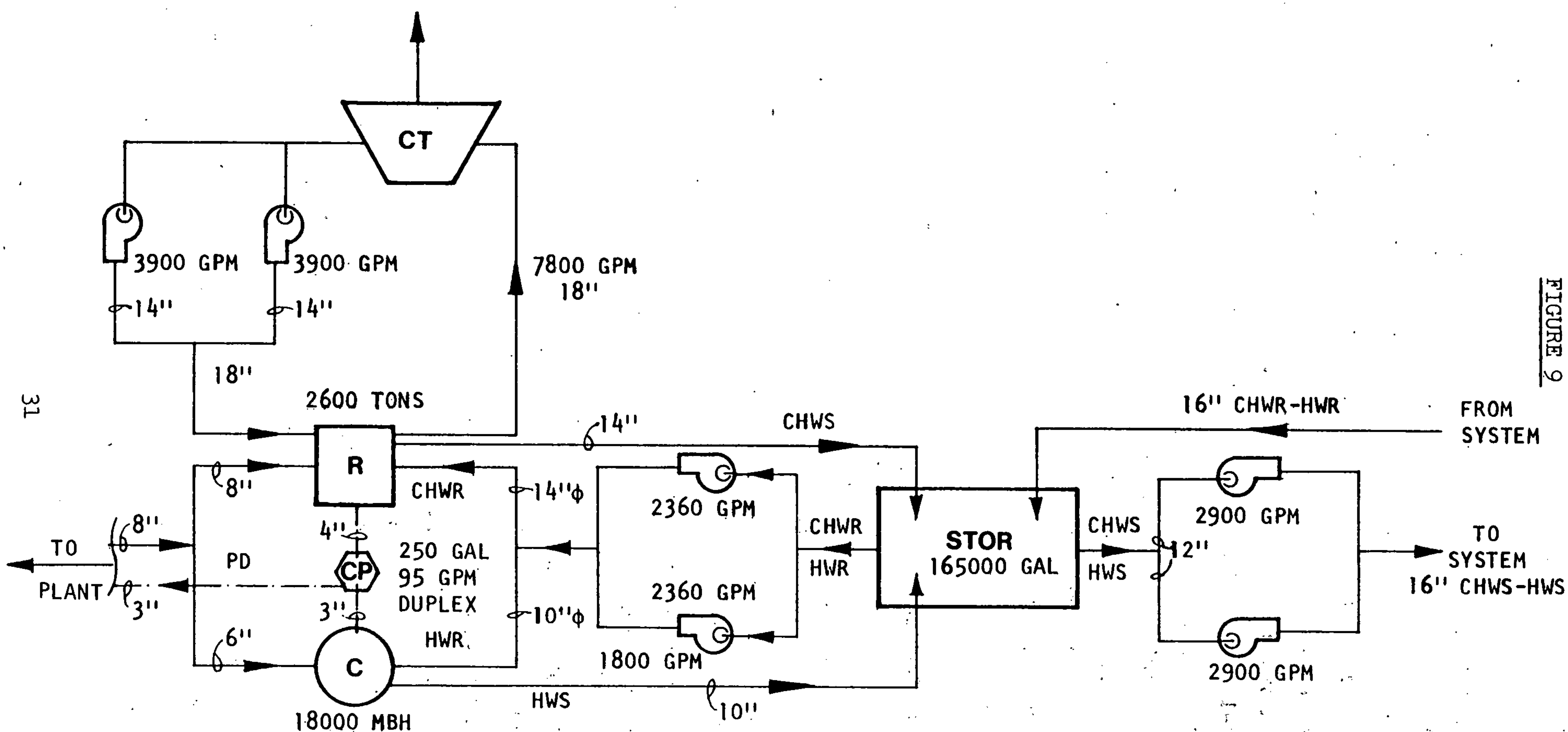



FIGURE 8

FIGURE 9

GROUP-1: C E C SCHEMATIC




| | |
|---|---|
| **CEC** | CENTRAL EQUIPMENT CENTER |
| **CT** | COOLING TOWER |
| **R** | REFRIGERATION MACHINE |
| **CP** | CONDENSATE RECEIVER/PUMP |
| **C** | CONVERTOR |
| **PD** | PUMP DISCHARGE |
| **STOR** | STORAGE TANK |

Energy Information Center

An additional benefit resulting from the placement of the ICES plant in the center of an intensively used circulation route is that it will serve as an "Energy Information Center." The ICES plant will be a highly visible building in Trenton, the New Jersey State Capital. The elevated sidewalk and the ICES plant will be separated by a wall of acoustical glass. The equipment will be color coded. Explanatory plaques and diagrams along the sidewalks will explain the function of the plant equipment as well as the basic concepts of ICES. Display cabinets and panels will house energy-related exhibits and information describing energy conservation techniques. Graphic material describing the ICES plant is included in Figures 6 through 9 and 12 through 20.

Thermal Distribution

The basic distribution system consists of primary 150 psig steam distributions to six central equipment centers which utilize the steam to produce hot water for heating, domestic and process use, reduced pressure steam for process use, and chilled water for space cooling. Each central equipment center will contain steam-hot water converters, two-stage absorption chillers, condensate receivers/pumps, cooling towers, pumps and auxiliary equipment and storage capacity.

## 3.2 ENERGY AND COST ANALYSES

Capital Costs

The preliminary estimate of the cost of the complete ICES system based on the design described above and the equipment is $8,038,800 in 1977 dollars and exclusive of normal construction overhead, profit, and contingencies and Engineering fees. With these items added, the total cost of the ICES system becomes $11,138,800.

The cost of the central ICES plant including heat recovery equipment is $6,655,100.

The cost of the distribution system is $1,464,700.

The cost of the terminal equipment at the buildings being served by ICES is $3,019,000.

Fuel Input versus Energy Output

In order to complete the economic evaluation of ICES, a fuel input/energy output analysis was developed. This was simulated on an hour-by-hour basis for a typical year.

For the year simulated, the oil consumption for the ICES plant is 73,364 barrels, the total electrical output is 28,079 megawatt hours, and the net steam output is 176,822,000 pounds.

The simulation identifies whether the electricity is produced during on-peak or off-peak hours, and the value assigned to the electricity is based on the time-of-day of production.

Other Costs

Operation and maintenance costs are assigned to ICES based on the Utility's experience and on a careful analysis of the type of staff and maintenance procedures required by this particular installation. Credits are assigned to the capital value of the ICES plant to the Utility.

Similar analyses were performed for conventional supply of thermal energy using oil-fired boilers in one case and electric driven heat pumps in another.

Economic Analysis

A "total system" approach was applied in which the total costs of the ICES were compared to those of a conventional system. The costs for the ICES and conventional system follow:

ICES Costs

1. Those costs associated with the total ICES energy production including capital, fuel, operating and maintenance.

2. The savings associated with supplying less electric energy required by the community, as compared to the conventional system, at the applicable rates.

3. A credit for the value to PSE & G of the energy and capacity provided by the ICES plant

4. A credit for PSE & G transmission and distribution long-term savings resulting from the generation of the ICES plant.

Conventional System Costs

1. The costs associated with the conventional heating facilities to provide steam output equivalent to that of ICES, including capital, fuel, operating and maintenance.

The ICES cost and the conventional system cost were then compared on the basis of "present worth of all future annual revenue requirements." It may be pointed out that a "zero" bottom line indicates that the ICES would be profitable.

The ICES shows a competitive economic position compared to both conventional alternatives. The Phase I analysis shows a marginal annual penalty to ICES of $100,000 as compared with the oil-fired conventional system, and $260,000 as compared with the electric heat pump conventional system viewed in 1982 dollars. Based on a 1982 capital value of $14,215,000 these differences are less than the anticipated error in this preliminary economic evaluation. This analysis also assumes that all the costs of the system are borne by the ICES owner and customers. In fact, ERDA funding support of Phase II alone would be equivalent to a reduction of the ICES annualized cost of approximately $100,000 per year.

Fuel Analysis

The analysis of fuel use made for the economic evaluation also permits the following energy comparison for the three approaches.

The ICES system requires a total annual fuel input of 73,364 barrels of oil ($425.5 \times 10^9$ Btu) to produce its total electric and thermal output.

The conventional system, using oil-fired boilers, requires an annual input of 40,975 barrels of oil ($243.5 \times 10^9$ Btu) for the provision of thermal energy alone. This thermal energy is somewhat less than the thermal output of the ICES plant due to the use of electric vapor chillers. Based on PSE & G's present and projected generation mix, incremental electricity during on-peak hours will be produced by oil-fired plants and during off-peak hours will be produced by coal-fired plants. The simulation of the community demand for the conventional system using oil-fired boilers permits the identification of on-peak and off-peak usage. Based on the above, the annual fuel use due to this electrical production is 27,779 barrels of oil ($166.7 \times 10^9$ Btu) plus 6,440 tons of coal (27,903 equivalent barrels of oil or $167.4 \times 10^9$ Btu). In other words, the total oil input for the conventional system with oil-fired heating to provide the equivalent output of ICES is 68,754 barrels of oil plus 6,440 tons of coal or a total of 96,657 equivalent barrels of oil or $579 \times 10^9$ Btu.

Based on the same methodology, the conventional system using electric heat pumps in the proposed buildings shows a total annual fuel use of 32,802 barrels of oil ($194.6 \times 10^9$ Btu for the provision of thermal energy). The electricity demand of the community requires a fuel input of 34,353 barrels of oil (206.1 x $10^9$ Btu) plus 7,960 tons of coal (34,500 equivalent barrels of oil or 207.0 x $10^9$ Btu). This amounts to a total annual fuel input of 67,155 barrels of oil plus 7,960 tons of coal or 101,655 equivalent barrels of oil or 601.0 x $10^9$ Btu.

ICES Versus Conventional System Fuel Use

A comparison of the three analyses shows the ICES plant consuming slightly more oil per year than the conventional alternatives and considerably less total fuel.

> The conventional oil-fired system consumes 4,610 barrels of oil (6 percent) less than the ICES plant. However, the conventional oil-fired system consumes 23,293 equivalent barrels of oil (32 percent) more than the ICES plant.

> The conventional system with electric heat pumps consumes 6,209 barrels of oil (9 percent) less than ICES. However, the conventional system, utilizing electric heat pumps, consumes 28,269 equivalent barrels of oil (39 percent) more than ICES.

The above information compares volume of different grades of oil. If the same comparison is made using the thermal content of the oil used, the results are as follows:

> The conventional oil-fired system consumes 15.3 x $10^9$ Btu (4 percent) less oil than ICES. However, the conventional oil-fired system consumes 152.1 x $10^9$ Btu (36 percent more) fuel than ICES.

> The conventional system with electric heat pumps consumes 24.8 x $10^9$ Btu (6 percent) less oil than ICES. However, the conventional system with electric heat pumps consumes 182.2 x $10^9$ Btu (43 percent more fuel than ICES).

These data are summarized graphically in Figures 10 and 11.

FIGURE 10

FUEL COMPARISON: ICES VS. OIL HEATING

NOTE 1: ICES REQUIRES 23,293 EQUIVALENT BBLS OF OIL ($152.1 \times 10^9$ BTU) PER YEAR LESS THAN THE CONVENTIONAL SYSTEM.

NOTE 2: ICES REQUIRES 4,610 BBLS OF OIL ($15.3 \times 10^9$ BTU) PER YEAR MORE THAN THE CONVENTIONAL SYSTEM.

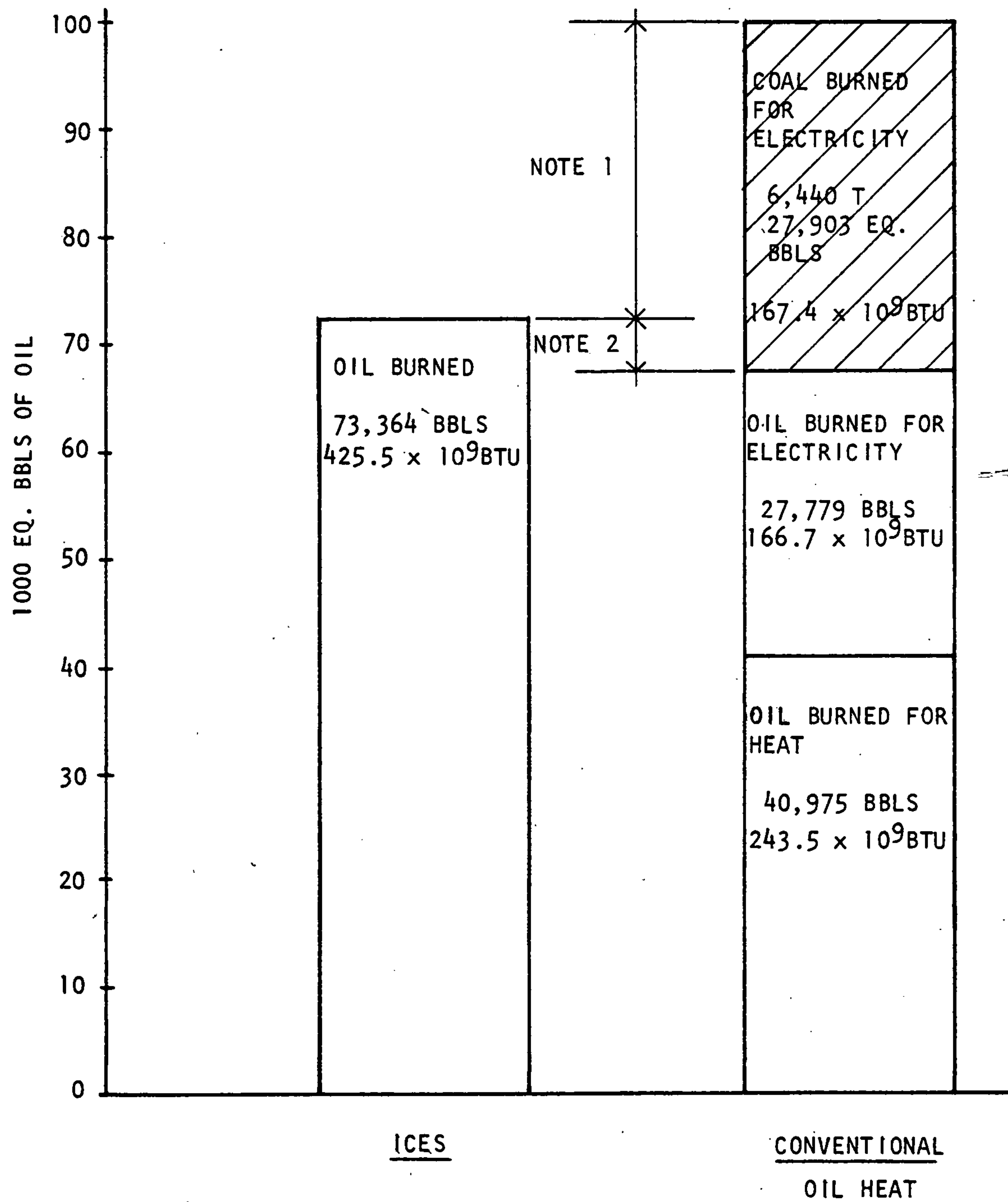
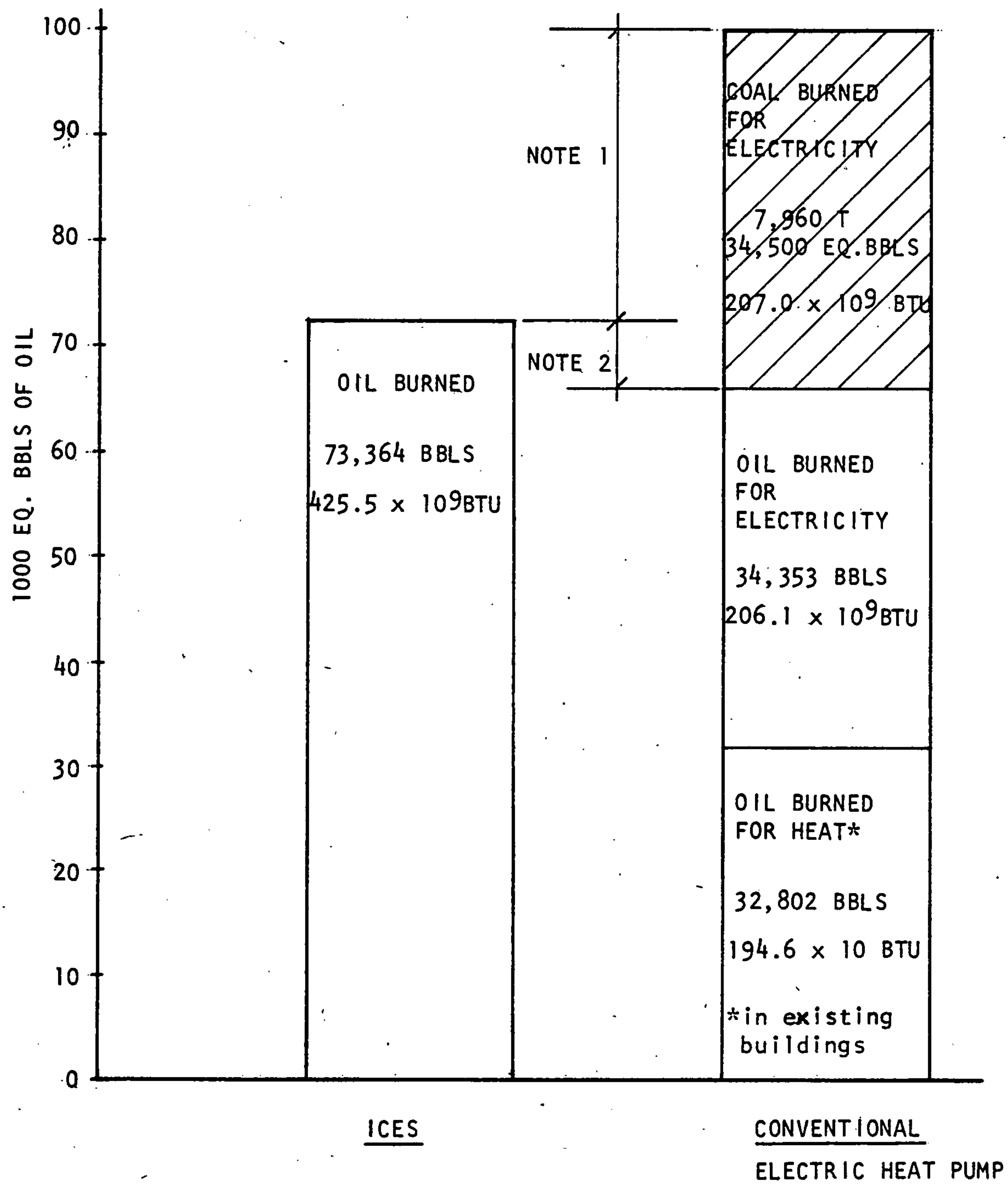


FIGURE 11

FUEL COMPARISON: ICES VS. ELECTRIC HEAT PUMPS

Note 1: ICES REQUIRES 28,291 EQUIVALENT BBLS OF OIL ($182.2 \times 10^9$ BTU) PER YEAR LESS THAN THE CONVENTIONAL SYSTEM.

Note 2: ICES REQUIRES 6,209 BBLS OF OIL ($24.8 \times 10^9$ BTU) PER YEAR MORE THAN THE CONVENTIONAL SYSTEM.



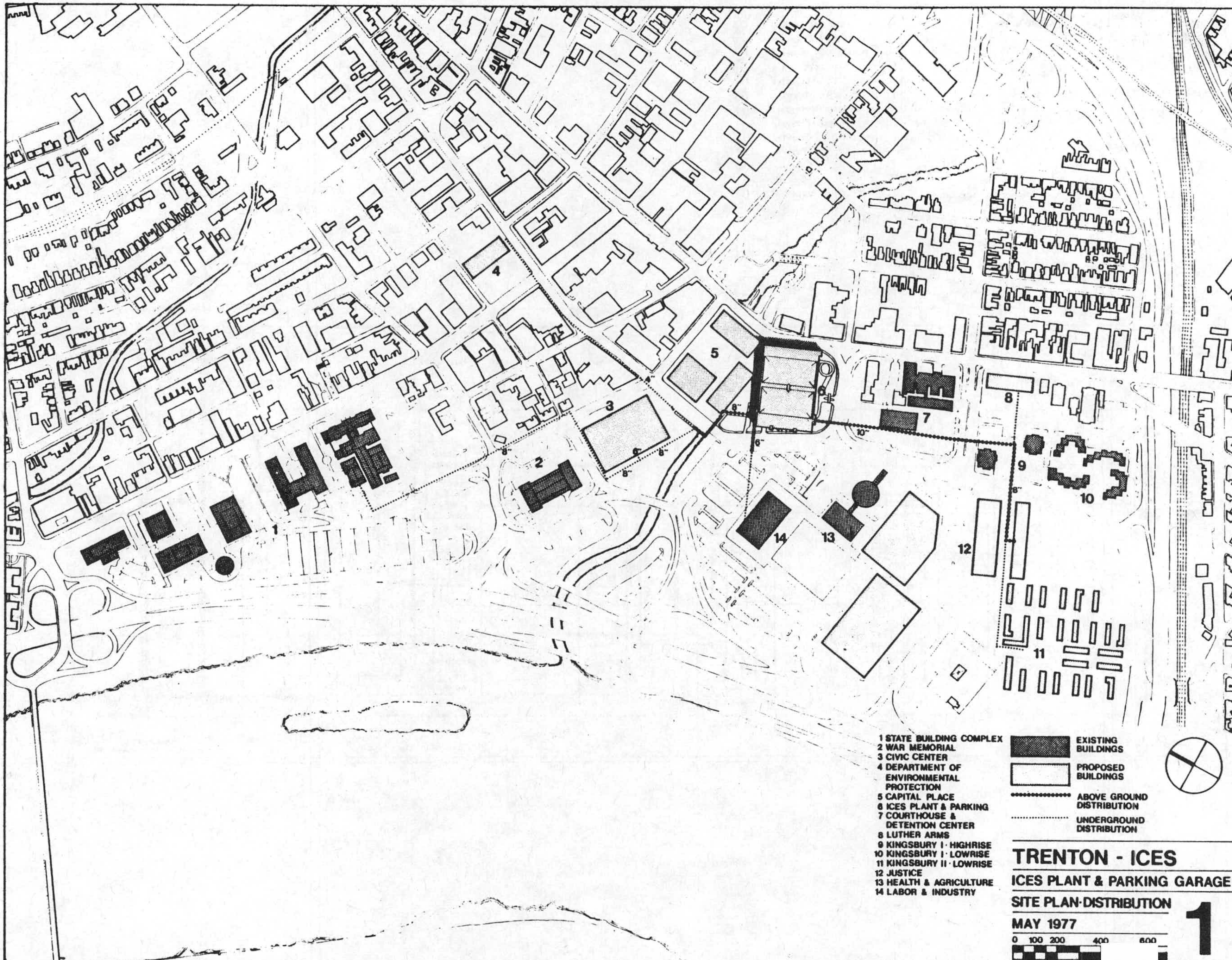
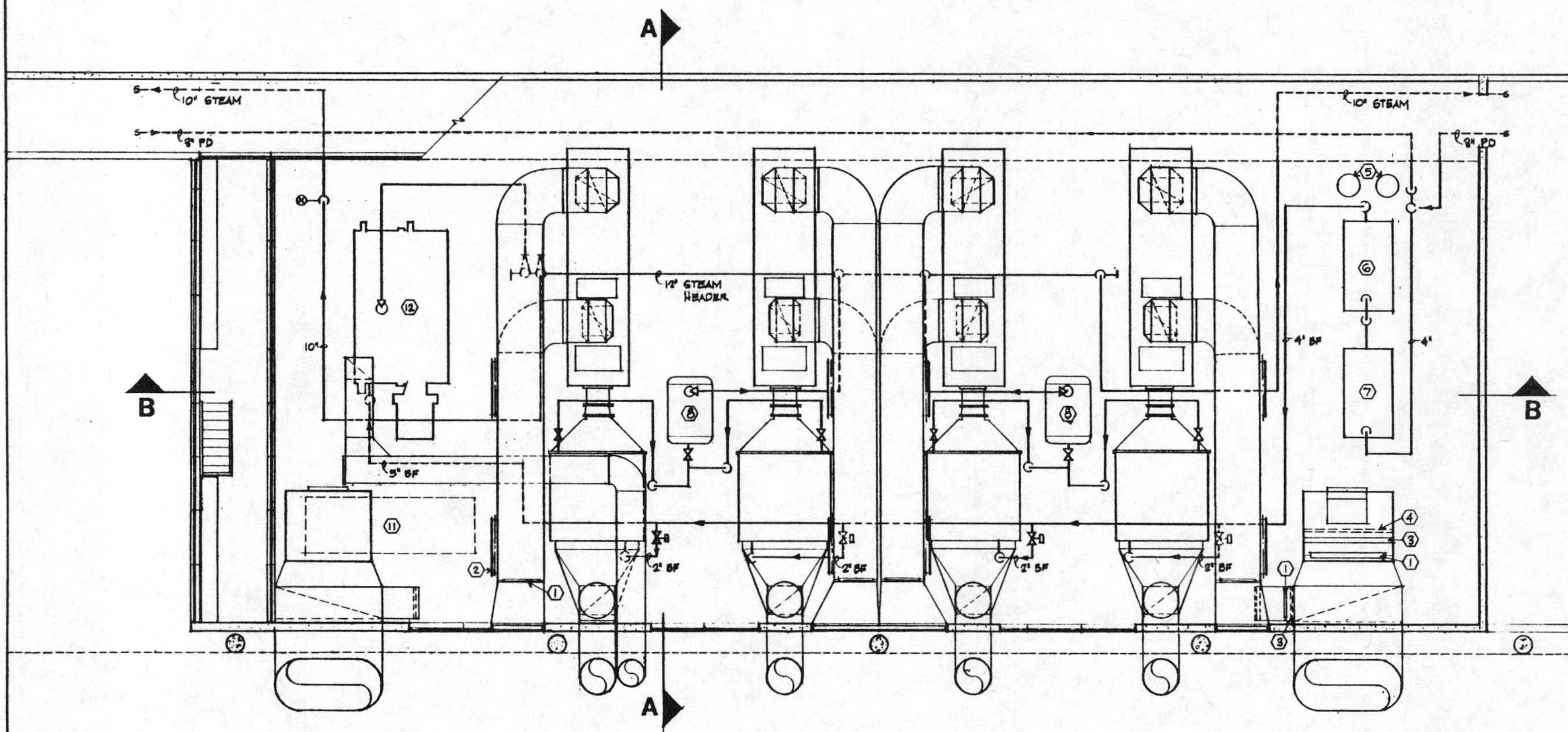

1 STATE BUILDING COMPLEX
2 WAR MEMORIAL
3 CIVIC CENTER
4 DEPARTMENT OF ENVIRONMENTAL PROTECTION
5 CAPITAL PLACE
6 ICES PLANT & PARKING
7 COURTHOUSE & DETENTION CENTER
8 LUTHER ARMS
9 KINGSBURY I · HIGHRISE
10 KINGSBURY I · LOWRISE
11 KINGSBURY II · LOWRISE
12 JUSTICE
13 HEALTH & AGRICULTURE
14 LABOR & INDUSTRY
EXISTING BUILDINGS
PROPOSED BUILDINGS
ABOVE GROUND DISTRIBUTION
UNDERGROUND DISTRIBUTION
TRENTON - ICES
ICES PLANT & PARKING GARAGE
SITE PLAN·DISTRIBUTION
MAY 1977
0 100 200 400 600
1

FIGURE 12




**LEGEND**

1. AUTOMATIC CONTROL DAMPER
2. REGISTER
3. FILTER
4. HEATING COIL
5. CHEMICAL TREATMENT TANK
6. DEAERATOR TANK & B.F. WATER PUMPS
7. CONDENSATE ACCUMULATOR TANK & TRANSFER PUMPS
8. STEAM SEPARATOR
9. SILENCER
10. OIL COOLER
11. OPTIONAL SINGLE STAGE ABSORPTION CHILLER
12. AUXILIARY BOILER
BF. BOILER FEED WATER

**TRENTON - ICES**

**ICES PLANT & PARKING GARAGE**

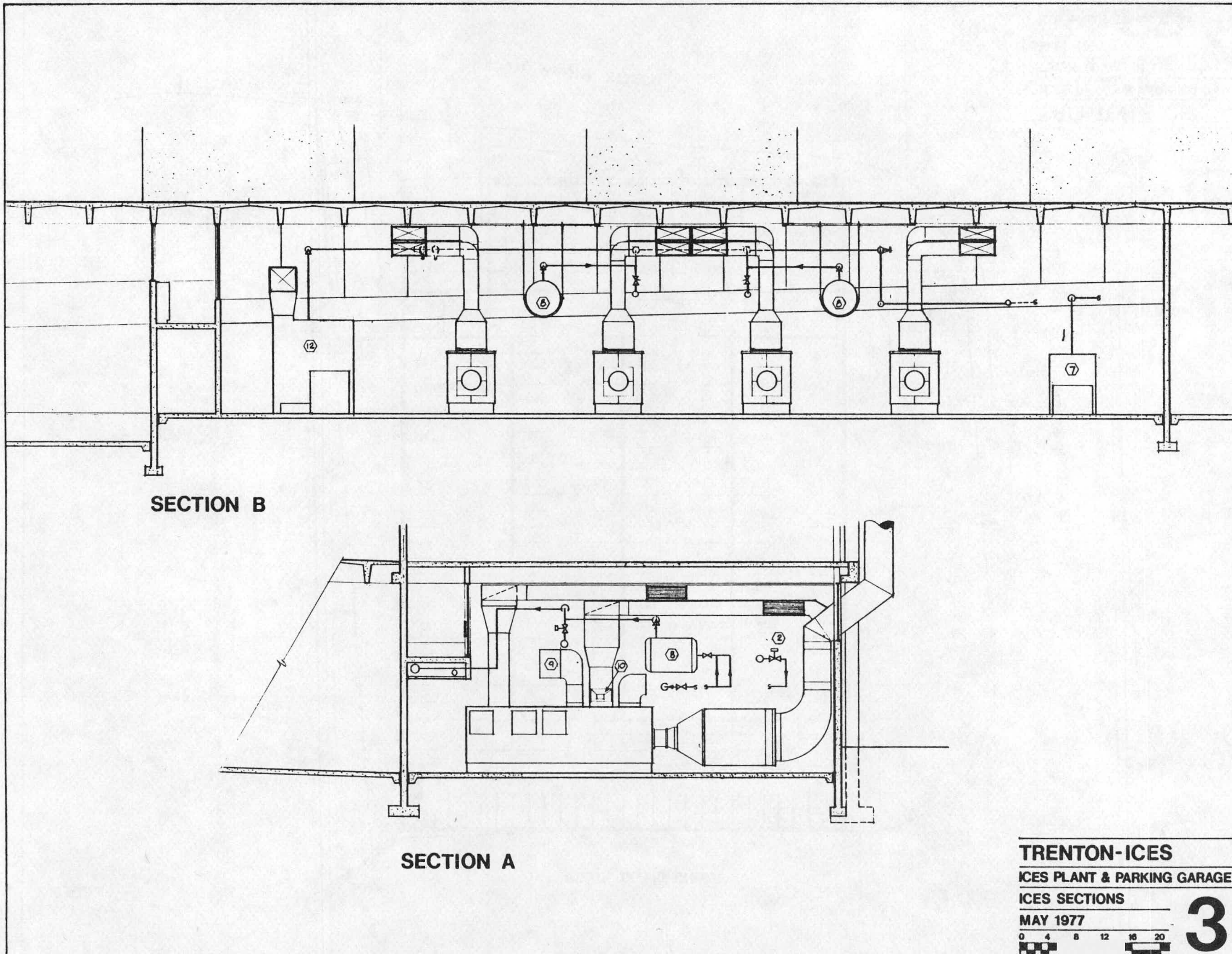
**ICES PLAN**

**MAY 1977**

0 4 8 12 16 20

**2**

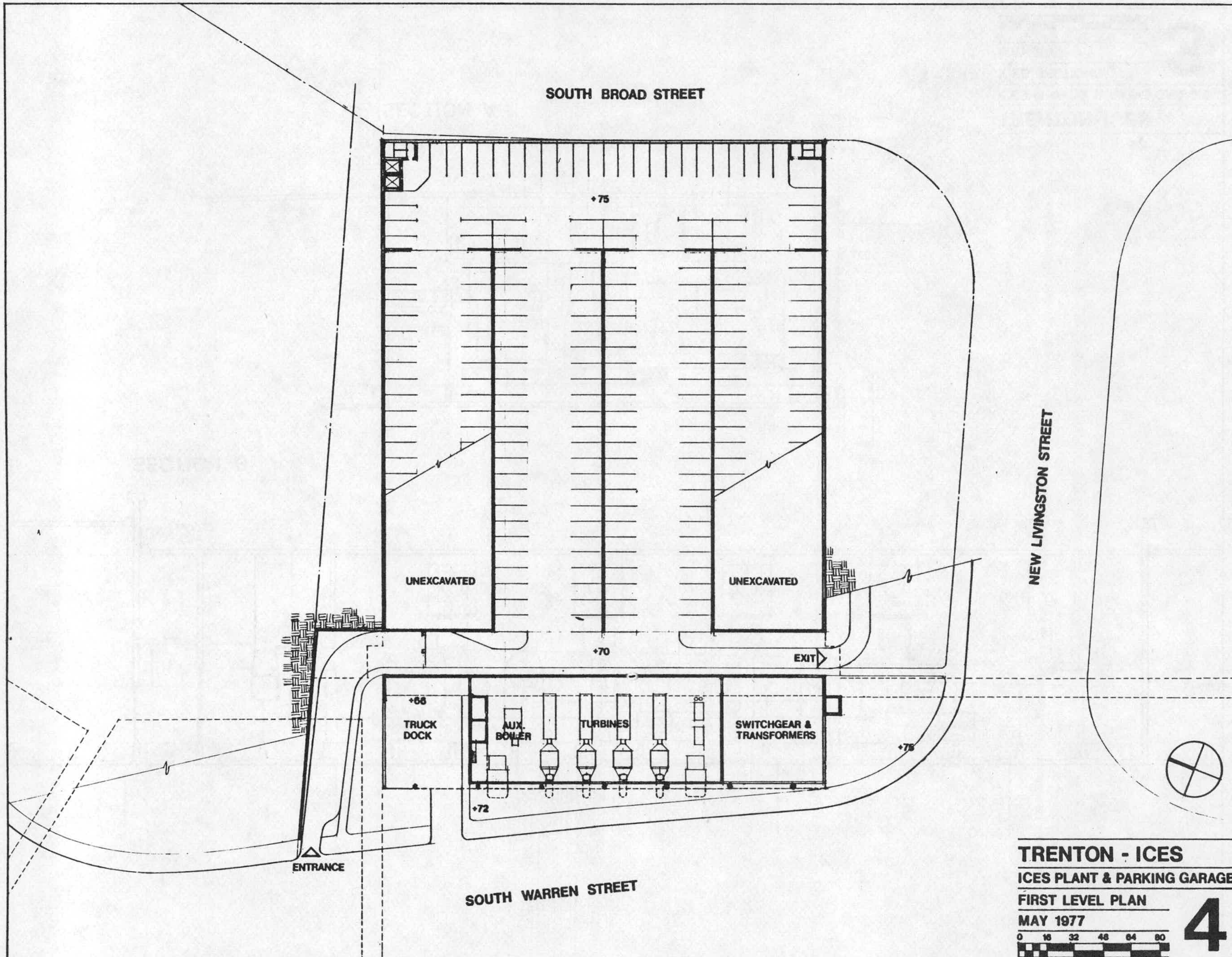
FIGURE 13



SECTION B
SECTION A
TRENTON-ICES
ICES PLANT & PARKING GARAGE
ICES SECTIONS
MAY 1977
0 4 8 12 16 20
3


FIGURE 14

FIGURE 15


SOUTH BROAD STREET
+75
UNEXCAVATED
UNEXCAVATED
+70
EXIT
+66
TRUCK DOCK
AUX. BOILER
TURBINES
SWITCHGEAR & TRANSFORMERS
+75
+72
NEW LIVINGSTON STREET
ENTRANCE
SOUTH WARREN STREET
TRENTON - ICES
ICES PLANT & PARKING GARAGE
FIRST LEVEL PLAN
MAY 1977
0 16 32 48 64 80
4

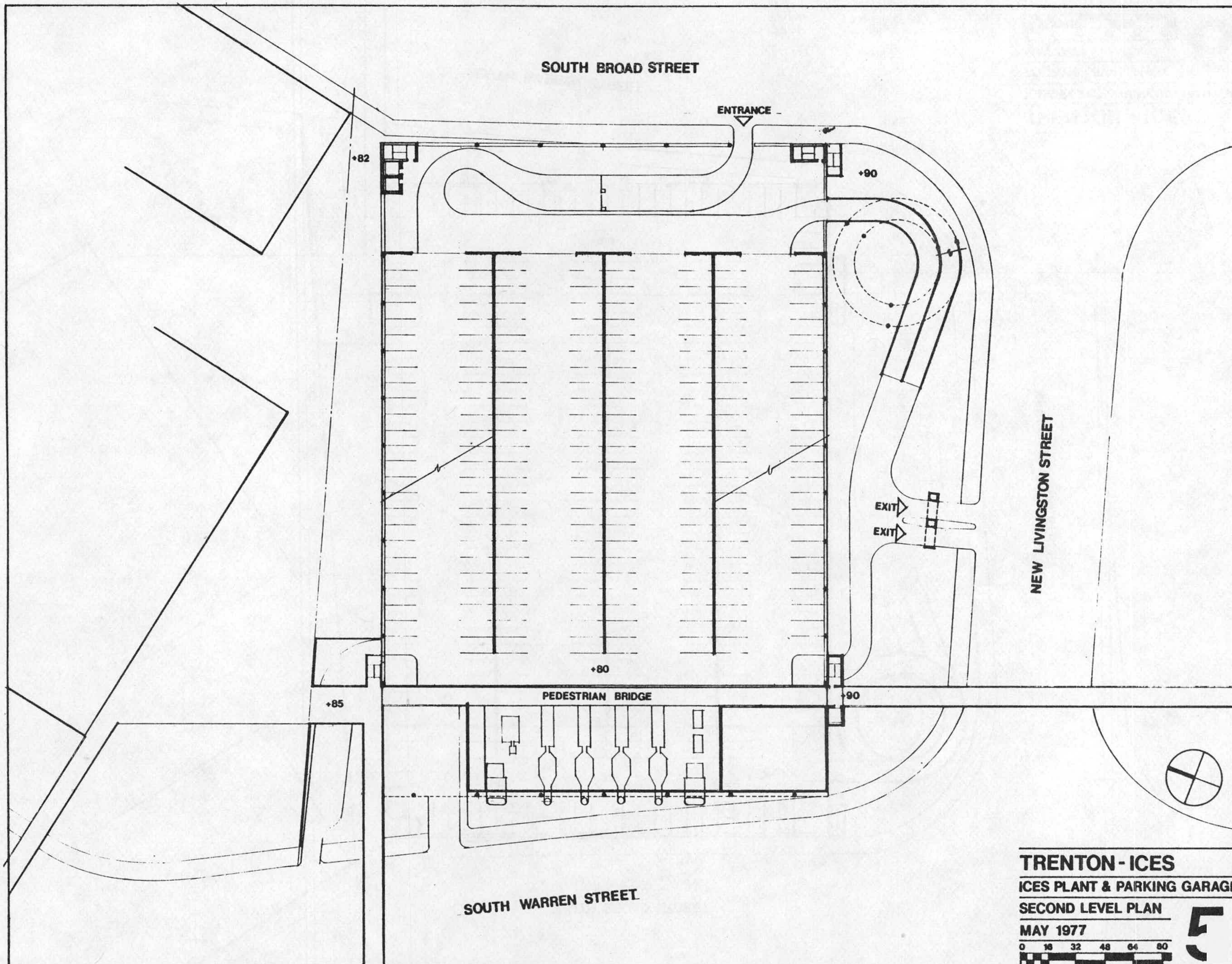

SOUTH BROAD STREET
ENTRANCE
+82
+90
EXIT
EXIT
NEW LIVINGSTON STREET
+80
PEDESTRIAN BRIDGE
+85
+90
SOUTH WARREN STREET
TRENTON - ICES
ICES PLANT & PARKING GARAGE
SECOND LEVEL PLAN
MAY 1977
0 16 32 48 64 80
5

FIGURE 16

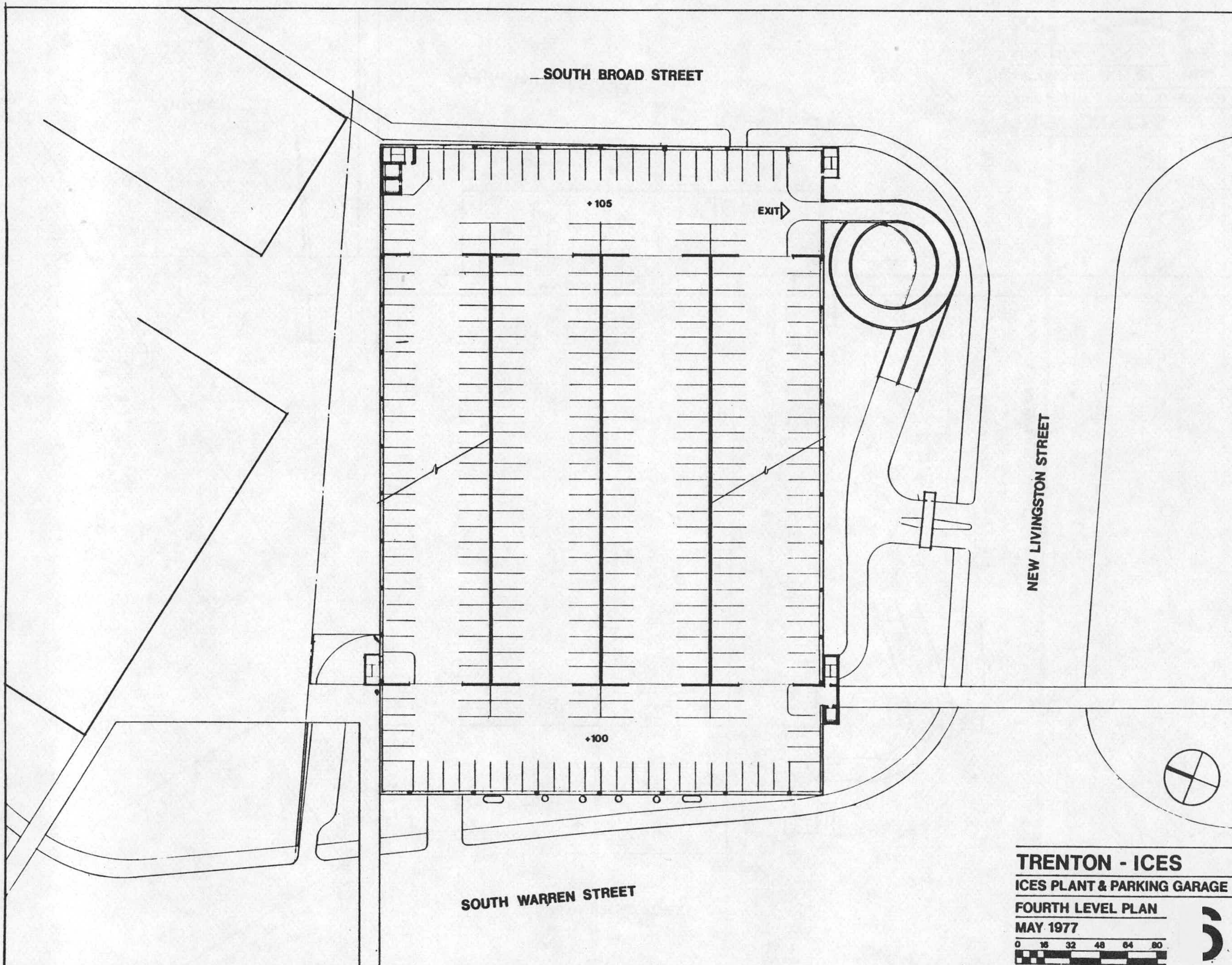

SOUTH BROAD STREET
+105
EXIT
NEW LIVINGSTON STREET
+100
SOUTH WARREN STREET
TRENTON - ICES
ICES PLANT & PARKING GARAGE
FOURTH LEVEL PLAN
MAY 1977
0 16 32 48 64 80
6

FIGURE 17

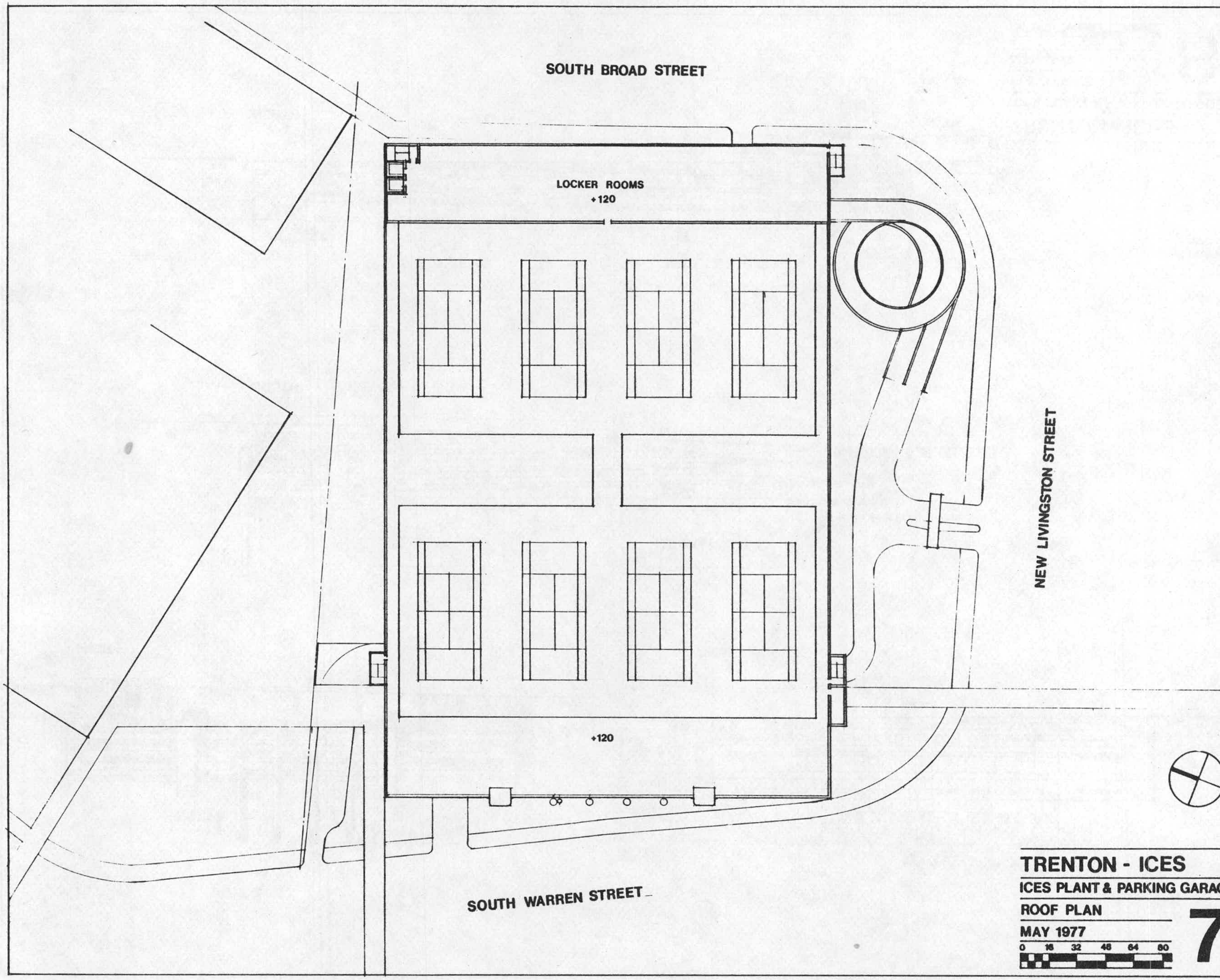
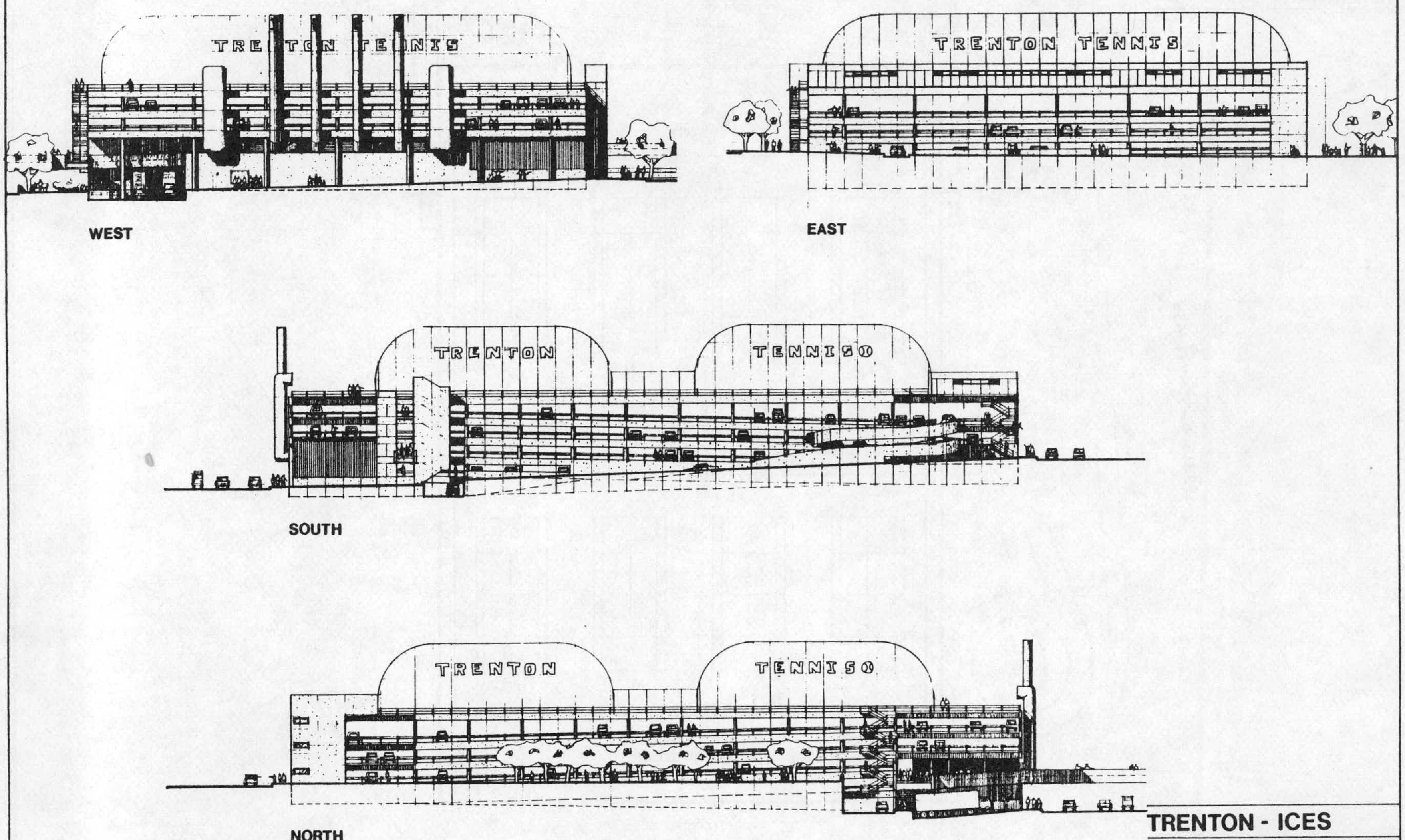

SOUTH BROAD STREET
LOCKER ROOMS
+120
+120
NEW LIVINGSTON STREET
SOUTH WARREN STREET
TRENTON - ICES
ICES PLANT & PARKING GARAGE
ROOF PLAN
MAY 1977
0 16 32 48 64 80
7

FIGURE 18




**TRENTON - ICES**

**ICES PLANT & PARKING GARAGE**

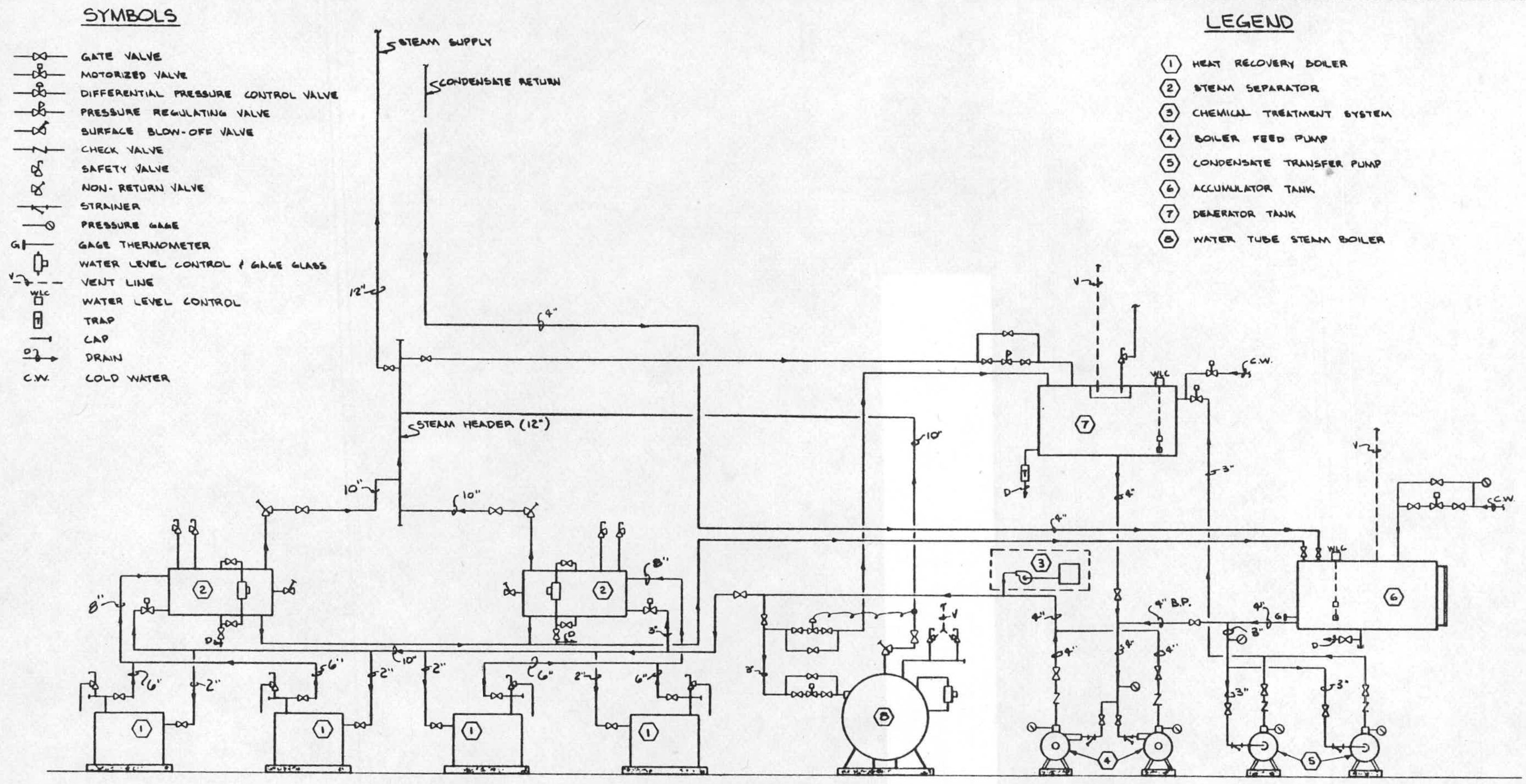
**ELEVATIONS**

**MAY 1977**

0 16 32 48 64 80

**8**

FIGURE 19




ICES PLANT THERMAL SYSTEM SCHEMATIC

FIGURE 20

**TRENTON - ICES**
**ICES PLANT & PARKING GARAGE**
**ICES THERMAL SYSTEM**
**MAY 1977**
**9**

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# task IV

## firming up commitments

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## 4.1 FIRMING UP COMMITMENTS

The Demonstration Team has considered three areas where essential commitments must be made in order that the ICES system reach the implementation stage. The first area is securing the commitments from the principal parties involved in the Demonstration Team as to their continued participation in this Deomonstration Program. The second area is securing the commitment on the part of the customers to receive the service. The third group of commitments to be secured are those from the various regulatory agencies identified in Task II Institutional Assessment.

### Demonstration Team

All of the participants in the Demonstration Team are committed to performing the Phase II contract and are optimistic that the detailed feasibility study of Phase II will confirm the preliminary feasibility analysis which shows that the Trenton ICES not only saves fuel but also will provide thermal energy to customers at a competitive cost while providing Public Service Electric and Gas Company a reasonable return on investment.

### Demonstration Community

The Demonstration Team has kept the observer-participants informed as the project has proceeded. An introductory working session was held on February 16th, 1977 when representatives of the various ICES Demonstration Community owners attended a briefing session with the working members of the Demonstration Team.

These representatives, along with several other interested parties attended an executive summary session of the mid-term review with ERDA officials, held on April 7th, 1977 at Trenton, New Jersey. Based on the preliminary feasibility study Phase I, the Demonstration Community customers have expressed enthusiasm about joining the system.

Regulatory Bodies

In order to secure initial review and commitment from the various regulatory agencies, the Demonstration Team contacted appropriate agencies to meet with them and to discuss the ICES concept, its application in downtown Trenton, the ramifications to those agencies and their requirements for approvals. The following agencies were contacted:

1. The New Jersey Department of Environmental Protection
2. The Delaware Valley Regional Planning Commission
3. The Delaware River Basin Commission
4. The New Jersey Public Utility Commission
5. The New Jersey State Energy Office
6. The Trenton Planning Board
7. New Jersey Department of Labor and Industry, Mechanical Inspection Bureau

In each case the Demonstration Team found the regulatory agencies helpful in their suggestions and guidance in meeting their review requirements. No serious difficulties were encountered at this preliminary review stage.

4.2 FINANCING

The Demonstration System will be owned and operated by Public Service Electric and Gas Company. As part of their large electric and gas utility system (third largest in the nation) the project would be financed by its normal process of issuing securities and using internally generated funds. However, the Demonstration Team recognizes that in order to increase the margin of economic feasibility of this Demonstration Project and thereby insure its success, alternative means of financing which could lower the cost of money to PSE & G will be explored.

## 4.3 FUEL ALLOCATION

At this time it is not possible to get a definite statement from the Federal Energy Administration that oil will be allocated to PSE & G for the ICES plant. President Carter's energy message indicates that electric utilities will be admonished to convert to coal where possible. However, PSE & G's experience in this area indicates that oil will be readily available to fuel this plant. Since the fuel will be consumed so efficiently that it will conserve fossil fuel in the form of coal for use elsewhere, the Demonstration Team feels confident that there will be an adequate supply of fuel oil for this project.

Also, the present natural gas supply situation would not allow PSE & G to use gaseous fuel for combustion turbine. However, if additional gas supplies could be made available from new sources such as Atlantic off-shore drilling, coal gasification, etc., then gas may be considered as a viable future fuel supply for the ICES plant in order to conserve oil.

With minor modifications, combustion turbines can be converted to burn either oil or gas.

## 4.4 OWNERSHIP AND OPERATION

The Trenton ICES Demonstration Project will be owned and operated by Public Service Electric and Gas Company as part of the overall power generation system of PSE & G and the Pennsylvania-New Jersey-Maryland (P-J-M) Interconnection Power Pool. PSE & G will operate the system in response to thermal demand in accordance with the ICES concept with the possible exception of an emergency situation when all other PSE & G and P-J-M peaking generators are on line and additional electrical system demand must be met on a short term basis.

## 4.5 CUSTOMER INDUCEMENTS

Decision Process

Choices for energy supply to buildings for use in heating, ventilating and air conditioning (HVAC) System are usually based on one or more of the following parameters:

1. Capital cost of the system
2. Fuel Cost and Availability
3. Life of Equipment
4. Ease of Maintenance and Complexity of the System
5. Operating and Maintenance Expenses (O & M)
6. Reliability, noise, aesthetics, ease of control, etc.

The interaction of these parameters impacts on the building owners' decision process based on yet another group of parameters.

1. How is the capital generated? Is capital money more easily obtained than operating subsidies?

2. Does the owner also operate the system?

3. Does the owner/operator have a more favorable investment alternative available to hire? (e.g. another apartment rather than an expensive HVAC System)

4. What is the estimated life of the project?

5. What is the total cash flow of the project and what percentage does the HVAC alternative represent?

With some variations, decisions regarding HVAC Systems and their energy supply are based on a life-cycle cost analysis. Using this approach, the capital, O & M and energy costs are evaluated for available fuels using the estimated life of the project. The alternative which yields the lowest present worth of all future costs is usually chosen. The difference between alternatives, must, however, be significant enough to off-set or override the other parameters mentioned above.

Existing Buildings

For the existing buildings, the decision will be made using a comparison between the customer's present energy supply and associated costs and the conversion operating, maintenance and thermal costs of an ICES system. The two most sensitive areas in this analysis are the capital conversion costs and the thermal costs including contract duration, minimum charges and termination costs.

New Buildings

For the new buildings, a much more advantageous economic position is possible for ICES due to the complete capital amortization of both terminal systems. In this case, thermal costs alone are the most sensitive area.

In addition, some members of the Demonstration Community may find social and political advantages to becoming part of ICES. Trenton ICES would be looked on as a first of its kind and is a visible symbol of energy saving. Both of these aspects are newsworthy.

Inducements

With an eye towards customer inducement, the ICES project team must develop steam rates or contracts which will accomplish the following:

1. Offer some margin of life cycle cost advantage over conventional systems.

2. Encourage summer and winter use of thermal energy consistent with user needs.

In addition, the use of a non-restrictive policy must be evaluated and established regarding the conversion costs for existing buildings.

# task V

## work management plan

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## 5.1 SCHEDULING REQUIREMENTS

In order to meet the stringent time requirements necessary for the Demonstration System to be on line when the first new portions of the Demonstration Community are constructed, an aggressive time schedule has been established.

Capital Place I will be ready for occupancy in May 1979, therefore the Work Management Plan consists of a two-tiered fast track approach. The Demonstration System must have thermal capacity available by May 1979; this means that the plant enclosure including the parking garage (of which it is an intergral part by the nature of its urban design), the back-up boiler system and the first portion of its distribution system must be completed by that date. We have therefore established two stages of construction for the Demonstration System: Stage "A" which consists of the back-up boiler (used to provide steam to Capital Place I, Luther Arms and the Justice Complex until the turbines-generators and waste heat boilers are on line), the portion of the distribution system serving Capitol Place I, the Mercer County Detention Center-Courthouse Complex, Kingsbury I, Luther Arms and the Justice Complex, and the plant enclosure including the parking garage; and Stage "B" which consists of the electrical generation and waste heat recapture systems, controls, etc., and the remainder of the steam distribution network, and the electrical interconnection with the Utility grid.

5.2 WORK MANAGEMENT: PHASE II

Task I Energy Analysis

A. Reassessment of Phase I Work

   1. Reassess Demonstration Community and modify energy profiles.
   2. Investigate possible use of coal technology as a retrofit including on-site coal gasification and/or use of PSE & G multiple-source gas supply including coal gasification.
   3. Assess future growth of community.

B. Further Investigation of Economic Parameters

   1. Investigate module size for potential incremental growth of the Demonstration System.
   2. Develop demand profiles year by year as the Demonstration Community develops.
   3. Investigate alternate designs for the ICES plant enclosure.
   4. Reassess ICES economics including a sensitivity analysis based on variations of significant parameters.

Task II Institutional Assessment

A. Development of draft forms of agreement where necessary:

   1. Urban renewal parcel land disposition
   2. Easements and rights-of-way for thermal distribution and storage facilities
   3. Customer service agreements

B. Preliminary approval of oil allocation from the U.S. Federal Energy Administration.

C. Amendment of the John Fitch Way Urban Renewal Plan.

D. Evaluation of alternative financing arrangements.

E. Draft environmental assessment.

F. Determination of PSE & G steam service policy.
   1. Service application procedures
   2. Inspection of customer's facilities
   3. Service additions and alterations
   4. Access to customer's premises
   5. Metering and service configuration

G. Determination of steam rate policy

H. Analyze the effect of building the ICES Demonstration System.
   1. PSE & G: financial analysis
   2. Each customer: life cycle cost study
   3. City of Trenton: tax benefit analysis

<u>Task III Preliminary Engineering Design</u>

A. Preliminary design of power and thermal systems, subsystems and controls.

B. Preliminary design of steam distribution and thermal storage systems.

C. Preliminary design of the ICES plant enclosure including the elevated walkways.

<u>Task IV Final Engineering Design of the Stage "A" Construction Including Construction Documentation</u>

A. Final engineering and architectural design of the standby boiler (which will provide thermal service until the entire Demonstration System is operable) the ICES plant enclosure, and the Stage "A" thermal distribution and storage network to serve Capital Place I, the Mercer County Detention Center and Courthouse, Kingsbury I, Luther Arms and the New Jersey State Justice Complex.

Task V Customer Liaison

A. Establishment of contact with the necessary operating and management personnel for each member of the Demonstration Community.

B. Obtain any necessary final commitments and arrange for customers to allow ERDA to conduct end use tests. Determine final financial status of each customer.

5.3 WORK MANAGEMENT: PHASE III

Task I Final Design and Construction Documentation

A. Final design and construction documentation of power and thermal systems, subsystems, components and controls.

B. Final design and documentation of thermal distribution and storage systems.

Task II Construction of the Stage "A" Demonstration System

A. Receive bids and/or negotiate construction contracts and construct the Stage "A" Demonstration System as described in Phase II, Task IV above.

Task III Operation and Maintenance Procedures

A. Prepare a detailed operations and maintenance procedure manual.

Task IV Customer Liaison

A. Continue customer liaison to define customer's requirements for end-use equipment and metering.

5.4 WORK MANAGEMENT: PHASE IV

Task I Construction Management

A. Preconstruction planning and activities plus management of the construction process.

Task II Construction

A. Perform the remaining construction to complete the ICES system.

Task III Customer Liaison

A. Continuation of customer liaison to coordinate service connection.

Task IV Billing Procedure

A. Establishment of meter reading and billing procedures.

B. Train appropriate customer accounts personnel.

5.5 WORK MANAGEMENT: PHASE V

Task I System Installation Tests

A. Testing to verify that the equipment installations have been made in accordance with the construction documents.

Task II Start-Up Tests

A. Preparation of schedule of start-up tests.

B. Conduct Start-up Tests with U.S. ERDA concurrence.

Task III Installation of Monitoring Equipment

A. Design and installation of Monitoring Instrumentation Systems (MIS) for detailed data collection.

Task IV Performance Test

A. Provide for and perform a 1-year performance test of the ICES Demonstration System.

Task V Customer Liaison

A. Continued customer liaison to assure proper communications and billing.

5.6 WORK MANAGEMENT: PHASE VI

Task I Operation and Maintenance Management

A. Operation and Maintenance of the Demonstration System according to the schedule established in Phase III, Task III above.

Task II Long Term Demonstration Evaluation

A. Preparation of reports to evaluate the Demonstration System.

Task III Post Contract Operation

A. Preparation of a post contract program plan for the continued operation of the Demonstration System.

Task IV Customer Liaison

A. Continuation of on-going customer liaison program.

5.7 DEMONSTRATION COST ESTIMATES*

NON-CONSTRUCTION DEMONSTRATION COSTS

| Phase | ERDA Share | ICES Demonstration Team Share |
|---|---|---|
| I | $176,900 | --- |
| II | $920,100 | --- |
| III | --- | $937,450 |
| IV | --- | $360,400 |
| V | --- | $111,000 |
| VI | $ 10,000** | $ 45,000 |

CONSTRUCTION COSTS

| Phase | ERDA Share | ICES Team Share |
|---|---|---|
| I | --- | --- |
| II | --- | --- |
| III | --- | $2,489,500 |
| IV | $120,000 + | $7,439,200 |
| V | Cost of MIS ++ | --- |
| VI | --- | --- |

* Note: All costs in 1977 dollars.

** Costs to vary with the reporting requirements of ERDA.

\+ Possible ERDA subsidy to existing buildings for capital costs of connection to the Demonstration System, if the New Jersey Public Utilities Commission will not permit differential steam contract rates for new and existing construction.

++ Monitoring Instrumentation Systems as required by ERDA or the National Bureau of Standards.

Trenton ICES PERT Chart Phases II through VI

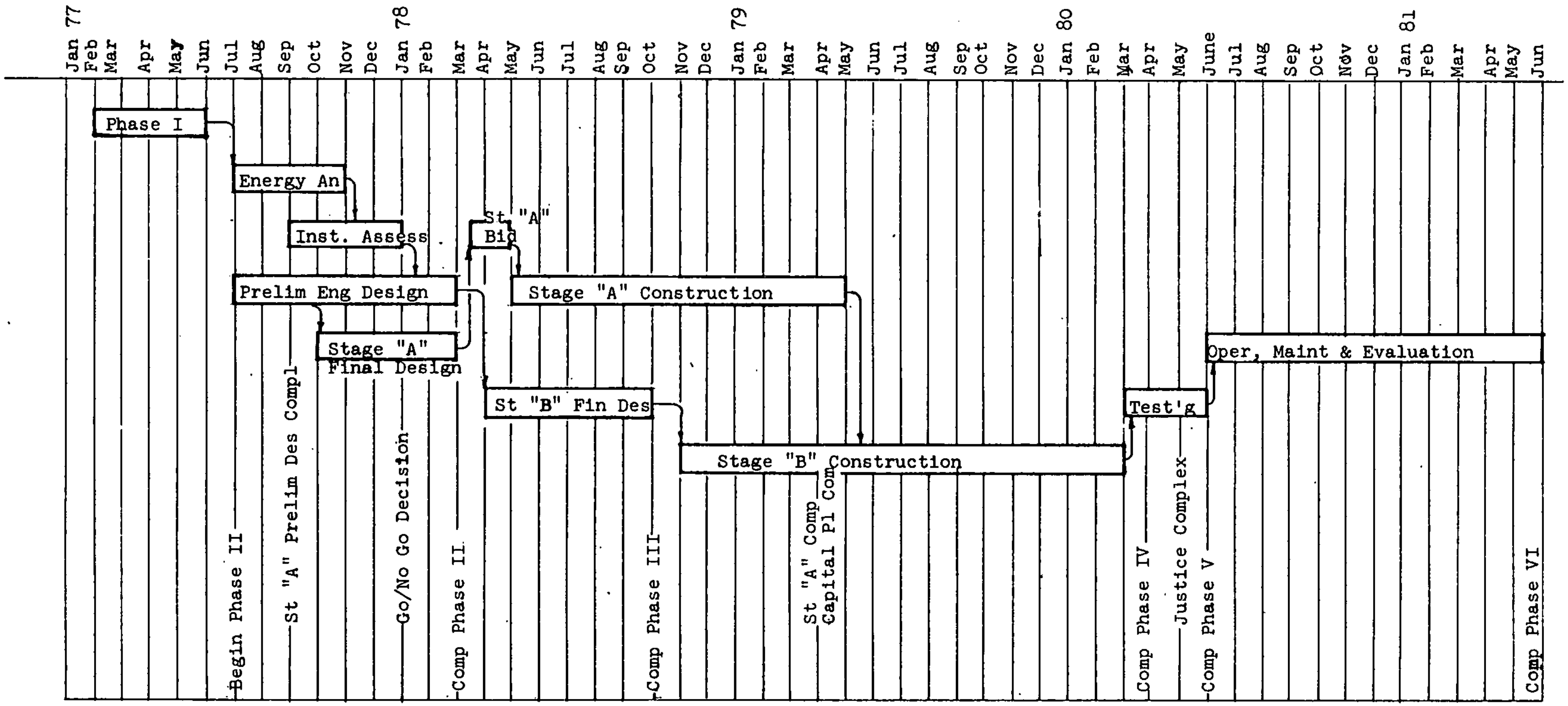


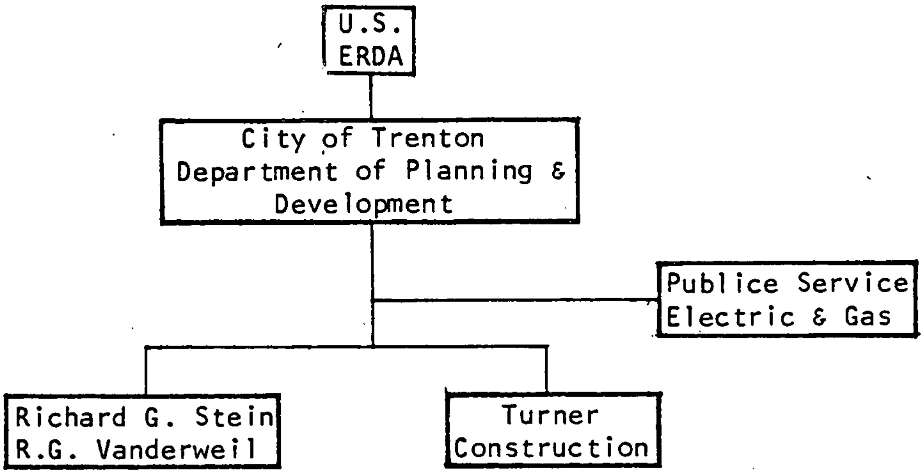

FIGURE 21

FIGURE 22

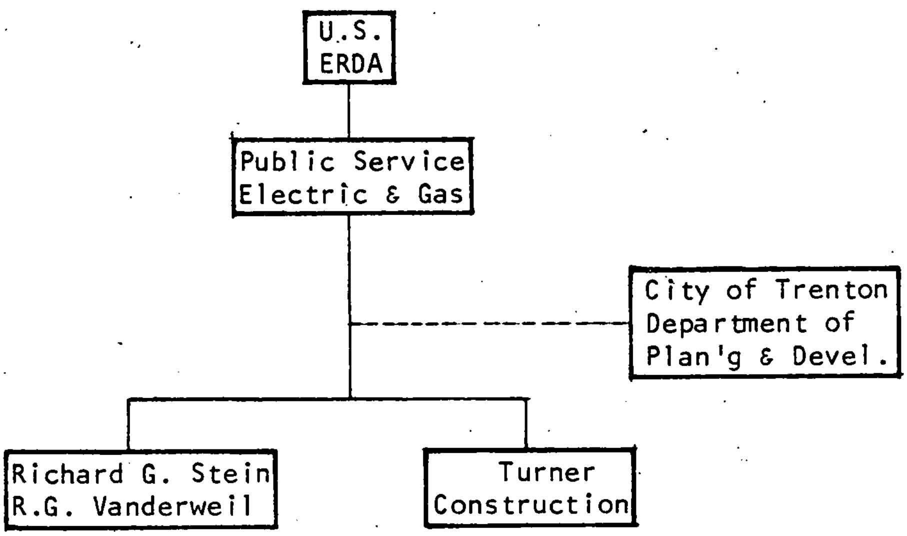
## 5.9 DEMONSTRATION TEAM ORGANIZATION

Trenton ICES

DEMONSTRATION TEAM O- AN! IONAL
CHARTS- 'ASE II ANu .HASES III - VI




PHASE II DETAILED FEASIBILITY AND
PRELIMINARY DESIGN




PHASE III THROUGH VI