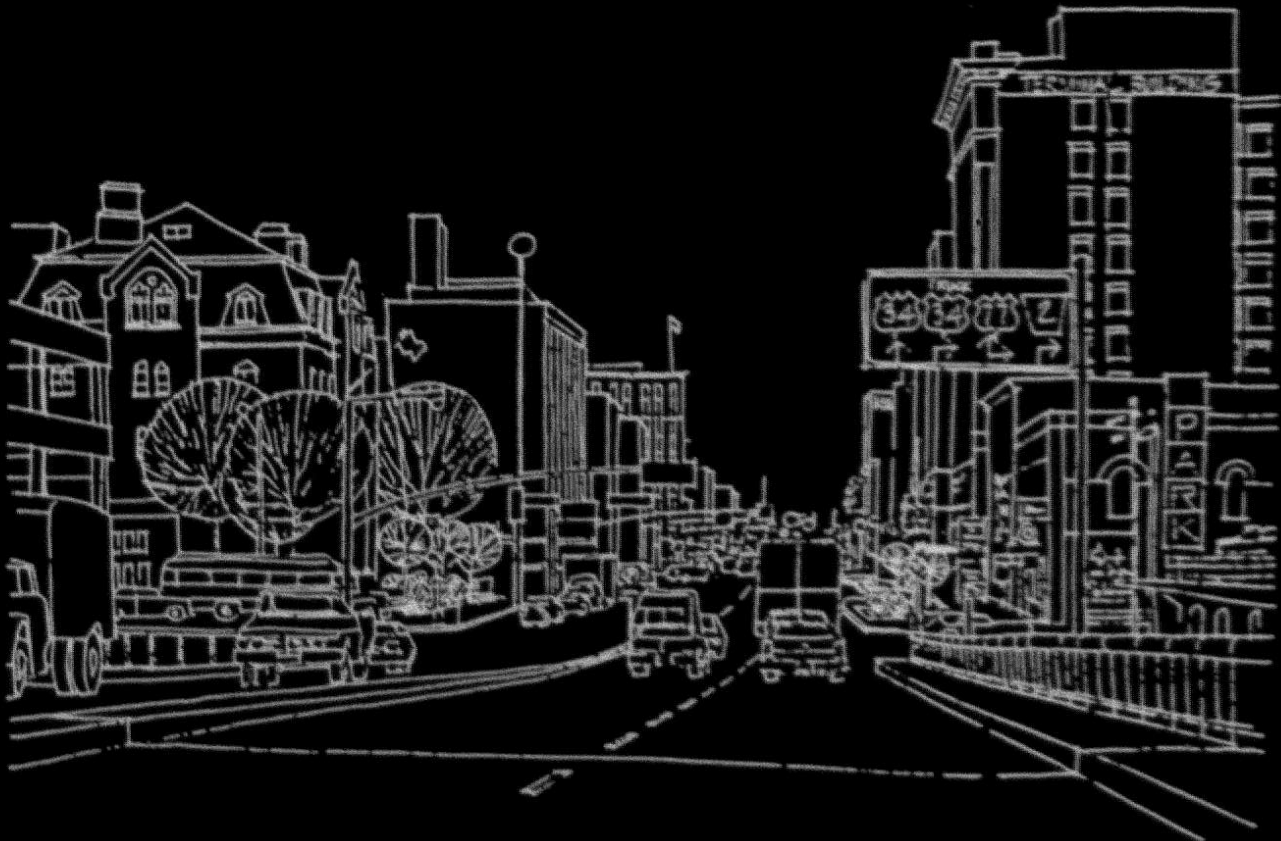


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# DISTRICT HEATING AND COOLING ASSESSMENT

11/1/87



LINCOLN

City of Lincoln

Lincoln, Nebraska 68506

Roland A. Luedtke, Mayor

**-LES**

LINCOLN ELECTRIC SYSTEM

Walter A. Canney, Administrator

SUBMITTED IN RESPONSE TO  
DOE SOLICITATION No. DE-P301-84CE265

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DOE/CE/26526--T1

PHASE I FEASIBILITY REPORT

DE87 009076

FOR THE

PROPOSED HAYMARKET DISTRICT HEATING AND COOLING SYSTEM  
LINCOLN, NEBRASKA

OCTOBER 27, 1986

FGCI-15CE 26526

Prepared by  
The City of Lincoln, Nebraska  
and  
Lincoln Electric System

MASTER



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## ABSTRACT

The concept of district heating and cooling is not new. It existed in many cities in the U. S. during the first half of this century. These systems usually took the form of downtown steam heating systems. In fact, Lincoln had such a system which like most systems of that vintage had no condensate return and had to be eventually abandoned because of the deteriorated condition of the piping and poor economics of operation.

During the 1950's and 60's energy was abundant in this country and the incentive to renovate these systems was nonexistent. This situation differed substantially from that of the European Community and particularly the Scandinavian countries which were dependent on foreign oil for heating fuel. Sweden, for example, has aggressively pursued district heating over the past 20 to 25 years. Many Swedish communities now have systems that not only cover downtown areas but also service as much as 70% of the residential portion of the community.

In this study we have attempted to examine the prospects of serving a 16 block downtown area with a new district heating and cooling system. The system would deliver hot water and chilled water to the various buildings in the district who choose to be connected. The core of the system would be large water source heat pumps which would utilize waste water effluent from the Theresa Street Plant. By incorporating the heat pump into this system the waste water effluent becomes the primary source for heat extraction and rejection for the district system. The advantages to the building owner include: 1) hot water and chilled water can be purchased at a rate comparable or below that of operating their own boiler and chiller. 2) The need for a boiler and chiller are eliminated which substantially reduces capital cost of equipment and on-going maintenance costs. 3) The elimination of related costs such as water treatment, insurance and maintenance labor. 4) The gain of space in the building which would be occupied by the equipment could be utilized for alternative purposes.

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## Overview

This study was performed under a cost sharing arrangement between the City of Lincoln, Nebraska and the U. S. Department of Energy in accordance with the criteria set forth under Solicitation Number DF-PS01-84CE26508 entitled "District Heating and Cooling Assessment Program."

The report was prepared under the direction of the City of Lincoln with the assistance of the Lincoln Electric System, the Lincoln Water System, and the consulting firms of Hoskins-Western-Sonderegger and Resource Development Associates.

The study was performed to determine preliminary feasibility, economic and technical parameters of using large scale water source heat pumps in a central plant location to produce bulk heating and cooling for distribution to buildings located in an approximate sixteen block area in the downtown Lincoln.

## TASK I

### Conclusion and Recommendations

A district heating and cooling system serving a downtown core is an attractive and economically competitive alternative to conventional single building heating and cooling systems. This conclusion is enhanced by several opportunities which are present in the City of Lincoln downtown area. Before describing the specific merits of the Lincoln DH&C system it is important to state conditions which are necessary for the initial development of any new utility and more specifically a district heating and cooling utility.

The first requirement is for the presence of a customer load base which is sufficient in size to enable a capital intensive utility to design and install the necessary equipment and energy delivery systems. The major benefit of energy utility service over individual systems is in the economy of scale and the ability to serve a diverse load with a smaller installed production capacity than the sum of required capacities of individual systems.

A second criteria is that an energy source be available which will allow the utility to supply energy competitively priced against alternate resources. As with most energy businesses the energy component must cost less relative to alternative fuels in order to allow the utility to offset the capital component of the utility production costs.

A third requirement for a utility to be successful is the ability to adequately manage and operate the system. Utility reliability and performance must be maintained at an equal or higher level than competing services.

A fourth criteria for successful utility development is that the product should offer the customer savings other than energy costs. The product may be in a more readily usable form or may save the customer the operation costs associated with fuel consumption, energy conversion or in space, and labor requirements.

The proposed Lincoln DH&C system can satisfy all of the above basic requirements. The proposed customer base load consists of the new downtown redevelopment area. Within this multiblock development the DH&C utility can offset significant capital expenditures for individual building heating and cooling equipment and can free additional space within the development which otherwise would be required for mechanical equipment. In order to further expand the system service area, additional buildings on the perimeter of the new development would be included. Several of these existing buildings are undergoing renovation and could be interconnected to a district system during the extended construction phase for the new development.

The second criteria which Lincoln readily meets is the availability of an inexpensive energy source. The use of large heat pumps to provide both heating and cooling for the district enables the utility to utilize heat recovery from sewage effluent or ground water resources. To drive the heat pumps the utility would have access to an inexpensive and stable electrical



supply. The generation of this electrical energy is provided from a diversified resource mix including new coal fired generators, nuclear resources, and federal hydro-electric generating capacity. The electrical rates for the City of Lincoln are presently among the lowest in the United States and are projected to remain very competitive well into the future.

The third utility requirement met in the Lincoln case is the ability to successfully operate and maintain the DH&C system. The requirement can be satisfied through several organizations. This report has analyzed both private and public ownership for the system and has indicated that public ownership would provide the least expensive energy product. With the exception of the natural gas system all of Lincoln's utilities are publicly owned and operated. The operation and maintenance of a DH&C system could be integrated into the existing framework of one of these utilities. This method of ownership and operation could provide for utilization of existing materials, equipment, organizational and infrastructure not available to a completely new utility organization.

The final requirement outlined above is that the utility supplied product should provide the customer with benefits above those related to product cost. This additional benefit in the DH&C system would be provided in the area of building operation, maintenance and space utilization. The individual building owner would no longer be required to provide equipment and labor for an energy conversion process. The interconnected building would no longer contain boilers, chillers, fuel storage, and cooling towers, but would directly utilize hot and cold water for building heating and cooling systems.

This report has analyzed various ownership scenarios, various system size options and several mechanical configurations. However, to generally state the competitive advantage which a DH&C system could provide over alternative energy supply options the following graphical presentation is included. The three areas of significance for this comparison are:

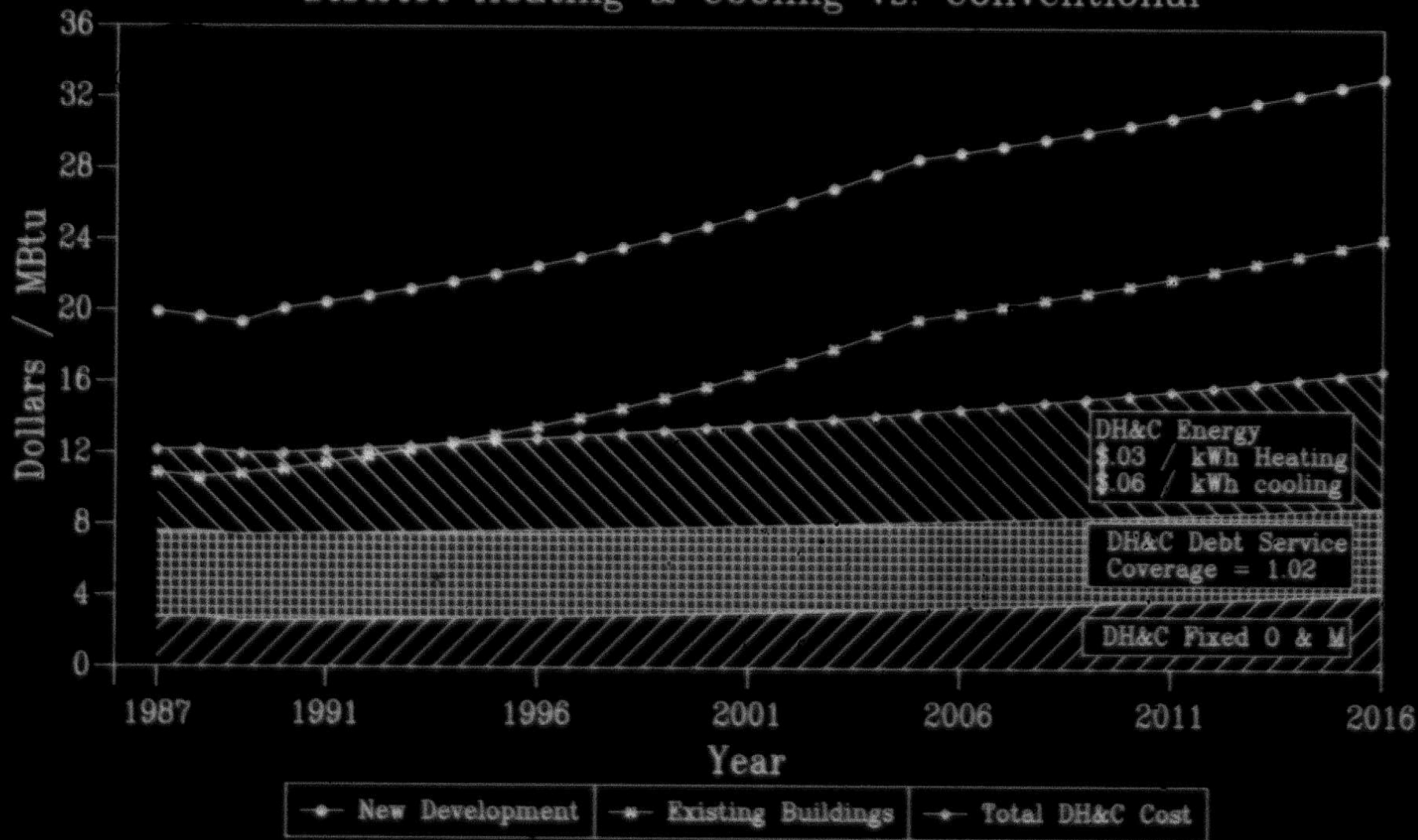
- Estimated "New Development" Total Energy Cost. This includes all operation, maintenance, energy costs, and amortized capital costs for a new single building central mechanical plant.
- Estimated "Existing Building" Energy Costs. This includes all costs which are in "New Development" except capital cost since mechanical systems are assumed to be in place.
- The three components making up the "Total District Heating and Cooling Cost." The total production cost includes operation and maintenance, energy, and DH&C debt service.

The graph first indicates that the "New Development" Total Energy Cost is significantly higher than the DH&C alternative. The primary reason for this cost difference is the embedded equipment cost or debt service in the new development buildings. In addition the efficiency of smaller single building mechanical systems cannot match that of the DH&C system. Both capital and energy components are higher in cost than the respective DH&C components and the operation and maintenance cost were assumed equal for this analysis.

If the capital component for the "New Development" energy rate is removed the

remaining costs make up the estimated per unit energy production costs for existing buildings. The energy cost for existing buildings, while initially lower than DH&C, escalates above the DH&C cost within approximately six years. This spread is caused by increases in the energy cost component for the existing building energy. The energy component contributes a higher percentage of the existing building cost and even if the same energy escalation rate is assumed for both the existing customers and DH&C service the existing customer cost will rapidly increase above the DH&C cost.

# Energy Costs District Heating & Cooling vs. Conventional



## TASK 2

### Identification of Potential District Energy System Projects

The purpose of this task was to attempt to identify, quantify, and configure a technically and economically viable district heating system, based on water source heat pumps, that has a realistic potential for development. The task was broken down into six interdependant subtasks for evaluation.

1. Thermal Loads
2. Thermal Distribution System
3. Thermal Sources
4. Central Plant
5. Thermal Storage
6. UNL Interconnection

## 1. Thermal Loads

Thermal load analysis involves the approximation of both heating and cooling energy consumption and the area to be served.

Heating load determination should account for building size, type of construction, occupancy, location, climatic conditions and general usage.

Cooling loads are strongly dependent on size, type of construction, occupancy, location, usage, solar gain, latent loads, outdoor temperature and humidity.

There are a number of energy estimation methods available that vary considerably in complexity and sophistication depending on the number of variables included in the analysis. Accuracy of the estimates can be significantly enhanced through the use of detailed simulation methods that evaluate the dynamic influence of variables with respect to time. Comprehensive computer simulation of building energy loads are time consuming and are expensive to perform adequately.

Simplified energy estimation methods reduce the effort and expense required, by examining only the most critical factors influencing consumption; however, these methods are less accurate.

A simplified method for estimating the heating and cooling load in a

large area encompassing a number of structures, can include the review of past energy records. Historical energy consumption data was obtained from Lincoln Electric System and Minnegasco for 27 buildings in the study area. On site surveys were also conducted for several larger buildings in order to determine the type, age, and condition of existing physical plant equipment, nameplate data, installed capacity, information on terminal systems, and other pertinent building data such as floor area, insulation specifications, occupancy, and operating hours. All available data was compiled on a "District Heating Assessment Commercial User Survey" for each building. A sample of the survey form has been included in the appendix.

The study area is represented in Exhibit 2-1 and a list of the buildings included in the assessment is summarized in Exhibit 2-2. During the thermal analysis, a number of factors made it difficult to conclusively quantify the information collected.

These factors included:

- a. Incomplete or inconsistent energy consumption histories for some buildings due to extended vacancies,
- b. Lack of submetering on energy supplies serving multiple uses such as, combined heating/cooking and lighting/cooling loads,
- c. Partial building occupancies,

- d. Changes in building ownership and use during the historical period,
- e. Recent renovation or remodeling work in progress altering available floor area and usefulness of historical data,
- f. Announcement of proposed plans to significantly alter the configuration of the study area,
- g. Interest by building owners outside of the study area,
- h. Significant changes in historical heating and cooling costs due to energy conservation programs.
- i. Difficulty in identifying which buildings would be candidates for inclusion on the system.



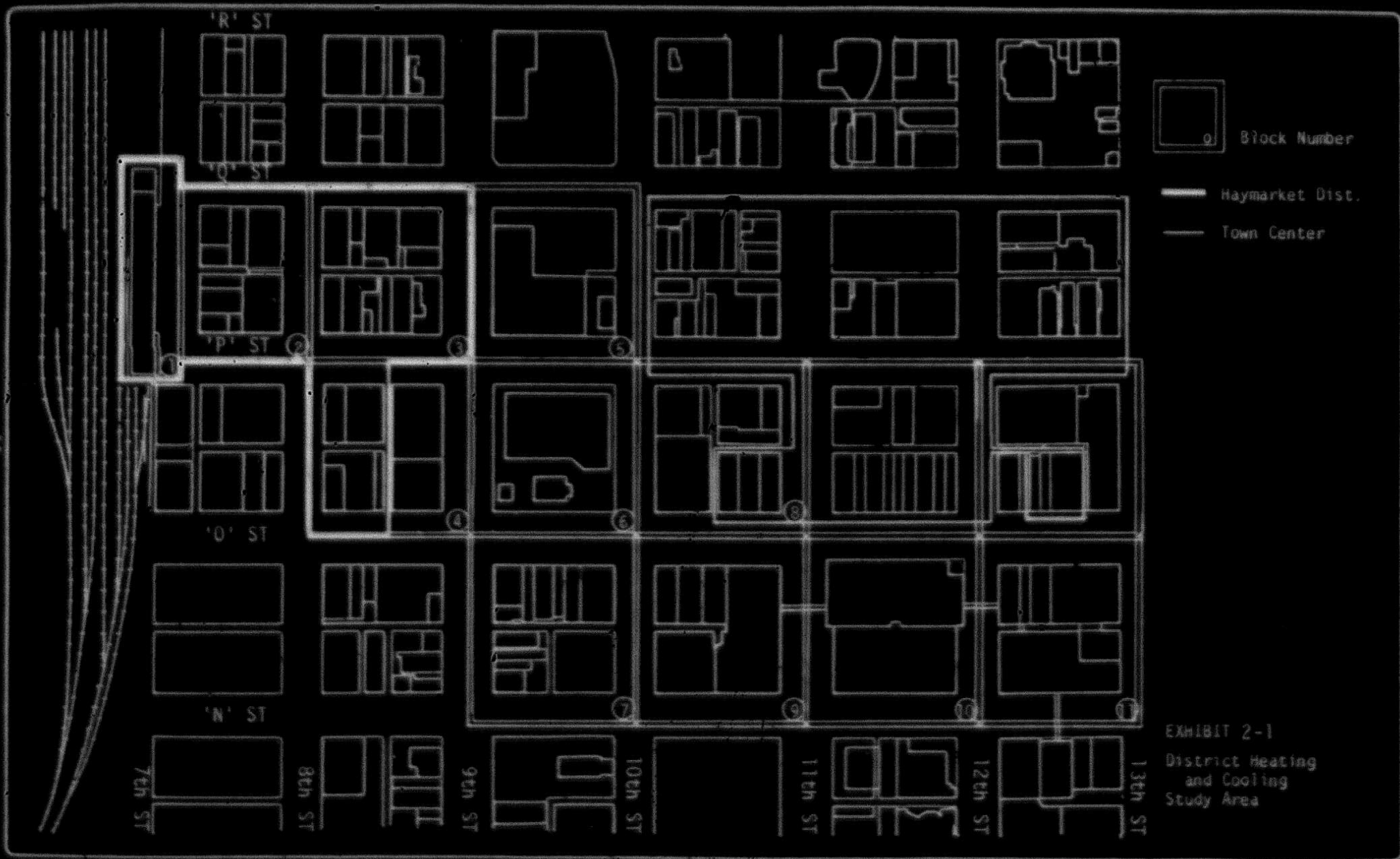
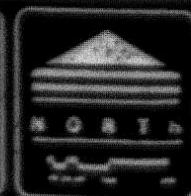


EXHIBIT 2-1  
District Heating  
and Cooling  
Study Area

**LINCOLN**  
DIV OF LINCOLN ELECTRIC  
SERVING A LIVING CITY

**LES**  
LINCOLN ELECTRIC SYSTEM

**DISTRICT  
HEATING AND COOLING  
ASSESSMENT**



## EXHIBIT 2-2

## BUILDING AREA SUMMARY

| BUILDING # | BUILDING NAME            | SQ. FEET | HEATING | COOLING |
|------------|--------------------------|----------|---------|---------|
| 1.01       | * Burlington Station     | 60,000   | GS      | EW      |
| 2.01       | * Candy Factory          | 146,640  | ER      | EC      |
| 2.02       | Haymarket Junction       | 11,855   | NA      | NA      |
| 2.03       | Side Track               | 2,345    | NA      | NA      |
| 2.04       |                          | NA       | NA      | NA      |
| 2.05       | Lo Rise Apt./Retail      | 5,963    | NA      | NA      |
| 2.06       |                          | NA       | NA      | NA      |
| 3.01       | Gas Station              | 1,700    | NA      | NA      |
| 3.02       | * Fizz                   | 28,400   | GF      | NA      |
| 3.03       | * Magnum Building        | 5,000    | GF      | EC      |
| 3.04       | Vieth Building           | 4,125    | GF      | EC      |
| 3.05       | * Harpham Building       | 35,500   | GF      | EC      |
| 3.06       | * Old Indian Center      | 26,696   | NA      | NA      |
| 3.07       | Samm Office/Warehouse    | 30,252   | NA      | NA      |
| 3.08       | Warehouse                | 11,160   | NA      | NA      |
| 3.09       | Barry's                  | 9,660    | NA      | NA      |
| 3.10       | * Brittany's             | 4,500    | GF/ER   | EC      |
| 3.11       | * Collar Factory         | 1,600    | ER/GF   | EC      |
| 4.01       | Small Office/Retail      | 10,244   | NA      | NA      |
| 4.02       | Oscar's                  | 11,176   | NA      | NA      |
| 4.03       | Large Office             | 33,250   | NA      | NA      |
| 4.04       | Small Office             | 41,478   | NA      | NA      |
|            | Haymarket District Total | 481,544  |         |         |
| 4.05       | Parking Garage           | NA       | None    | None    |
| 4.06       | Hilton Hotel             | 131,848  | NA      | NA      |
| 5.01       | Greyhound Bus Station    | 18,036   | NA      | NA      |
| 5.02       | * Journal Star           | 103,848  | GS      | EC      |
| 6.01       | * Old City Hall          | 21,600   | GS      | None    |
| 6.02       | * Old Federal Building   | 162,413  | GS      | EW      |
| 7.01       | Small Office             | 7,500    | NA      | NA      |
| 7.02       | Small Office             | 3,960    | NA      | NA      |
| 7.03       | Small Office             | 6,500    | NA      | NA      |
| 7.04       | Small Office             | 7,700    | NA      | NA      |
| 7.05       | Retail                   | 6,650    | NA      | NA      |
| 7.06       | Retail                   | 7,300    | NA      | NA      |
| 7.07       | Retail                   | 12,500   | NA      | NA      |
| 7.08       | Retail                   | 6,500    | NA      | NA      |
| 7.09       | Retail                   | 10,400   | NA      | NA      |
| 7.10       | * Terminal Building      | 107,010  | ES      | EC      |

EXHIBIT 2-2  
(Continued)  
BUILDING AREA SUMMARY

| BUILDING # | BUILDING NAME              | SQ. FEET                                         | HEATING | COOLING |
|------------|----------------------------|--------------------------------------------------|---------|---------|
| 8.01       | * Clayton House            | 51,000                                           | GS      | EC      |
| 8.02       | * Continental Bus Station  | 18,036                                           | GF      | EC      |
| 8.03       | * YMCA                     | 126,832                                          | EHP     | EHP     |
| 8.04       | Retail                     | 8,700                                            | NA      | NA      |
| 9.01       | * Golds                    | 320,000                                          | ES      | EC      |
| 9.02       | * Lincoln Building         | 77,452                                           | ES      | EC      |
| 9.03       | Senior Center              | 35,000                                           | None    | None    |
| 9.04       | St. George & Dragon        | 14,200                                           | NA      | NA      |
| 10.01      | Parking Garage             | NA                                               | None    | None    |
| 10.02      | * Centrum                  | 80,000                                           | ER      | EC      |
| 11.01      | * Atrium                   | 250,000                                          | ER      | EC      |
| 11.02      | * Miller & Paine           | 150,000                                          | GS      | EC      |
| TOTAL      |                            | 1,744,985                                        |         |         |
|            | Dept. Store A              | 200,000                                          |         |         |
|            | Dept. Store B              | 180,000                                          |         |         |
|            | Dept. Store C              | 160,000                                          |         |         |
|            | Office Building A          | 100,000                                          |         |         |
|            | Office Building B          | 160,000                                          |         |         |
|            | Retail #1                  | 240,000                                          |         |         |
|            | Retail #2                  | 60,000                                           |         |         |
|            | Hotel                      | 50,000                                           |         |         |
|            | Proposed Town Center Total | 1,150,000                                        |         |         |
| TOTAL      |                            | 3,376,529 square feet<br>(313,800 square meters) |         |         |

GS Natural Gas - Steam  
 GH Natural Gas - Hot Water  
 GF Natural Gas - Forced Air  
  
 EC Electric - Chiller/Refrigeration  
 EW Electric - Window A/C  
 ER Electric - Resistance  
 ES Electric - Steam  
  
 EH Electric - Hot Water  
 EHP Electric - Heat Pump  
  
 NA Not Available

Total building gross square footage in the study area, including preliminary estimates for the Town Center and excluding buildings scheduled for replacement, was estimated to be in excess of 3.3 million square feet.

In order to estimate a per unit energy production cost, it was necessary to develop an estimate of the capital costs for the central production plant and delivery system. Since these costs are dependant on the thermal load to be supplied, a decision was made to estimate the capital costs requirements for three alternate thermal load options, based on projected market penetration factors and plausible configurations to enable a reasonable routing of a thermal distribution system.

The first service area option selected included the new Town Center redevelopment area, the Old Federal Building and Old City Hall. This entire area includes an estimated 1.25 million square feet of retail, commercial and office space. This area, if redeveloped, will require new mechanical installations for both heating and cooling. The potential exists for serving all heating and cooling needs for this development from the centralized heating and cooling plant. In addition, anticipated demolition and reconstruction in this area would provide an opportunity for the installation of distribution piping with minimal impact regarding street and sidewalk closings. The ability to install all new utility service to the redevelopment buildings in conjunction with other construction activities in the area could reduce the cost of both materials and labor for distribution piping. The City owned buildings were included because of the proximity to the

redevelopment area and the future need for cooling plant installations for both buildings.

The second thermal load option included all of option one plus additional area to incorporate approximately 50% of the total square footage in the study area. For the purposes of this study the area added to Option 1 has been shown as the block bounded by 10th and 11th Street and N and O Street and includes approximately 625 thousand square feet of additional commercial, retail and office space, resulting in a total of 1,875 million square feet. This additional area fits closely with the distribution system defined in option one and could provide a significant expansion in load served at a minimal increased cost in distribution facilities.

The third thermal load option was defined as approximately 2.5 million square feet or 75% of the total square footage in the study area. The area encompasses the area included in Option 1 and 2, plus 625 thousand additional square feet of commercial, retail and office space within the area bounded by 9th and 13th streets and N and Q streets or within the Haymarket Area. For the purpose of developing budgetary costs for Option 3, the distribution system was selected to serve several existing buildings; however, any combination of building loads which total 625 thousand square feet in or immediately adjacent to this area could be considered equally suitable.

Since the thermal assessment conducted under the scope of this study is only intended to be preliminary, building energy usage factors were

approximated for hypothetical buildings, representative of the range of sizes and uses considered to be typical. These approximations may be applied to any configuration of buildings that may be proposed under a more definitive evaluation.

The annual heating and cooling energy was calculated for each of the three options using the simplified equivalent full load hours method. The results of the thermal load evaluation is summarized as follows:

| <u>Building Energy Usage Factors</u> |                                         |                                         |                                                 |
|--------------------------------------|-----------------------------------------|-----------------------------------------|-------------------------------------------------|
|                                      | <u>Demand</u><br>Btu/Hr/<br>Square Foot | <u>Equivalent</u><br>Full Load<br>Hours | <u>Annual Energy</u><br>Btu/Square<br>Foot-Year |
| Heating                              | 20                                      | 1,500                                   | 30,000                                          |
| Cooling                              | 20 (1)                                  | 1,000                                   | <u>20,000</u>                                   |
| Total Annual Energy                  |                                         |                                         | 50,000                                          |

These factors were then applied to the square footage approximations for each of the three options to develop an approximated thermal load for each case. The results of this evaluation are summarized in Exhibit 2-3.

(1)

$$\frac{1}{[(600 \text{ Square Foot/Ton}) / (12,000 \text{ Btu/Hr/Ton})]} = 20 \text{ Btu/Hr/Square Foot}$$

# EXHIBIT 2-3

## Feasibility Study Thermal Load Options

|           | <u>Buildings Served</u><br><u>No.</u> | <u>Sq. Ft.</u> | <u>Annual Energy Required</u> |                        |                         |
|-----------|---------------------------------------|----------------|-------------------------------|------------------------|-------------------------|
|           |                                       |                | <u>Heating</u>                | <u>Cooling</u>         | <u>Total</u>            |
|           |                                       |                | $10^6$ Btu                    | $10^6$ Btu             | $10^6$ Btu              |
| Option #1 | 10                                    | 1,250,000      | 37,500<br>(10,987 MWh)        | 25,000<br>(7,325 MWh)  | 62,500<br>(18,312 MWh)  |
| Option #2 | 14                                    | 1,875,000      | 56,250<br>(16,481 MWh)        | 37,500<br>(10,987 MWh) | 93,750<br>(27,469 MWh)  |
| Option #3 | 18                                    | 2,500,000      | 75,000<br>(21,975 MWh)        | 50,000<br>(14,650 MWh) | 125,000<br>(36,625 MWh) |

MWh = megawatt-hours (thermal)

The weather variables shown in Exhibit 2-4 were derived from the Lincoln Electric System weather data base. Exhibit 2-5 is a graphic representation of the minimum, maximum and average temperatures. The data utilized to calculate mean monthly temperatures, degree days, temperature humidity index, and wind chill factor, were based on one-hour interval observations reported by the National Oceanic and Atmospheric Administration (NOAA) for Lincoln, Nebraska for the years 1977 through 1985. Heating degree days were calculated using both the traditional 65°F mean daily temperature and a temperature of 45°F to reflect a lower balance point temperature to account for increased internal heat retention and lower thermostat settings currently experienced. Cooling degree days were calculated for both 65°F and 75°F to reflect higher thermostat settings demonstrated by recommended conservation practices. Because of the interest in the concepts of the project large amounts of data has been assimilated for future evaluation. This information will be available for subsequent refinement as the boundary areas become better defined.

#### **Thermal Load Recommendations:**

- a. Refine building energy consumption requirements and square footage assumptions of the Town Center development through contact with project architect/engineer and review of building code requirements.
- b. Determine degree of project interest by existing building owners to refine system configuration.



- c. Evaluate renovation and remodeling plans for future effect on system configuration.
- d. Perform detailed survey of prospective buildings to refine building data regarding system type, operating temperatures, potential for retrofit, energy consumption, building occupancy, and square footage for more accurate thermal load evaluation.

# EXHIBIT 2-4

## Weather Variables<sup>1</sup> 24-Hour Averages Lincoln, Nebraska

| Month | Mean Temperature |        | Degree Days <sup>2</sup> |       |       |       | Temperature<br>Humidity Index <sup>3</sup> | Average<br>Wind Chill <sup>4</sup> |
|-------|------------------|--------|--------------------------|-------|-------|-------|--------------------------------------------|------------------------------------|
|       | °F               | (°C)   | HDD65                    | HDD45 | CDD65 | CDD75 |                                            |                                    |
| Jan   | 18               | (-7.8) | 1,453                    | 832   | 0     | 0     | 30                                         | 1,077                              |
| Feb   | 25               | (-3.9) | 1,126                    | 566   | 0     | 0     | 35                                         | 981                                |
| Mar   | 38               | (3.3)  | 829                      | 257   | 0     | 0     | 45                                         | 813                                |
| Apr   | 52               | (11.1) | 409                      | 46    | 12    | 0     | 54                                         | 616                                |
| May   | 62               | (16.7) | 141                      | 0     | 51    | 2     | 62                                         | 439                                |
| Jun   | 72               | (22.2) | 14                       | 0     | 234   | 44    | 70                                         | 281                                |
| Jul   | 79               | (26.1) | 1                        | 0     | 422   | 140   | 74                                         | 186                                |
| Aug   | 75               | (23.9) | 2                        | 0     | 323   | 90    | 72                                         | 234                                |
| Sep   | 66               | (18.9) | 96                       | 3     | 136   | 23    | 65                                         | 369                                |
| Oct   | 53               | (11.7) | 384                      | 22    | 4     | 0     | 55                                         | 573                                |
| Nov   | 38               | (3.3)  | 821                      | 267   | 0     | 0     | 44                                         | 797                                |
| Dec   | 25               | (-3.9) | 1,256                    | 638   | 0     | 0     | 35                                         | 1,003                              |
| TOTAL |                  |        | 6,533                    | 2,630 | 1,183 | 299   |                                            |                                    |

1 Weather variables are monthly mean values of 24-hour averages.

2 HDD65 - Heating Degree Days calculated for mean daily temperature of 65°F.

HDD45 - Heating Degree Days calculated for mean daily temperature of 45°F.

CDD65 - Cooling Degree Days calculated for mean daily temperature of 65°F.

CDD75 - Cooling Degree Days calculated for mean daily temperature of 75°F.

3 Temperature Humidity Index  $THI = .55T + .2 T_{dp} + 17.5$

4 Wind Chill (Kg-cal/square meter-hour)  $WC = (10 WV + 10.45 - WV) (33.0 - T_c)$

where:  $T$  = Air Temperature (°F)

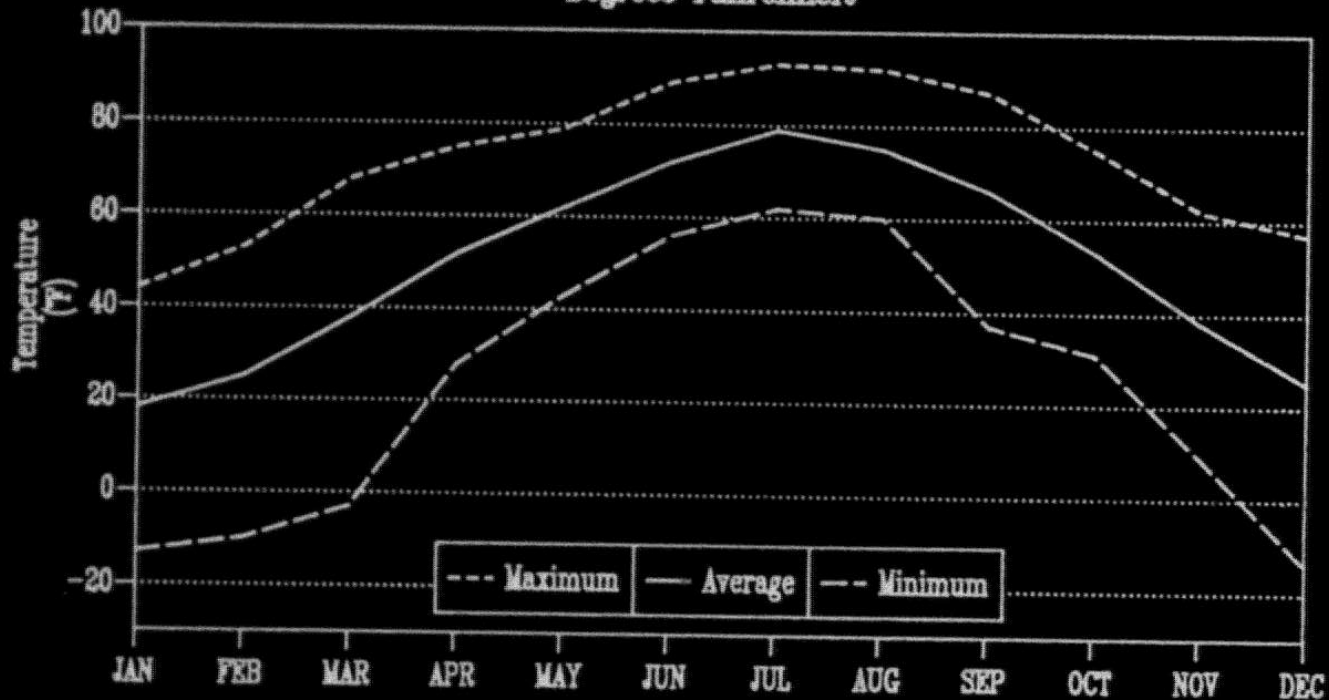
$WV$  = Wind Velocity (meters-sec)

$T_{dp}$  = Dew Point Temperature (°F)

$T_c$  = Air Temperature (°C)

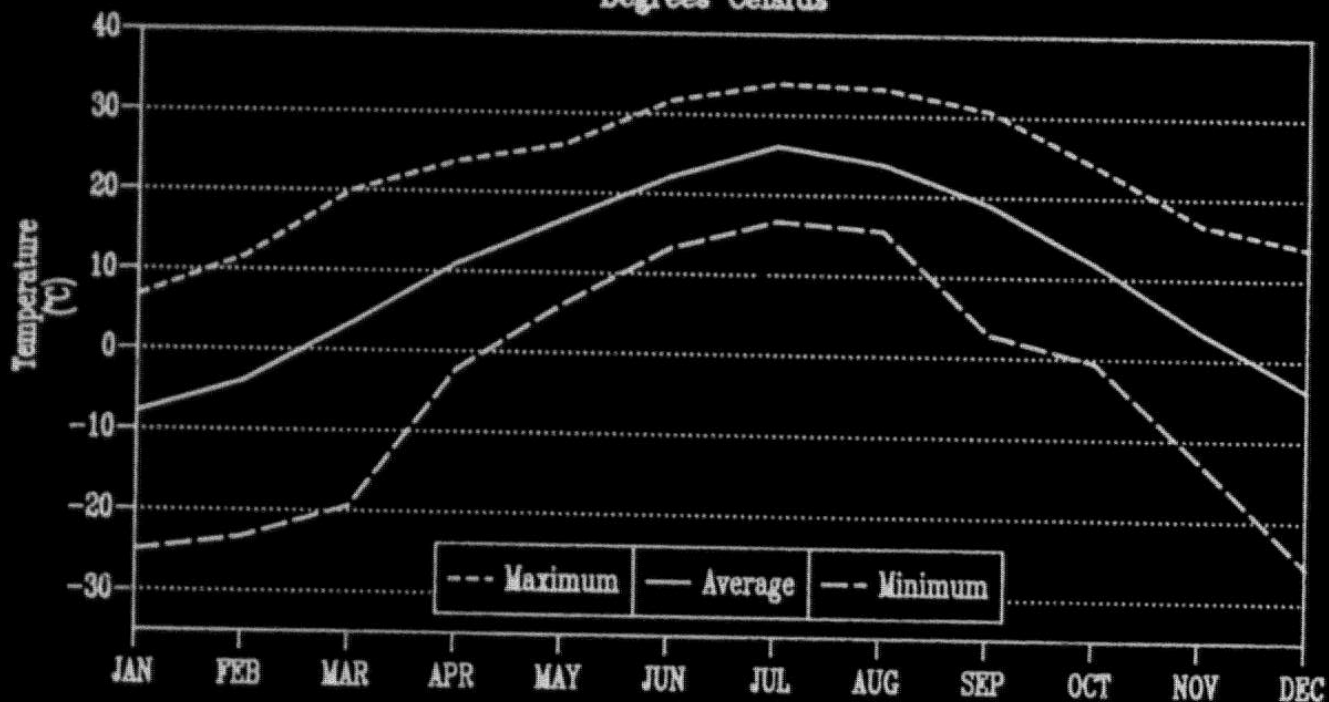
# Monthly Average Outdoor Temperature

1977 thru 1985  
Degrees Fahrenheit



# Monthly Average Outdoor Temperature

1977 thru 1985  
Degrees Celsius



## 2. Thermal Distribution System

Based on the potential thermal loads defined in the previous section, three distribution system options were developed. For all distribution cases the central plant or distribution starting point was located on a city owned lot at 10th and S Street as the closest practical location for the central plant facility to minimize distribution system cost. Approximately 1000 feet of main piping would be required between the central plant and the first thermal load in the service area which is a significant portion of the total distribution system cost. The distribution service areas for each of the three options is shown on Exhibit 2-6.

The philosophy used to analyze the DH&C distribution system was to start from a relatively dense core area and expand concentrically into adjacent areas. This method provided an opportunity to study systems of various sizes and provides a logical approach to evaluate system expansion and growth. This growth pattern can minimize capital investment and operating costs as load is added to the distribution network.

The distribution system parameters are shown in Exhibit 2-7. The system design would include four distribution pipes. One pair of these pipes would provide for heating load, while the second pair of pipes would provide chilled water for the cooling load. The heating pipe would be a composition construction, providing an integral insulation layer around

the steel pipe. The chilled water pipe would be an uninsulated pipe system since the temperature differential between the chilled water and earth would be relatively small. Both piping systems would incorporate protective coatings or jackets to reduce corrosion and to extend system lifetime and reliability. By selecting pipes fabricated for the specific temperature requirements the system material costs can be optimized. This four pipe system would also enable building cooling needs to be served during the winter heating season and domestic hot water or other heating requirements to be served during the summer cooling season.

A schematic one line representation of the projected four pipe distribution system is shown in Exhibit 2-8. The routing has not been specifically determined, but the system shown would have the capability to serve all three of the load options selected for this study. An effort was made to minimize the total length of distribution piping while allowing for expansion of the system to meet the concentric growth pattern previously outlined.

The development of distribution cost estimates for all three distribution options required a preliminary piping design and the performance of load calculations based on projected building loads. The options were simulated to evaluate the effects of flow rates and pressure drops to generate materials lists which detailed pipe sizing and preliminary fitting requirements. Budgetary per unit price estimates were obtained from manufacturers and from consultant supplied historical cost data. These costs were then used with the materials lists to approximate total distribution system costs. The distribution

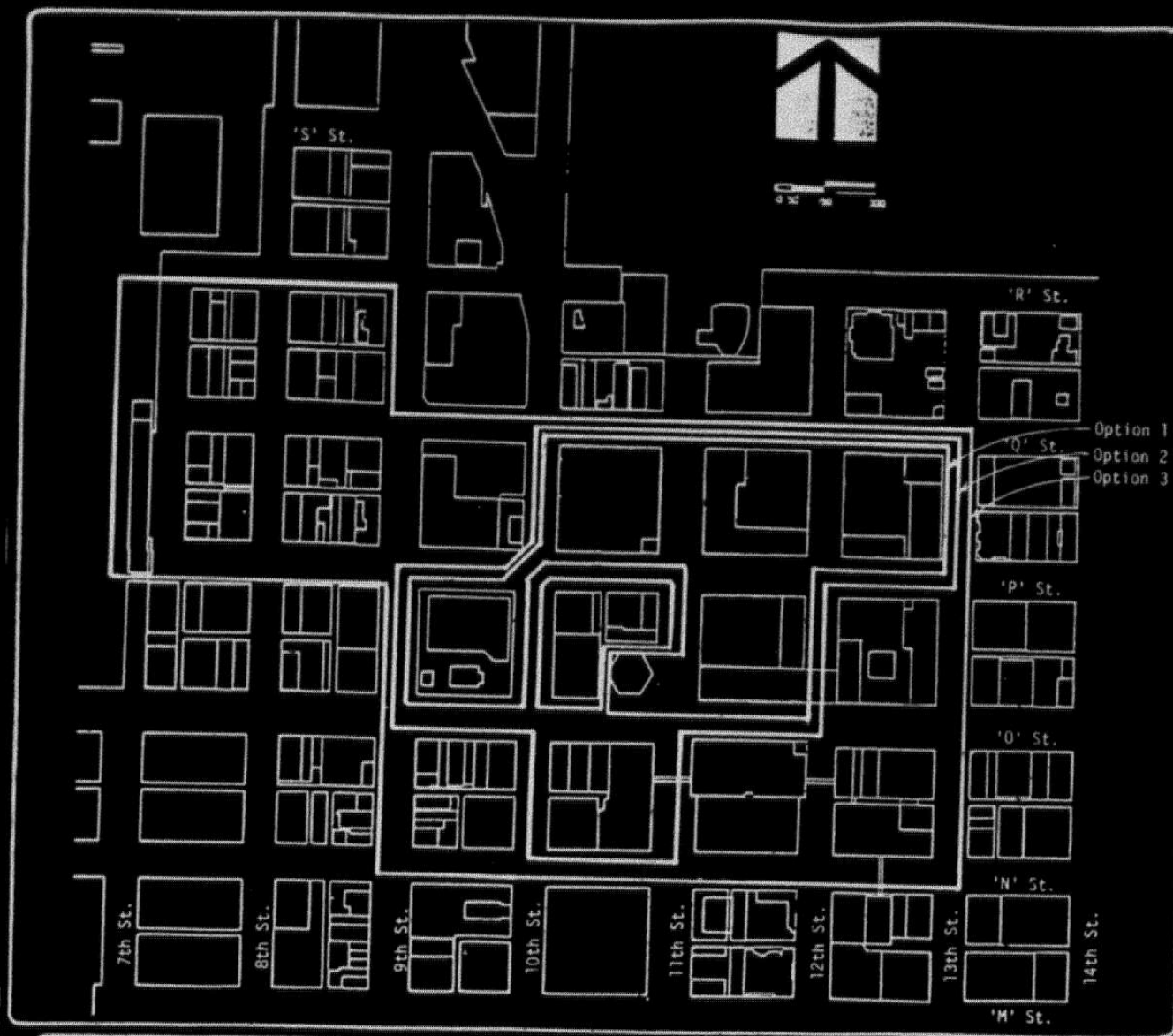
capital costs are summarized in Exhibit 2-9.

The estimated distribution capital cost summary indicates the importance of serving a significant load in a centralized, relatively dense core area with the initial distribution system installation. The system should be constructed with provisions for planned expansion which could be performed for incremental increases in first phase investment costs.

From the perspective of distribution system capital costs, it would appear that Option 2 would provide the best opportunity for maximizing thermal load service at the minimum capital investment. Distribution Option 2 would enable service to approximately 50 percent additional space with only a 12 percent increase in investment over Option 1.

#### **Thermal Distribution System Recommendations:**

- a. Further review pipe size and capital costs with regard to allowable water flow velocities, vibration, noise, cavitation, routing alternatives and pumping costs.
- b. Investigate alternate distribution piping materials.
- c. Refine simultaneous heating and cooling requirements.
- d. Investigate cost savings potential of incorporating installation of district heating and cooling piping network with required rework of city utility services during construction of proposed redevelopment project.



**LINCOLN**  
CITY OF LINCOLN, NEBRASKA

**-LES-**  
LINCOLN ELECTRIC SYSTEM

**DISTRICT  
HEATING AND COOLING  
ASSESSMENT**

EXHIBIT 2-6  
DISTRIBUTION SYSTEM SERVICE AREAS

## EXHIBIT 2-7

### DISTRIBUTION SYSTEM PARAMETERS

#### Peak Distribution Water Temperature:

|           |                                          |
|-----------|------------------------------------------|
| Heating * | 230°F (110°C) Supply/140°F (60°C) Return |
| Cooling   | 39°F (4°C) Supply/ 57°F (14°C) Return    |

#### Peak System Water Flow:

|          |                            |
|----------|----------------------------|
| Option 1 | 2,780 GPM (170 liters/sec) |
| Option 2 | 4,170 GPM (259 liters/sec) |
| Option 3 | 5,560 GPM (341 liters/sec) |

Customer Heat Exchanger Maximum Pressure Drop: 10 psi (68.9 kilopascals)

#### Maximum Distribution Pipe Size:

|         |                      |
|---------|----------------------|
| Heating | 12" Diameter (30 CM) |
| Cooling | 16" Diameter (40 CM) |

#### Distribution Pipe Materials: (Heating System)

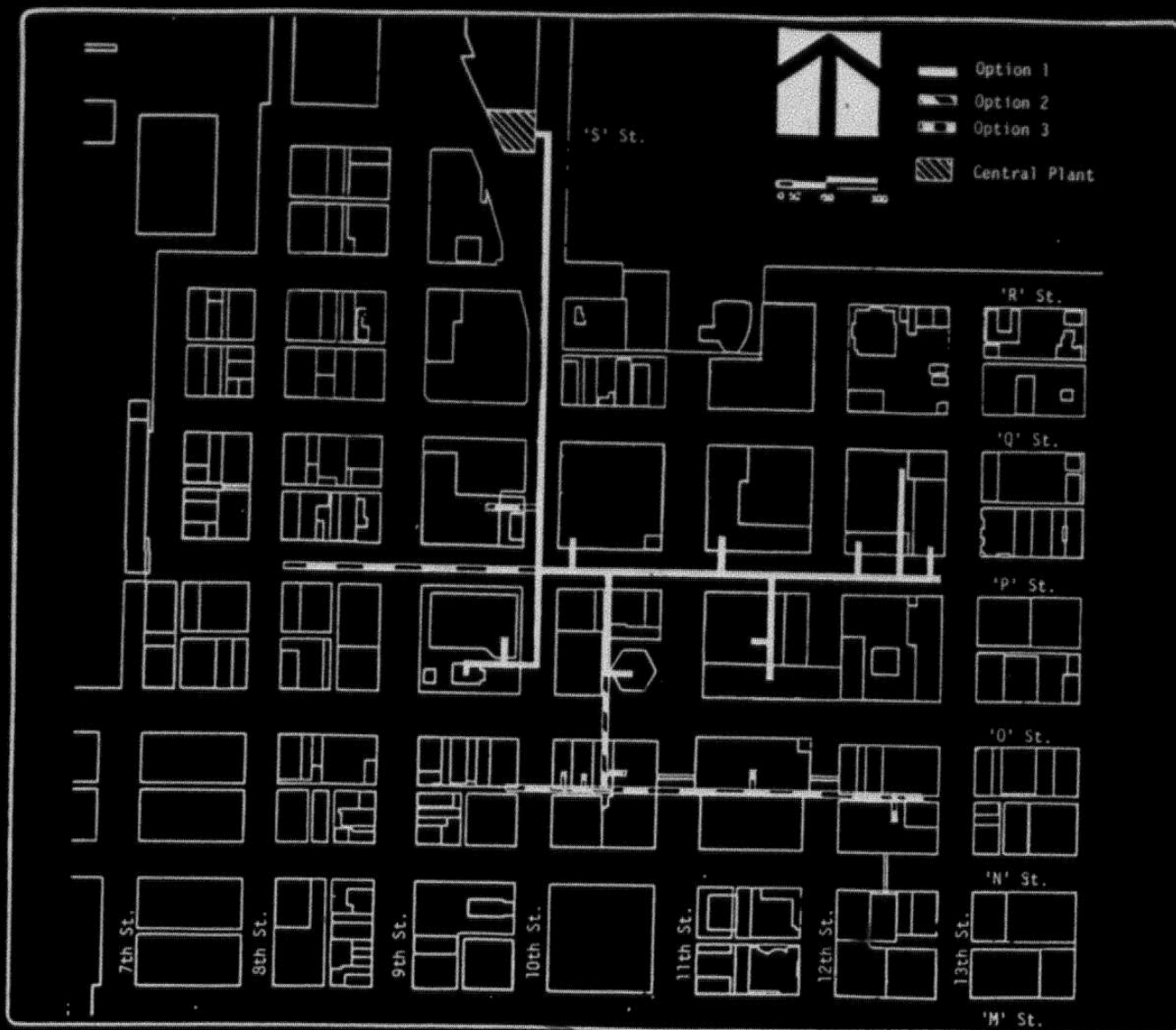
DIN Steel, Polyurethane Insulation, with  
seamless polyethylene jacket

#### Distribution Pipe Materials: (Cooling System)

Ductile Iron, coated class 250 water distribution piping.

\* Heat Pump delivery temperature would be 185°F (85°C) with the auxiliary boilers supplying the additional heating during peak heating periods.





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**DISTRICT  
HEATING AND COOLING  
ASSESSMENT**

EXHIBIT 2-8  
DISTRIBUTION SYSTEM ROUTING

## EXHIBIT 2-9

## Distribution Capital Cost Summary

|                                            | <u>Distribution Option</u> |                 |                 |
|--------------------------------------------|----------------------------|-----------------|-----------------|
|                                            | <u>Option 1</u>            | <u>Option 2</u> | <u>Option 3</u> |
| HEATING SYSTEM                             | \$697,000                  | \$768,000       | \$1,075,000     |
| COOLING SYSTEM                             | \$225,000                  | \$263,000       | \$ 355,000      |
|                                            | <hr/>                      | <hr/>           | <hr/>           |
| TOTAL DISTRIBUTION<br>SYSTEM COST          | \$922,000                  | \$1,031,000     | \$1,430,000     |
| TOTAL DISTRIBUTION<br>SYSTEM TRENCH LENGTH | 4,100 ft.                  | 4,600 ft.       | 6,500 ft.       |
| SYSTEM COST PER<br>INSTALLED FOOT          | \$225/ft.                  | \$224/ft.       | \$220/ft.       |

### 3. Thermal Sources

An essential part of any heating and cooling analysis is the procurement of a stable and readily available energy source. This requirement applies to the use of fossil fuels, electrical energy or in the case of a water source heat pump station, a dependable water supply for use as a heat source and sink. As part of the feasibility study conducted for this project, an independent water supply investigation was conducted by the firm of Hoskins-Western-Sonderegger Inc. of Lincoln, NE. The results of this study were presented in a December 31, 1985 report entitled "Report of Preliminary Water Supply Investigation for the Proposed Haymarket District Heating and Cooling System, Lincoln, Nebraska."

The two water sources investigated under this study were the groundwater source available in the vicinity of the downtown Lincoln area and the treated waste water effluent from the Theresa Street Sewage Treatment facility.

The results of the water source investigation indicated that either supply could technically fulfill the DH&C water supply requirements. The advantage of the well water system would be: (1) the relatively constant source/sink water temperature, which would aid in production of thermal energy independent of weather or seasonal conditions, and (2) the lack of competing uses, due to the highly saline nature of the area ground water. Historical test data indicate that adequate quantities of

water could be produced from a well field and several area facilities have in the past utilized this ground water as a cooling medium for industrial and commercial applications. One specific application included the use of a 1000 gallon per minute well as an auxiliary cooling supply for the now decommissioned K Street Power Plant.

The Hoskins-Western-Sonderegger report identified the potential for seasonal thermal storage within a geothermal well field. The possibility exists that well water withdrawn, tempered by the heat pump facility and then reinjected, could be stored for thermal energy recovery during the opposite season. This could be accomplished by reversing well flows and substituting the source wells for injection wells.

A disadvantage to utilizing ground water is the uncertainty that exists with the development of well field facilities. Significant expenditures can occur prior to and during a well development phase with indeterminate final well field production capabilities and long-term performance. The water withdrawn from a well field for use in geothermal applications must be replaced or reinjected in unpolluted condition into the same underground aquifer from which it is withdrawn. The current engineering practice is to provide twice as many injection wells as supply wells which substantially increases capital cost and the number for the wells required for a given flow requirement. Uncertainty regarding geothermal supply capabilities would exist until test production and injection wells could be completed and operated to gather performance data. No environmental restrictions were

found for the production and injection concept, however, development of such a facility would require further investigation to determine any potential present or future conflicts regarding the utilization of the underground water resource.

The treated wastewater effluent, which flows directly from the Theresa Street Station into Salt Creek, was the second thermal energy source/sink alternative investigated. Quality data for the treated sewage effluent is detailed in Exhibits 2-10 and 2-11 and a plot of the effluent temperatures is shown in Exhibit 2-12. Exhibit 2-13 has been included to indicate the average hourly flow rates and Exhibit 2-14 shows the monthly flow rates from the Theresa St. facility. Water quantities on the average exceed the projected requirements for the DH&C system. The treated sewage effluent temperature varies seasonally unlike the ground water source which maintains a relatively stable temperature of 55°F (12.7°C). This temperature variation would effect the performance of a heat pump central plant. The advantages of utilizing the treated effluent include the constant and continuous supply of thermal energy. This supply represents a known and probably increasing quantity and the cost of delivery of the water to a central plant can be readily calculated. Disposal of the treated effluent would be carried out by discharging into the same creek as is currently done. The only difference would be a seasonal temperature change consisting of an increase of 18°F (10°C) during peak summer cooling and a decrease of approximately 10°F (6°C) during the winter peak heating period, and the relocation of effluent discharge approximately 1.5 miles upstream from the existing location.

Disadvantages to using the treated effluent are: (1) minimum discharge flow rates require that thermal storage or backup water supply be constructed to allow the central heating plant to operate at required capacity levels during low treatment plant discharge periods or periods of treatment plant malfunction, (2) additional chemical treatment at the waste water facility to suppress biological growth and aeration may be required at the discharge point to reduce oxygen demand, which would be an added operating expense but could alleviate heat exchanger malfunction at the central plant facility, and (3) additional safety procedures may be required when working on the central plant heat exchangers because of the potential for methane gas accumulation.

For the purposes of this study, cost estimates were developed using the waste water effluent as the thermal source, since this supply is relatively stable and cost estimates could be readily developed. The physical configuration of the source system would consist of a pumping and chemical treatment station located at the Theresa Street facility which would supply a single sixteen inch (16") force main routed parallel with Salt Creek to the heat pump central plant as indicated on Exhibit 2-15. The force main would be constructed four to five feet below grade and would be approximately 12,000 feet in length. The effluent would provide the thermal source or sink to the central plant through the heat pump shell and tube condenser or evaporator and would then be routed back to Salt Creek through a 4,500 foot discharge main. The capital cost estimate for this source piping and pumping station is summarized in Exhibit 2-16. Various pump horsepower and efficient flow

options were derived for this cost summary, all of which would be dependent on the ultimate central plant capacity.

**Thermal source Recommendations:**

- a. Investigate water storage requirements and costs.
- b. Evaluate costs of relocating effluent discharge point at Theresa Street Station.
- c. Evaluate maintenance costs of force main.
- d. Determine requirements for establishing long-term usage rights for sewage effluent.
- e. Determine chemical treatment requirements for inhibiting biological fouling of heat exchanger.
- f. Determine environment effect of increased discharge temperatures on dissolved oxygen and Biochemical Oxygen Demand (BOD).

## EXHIBIT 2-10

Wastewater Treatment Plant  
Effluent Quality Data

|           | Biological Oxygen Demand (mg/L) |     |     | Dissolved Oxygen (mg/L) |     |     | Fecal Coliform (MPN) # |     |     | Temperature (°C) |      |      | Suspended Solids (mg/L) |     |     |
|-----------|---------------------------------|-----|-----|-------------------------|-----|-----|------------------------|-----|-----|------------------|------|------|-------------------------|-----|-----|
|           | Max                             | Min | Ave | Max                     | Min | Ave | Max                    | Min | Ave | Max              | Min  | Ave  | Max                     | Min | Ave |
| 1985      |                                 |     |     |                         |     |     |                        |     |     |                  |      |      |                         |     |     |
| January   | 49                              | 11  | 26  | 12.2                    | 7.9 | 9.3 |                        |     |     | 15               | 9    | 13.3 | 29                      | 6   | 18  |
| February  | 42                              | 11  | 25  | 10.1                    | 8.1 | 9.0 |                        |     |     | 15               | 12   | 13.3 | 41                      | 6   | 19  |
| March     | 47                              | 7   | 27  | 10.2                    | 7.6 | 9.0 |                        |     |     | 15.5             | 12.6 | 14.2 | 34                      | 9   | 25  |
| April     | 22                              | 3   | 13  | 9.9                     | 8.6 | 9.0 | 2400                   | <20 |     | 17.3             | 12.6 | 15.4 | 34                      | 6   | 16  |
| May       | 70                              | 8   | 27  | 9.0                     | 6.2 | 7.4 | 3500                   | <20 |     | 19.1             | 16.1 | 17.6 | 39                      | 4   | 14  |
| June      | 58                              | 8   | 19  | 8.4                     | 6.2 | 7.4 | 9200                   | <20 |     | 21.8             | 17.9 | 18.5 | 27                      | 3   | 10  |
| July      | 34                              | 6   | 18  | 7.6                     | 4.5 | 6.8 | 16000                  | <20 |     | 21.9             | 20   | 21.1 | 57                      | 6   | 16  |
| August    | 30                              | 7   | 17  | 7.9                     | 6.9 | 7.2 | 9200                   | <20 |     | 22.8             | 20   | 21.4 | 25                      | 4   | 10  |
| September | 48                              | 6   | 19  | 8.1                     | 6.0 | 7.1 | >24000                 | <20 |     | 23.2             | 19   | 21.9 | 26                      | 6   | 13  |
| October   | 37                              | 8   | 18  | 9.0                     | 6.3 | 7.9 |                        |     |     | 20.3             | 16.9 | 19.3 | 47                      | 4   | 15  |
| November  | 42                              | 15  | 27  | 8.6                     | 6.7 | 7.5 |                        |     |     | 18.6             | 14.3 | 17.3 | 31                      | 8   | 21  |
| December  | 44                              | 17  | 28  | 8.7                     | 6.7 | 7.8 |                        |     |     | 15.4             | 13.1 | 14.2 | 43                      | 20  | 29  |

Source: Lincoln Wastewater System

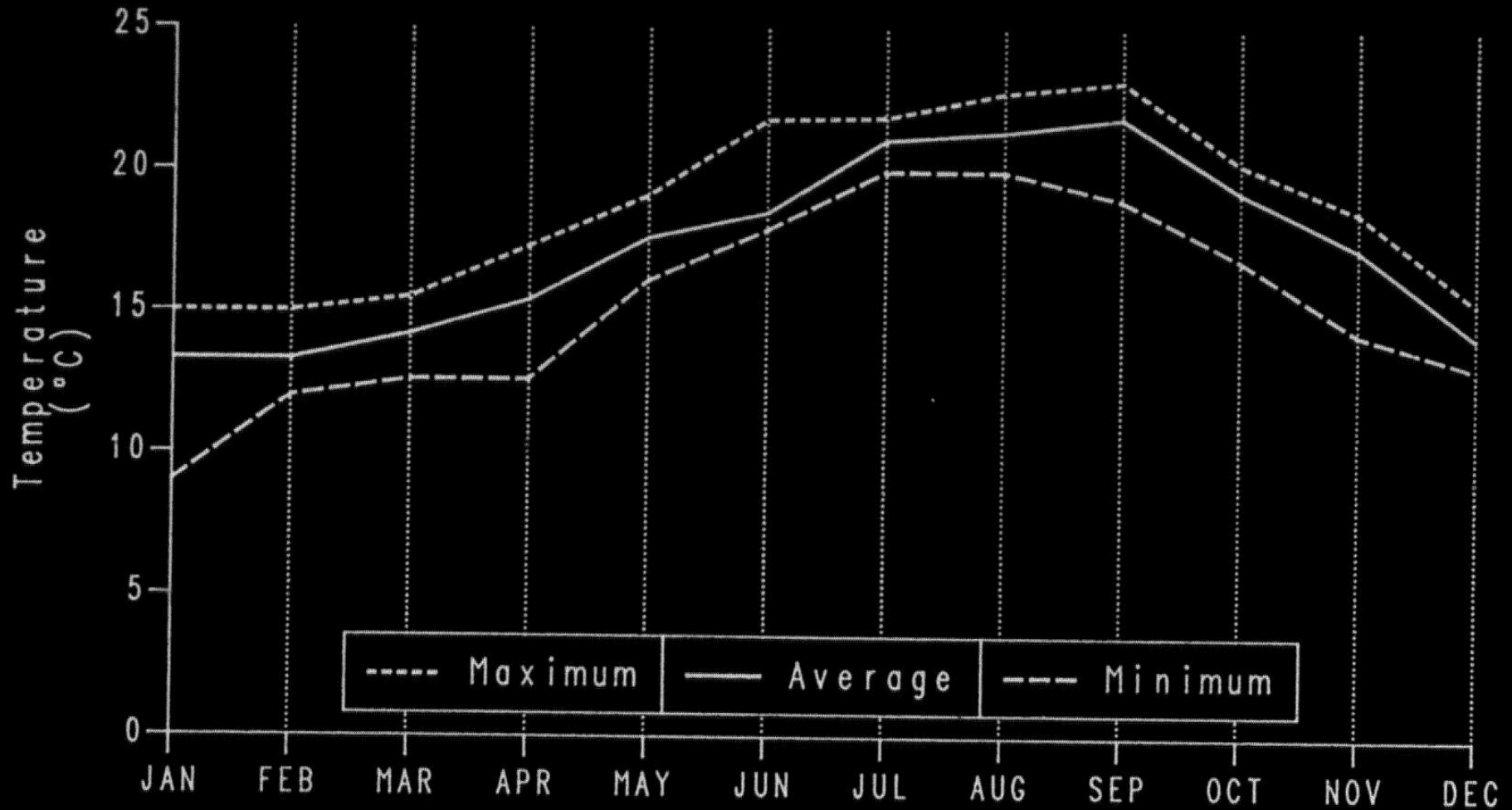


## EXHIBIT 2-11

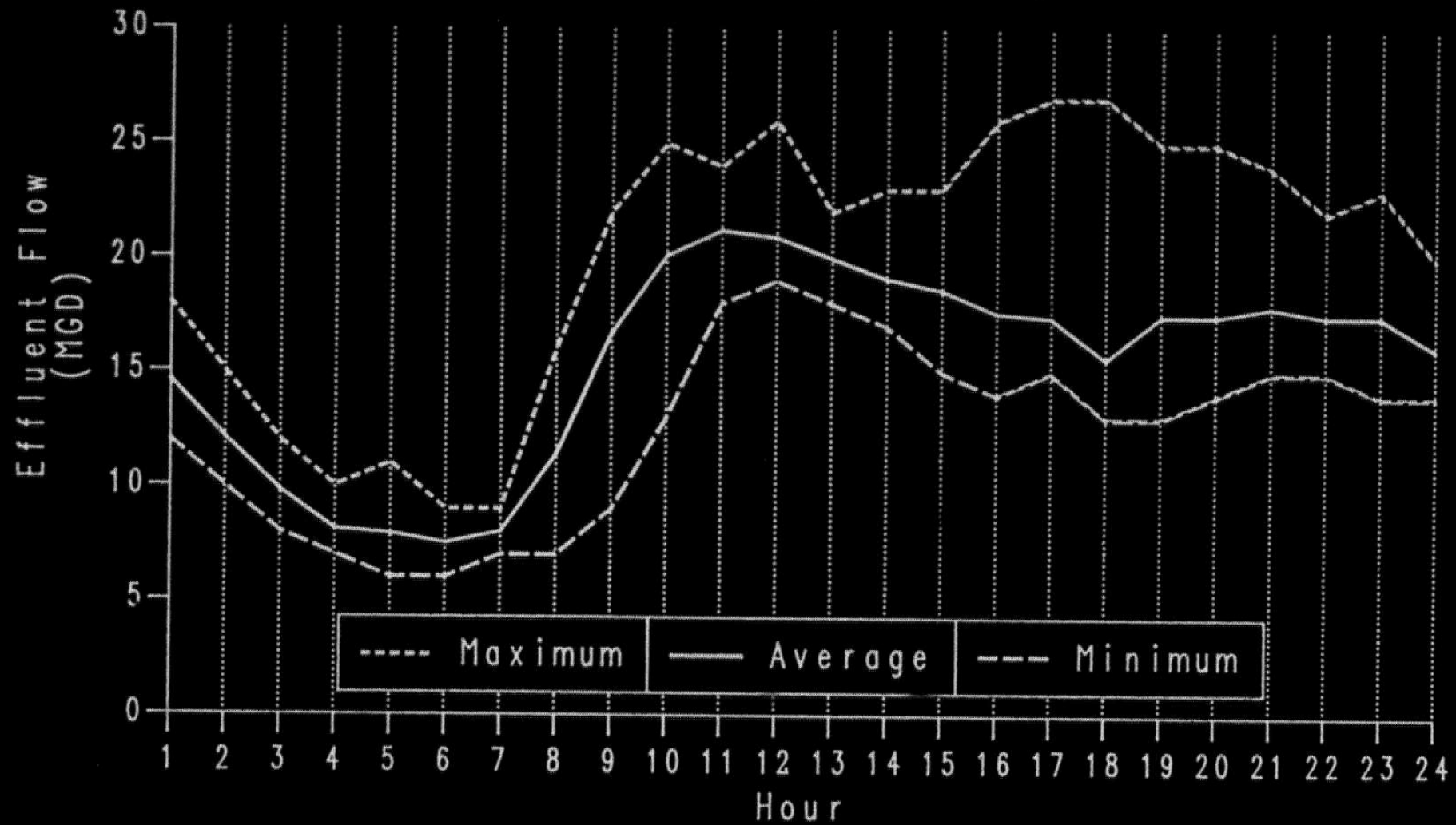
Theresa Non-Potable Effluent Water Analysis  
May 1985

| PARAMETER         | RESULTS, mg/l (except pH)   |
|-------------------|-----------------------------|
| Ammonia Nitrogen  | 13.6                        |
| Organic Nitrogen  | 4.3                         |
| Nitrate Nitrogen  | 2.9                         |
| TKN               | 18.1                        |
| BOD <sub>5</sub>  | 18 to 30                    |
| TSS               | 12 to 30                    |
| TDS               | 790                         |
| Chloride          | 134.3                       |
| Residual Chlorine | 0.6 to 2.0                  |
| Total Alkalinity  | 530 (as CaCO <sub>3</sub> ) |
| Temperature       | 17 to 20°C.                 |
| pH                | 7.4 to 7.6                  |
| Ortho-Phosphate   | 5.0                         |
| Boron             | 0.4                         |
| Calcium           | 38.0                        |
| Copper            | 0.01                        |
| Cadmium           | 0.004                       |
| Chromium          | 0.01                        |
| Nickel            | 0.04                        |
| Magnesium         | 13.2                        |
| Molybdenum        | 0.008                       |
| Lead              | 0.009                       |
| Potassium         | 20.8                        |
| Sodium            | 228.0                       |
| Zinc              | 0.02                        |
| Barium            | 0.37                        |
| Iron              | 0.12                        |

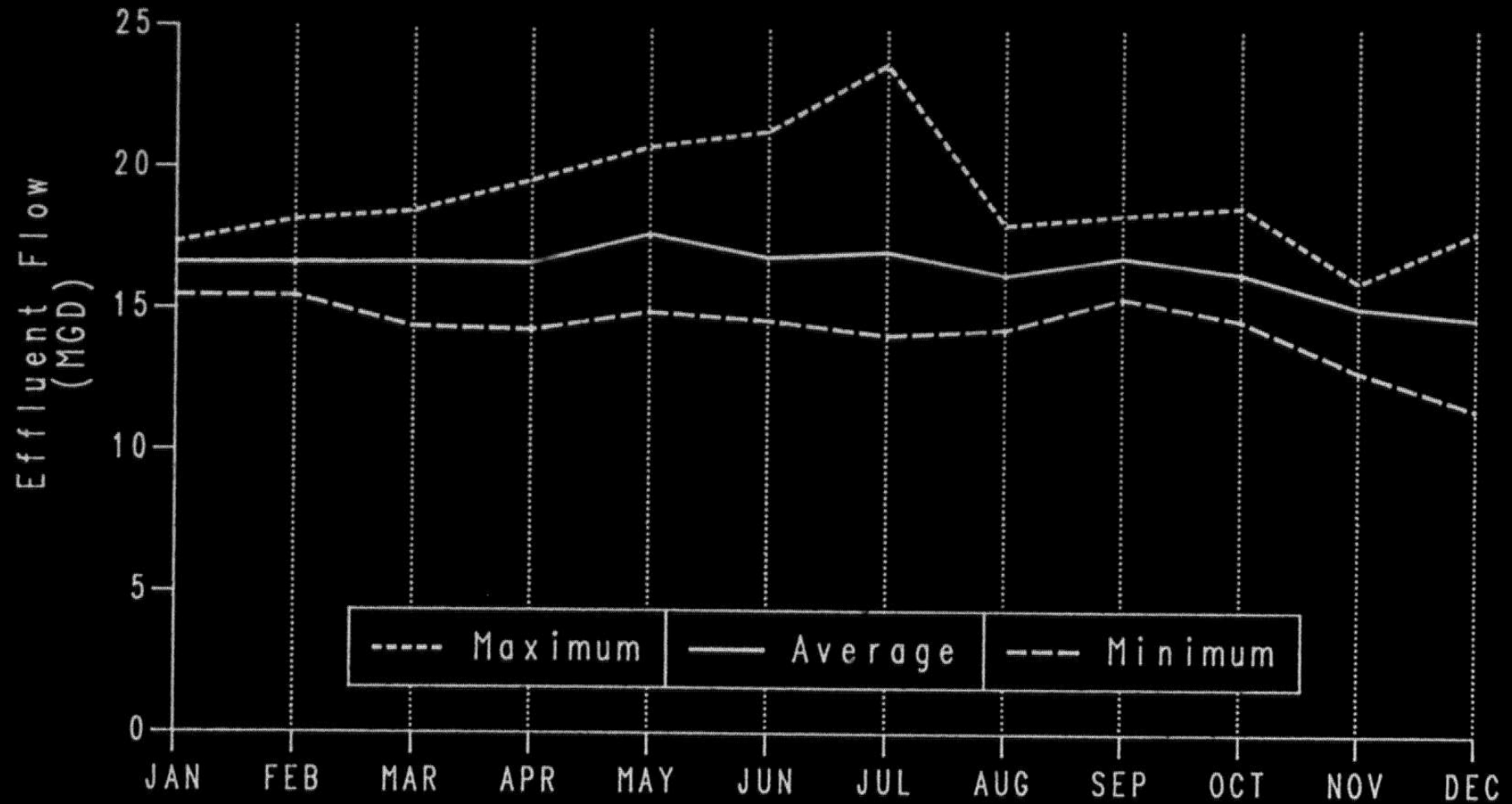
### Treated Effluent Temperature (Degrees Celsius)



Average Hourly Treated Effluent Flow  
Million Gallons per Day (MGD) Equivalent



### Daily Treated Effluent Flow Million Gallons per Day (MGD)





# EXHIBIT 2-16

## Wastewater Source System Capital Cost Estimate

|                                      |                   |
|--------------------------------------|-------------------|
| Force Main Cost (Supply System)      | \$ 480,000        |
| 16" 12,000 feet @ \$40/ft            |                   |
| Force Main Cost (Discharge System)   | \$ 180,000        |
| 16" 4,500 feet @ \$40/ft             |                   |
| Pump House                           | \$ 200,000        |
| Pumps, Controls, Header Piping, etc. |                   |
| <b>TOTAL</b>                         | <b>\$ 860,000</b> |

## Pipe size and pumping parameters

| <u>Flow Requirements<br/>(GPM)</u> | <u>Force Main<br/>Size (" )</u> | <u>Force Main<br/>Horsepower<br/>(Approx.)</u> | <u>Force Main<br/>Cost<br/>(\$/ft)</u> |
|------------------------------------|---------------------------------|------------------------------------------------|----------------------------------------|
| 1,850                              | 16                              | 30                                             | \$40.00                                |
| 2,780                              | 16                              | 130                                            | 40.00                                  |
| 3,700                              | 16                              | 280                                            | 40.00                                  |

#### 4. Central Plant

The location of the central plant is dictated by two factors: (1) the ability to deliver the thermal source/sink water to a particular site with relative ease and (2) the proximity to the district heating and cooling load to reduce the cost and extent of the thermal distribution system. In an attempt to meet these criteria, four potential locations were identified. The following is a description of each site:

**Site 1 - North 6th Street and Charleston** - This site consists of approximately four acres which is owned by the City of Lincoln located adjacent to Salt Creek. The major advantages for this site were 1) proximity to Salt Creek in which the waste water effluent would ultimately be discharged, and 2) the size of the parcel would allow room for thermal storage facilities. The major disadvantage to this site included the distance from the central district heating and cooling system.

**Site 2 - 9th and S Streets** - This triangular shaped site consists of approximately 5,000 square feet. The location was considered excellent except that the size of the parcel may be inadequate. The property is owned by the State of Nebraska and could be purchased for use as a district heating and cooling system.

**Site 3 - 8th and S Streets** - This site consists of approximately 14,000 square feet. The location was considered excellent and the size



would be adequate. It is currently in private ownership.

**Site 4 - 10th and S Streets** - This site is vacant and consists of approximately 16,000 square feet. It is currently owned by the City of Lincoln. This is the closest site to the district heating and cooling system and is also located adjacent to the Interstate Overpass. The overpass could possibly be utilized to support the wastewater effluent pipe.

Based upon the cost per foot of the four pipe distribution system in comparison to the cost of the wastewater effluent piping, it would appear that the closest possible publicly owned site with adequate size would make the best potential location for the central District Heating and Cooling Plant. The site that best meets this criteria is site number 4 at 10th and S Streets.

The central plant would contain large commercial or industrial grade heat pumps and ancillary equipment to produce thermal energy for distribution. Large scale heat pump technology for heating has been demonstrated numerous times in European applications, and is just now being promoted and developed in the United States. The underlining principle of this particular system is the recovery of waste heat or rejection of unneeded heat to a readily available medium. The thermal source and sink selected for this evaluation is treated waste water effluent, a technology that has been demonstrated on a number of other projects. The water utilized from the effluent stream is isolated from the distribution system by the heat pump and heat pump heat exchangers.



An energy balance diagram has been included in Exhibit 2-17 to demonstrate the principles of heat pump operation and illustrate how it is possible to recover waste heat in the heating mode. For every unit of energy put into the heat pump in the form of electricity two units of heat are withdrawn from the thermal source. The three units of heat are then obtained from the system as output. The measure of heat pump efficiency at any given set of operating conditions is called its coefficient of performance (COP). The coefficient of performance is defined as the ratio of the heating or cooling capacity to the work input.

$$\text{Coefficient of Performance (COP)} = \frac{\text{Energy Output}}{\text{Work Input}} = 3.0$$

Heat pumps are capable of exceeding a COP of 3.0 depending on thermal source conditions and operating conditions. The higher the COP the greater the efficiency and the lower the operating costs. An advantage of utilizing a thermal source such as treated sewage effluent is that the water source temperature is relatively stable with predictable flow conditions which allows estimation of equipment COP to be primarily dependent upon output temperature levels.

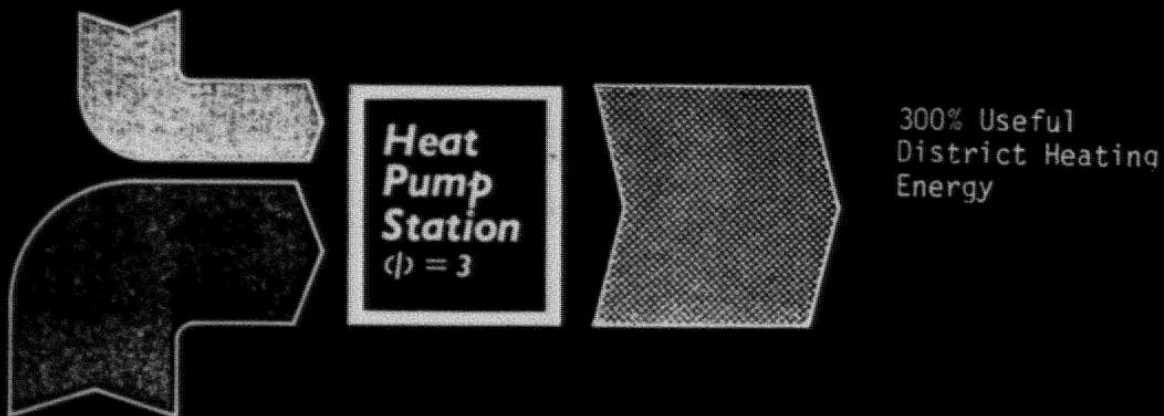
Heat pumps operate through the use of a vapor-compression cycle employing a working fluid or refrigerant which is recirculated through four basic physical processes or changes: compression, condensation, expansion and evaporation. The heat pump has four working parts to accomplish these changes: a compressor, two heat exchangers (one serving as a condenser and the other as an evaporator) and an expansion device.

EXHIBIT 2-17

Heat Pump

Energy Balance Diagram

Electrical  
100% Driving  
Energy



200% Waste Energy  
Supplied from  
Waste Water Effluent

2 parts waste energy  
+1 part driving energy  
=3 parts useful heat

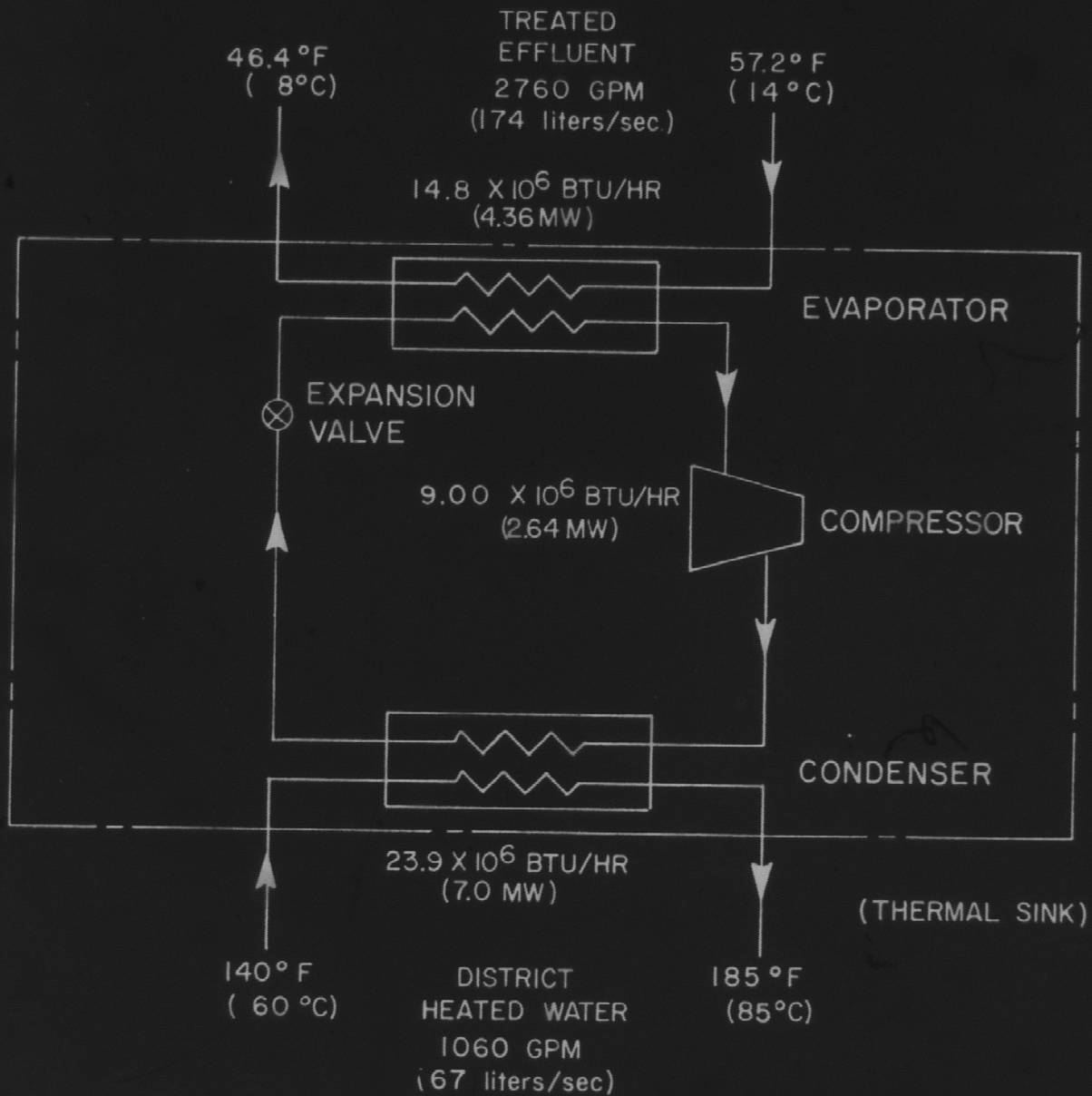
$$\text{Heat pump COP} = \frac{\text{Useful heat energy}}{\text{Driving energy}}$$

The basic difference between cooling and heating operations lies in which of the two heat exchangers supplies cold vapor to the compressor and which heat exchanger receives hot vapor from it. Cooling and heating can be provided from a single heat pump installation by reversing the thermal source and thermal sink water supplies as the heating and cooling seasons change.

Exhibit 2-18 illustrates the energy balance of the heat pump cycle operating in the heating mode. The water source or treated effluent enters the evaporator heat exchanger at a temperature of 57.2°F at a flow rate of 2760 gallons per minute (GPM), which would be variable depending on thermal load conditions. The low temperature, low pressure liquid/vapor refrigerant exiting from the expansion valve would absorb  $14.8 \times 10^6$  BTU's of heat from the effluent through the surfaces of the evaporator causing the liquid refrigerant to boil or evaporate into a low temperature, low pressure vapor. The effluent leaving the evaporator would be cooled 10.8°F in temperature and discharged back into Salt Creek at a temperature of 46.4°F. As the warmed refrigerant vapor is moved from the evaporator to the condenser through the compressor, it absorbs  $9.0 \times 10^6$  BTU's of additional heat from the electrical drive motor as it is compressed to a high temperature, high pressure vapor. Since the vapor temperature is above the temperature of the surroundings, a total of  $23.9 \times 10^6$  BTU's of heat would be available for transfer through the surfaces of the condenser to the water in the district heating distribution system. The temperature of the water in the distribution system would be increased from 140°F to 185°F at a flow rate of 1060 GPM. This transfer of heat would cause the refrigerant vapor to condense

EXHIBIT 2-18

TYPICAL WINTER OPERATION  
TWO STAGE HEAT PUMP CENTRAL PLANT



HEAT PUMP  
COEFFICIENT  
OF PERFORMANCE  
AT PEAK LOAD

$$= \frac{\text{HEAT PRODUCED}}{\text{ENERGY INPUT}} = \frac{23.9 \times 10^6 \text{ BTU/HR}}{9.00 \times 10^6 \text{ BTU/HR}}$$

C.O.P. = 2.65

LINCOLN ELECTRIC SYSTEM

TYPICAL WINTER OPERATION  
TWO STAGE HEAT PUMP CENTRAL PLANT

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D.S. 4-14-86

SCALE

DRAWING NO. MISC-A-27

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into a warm temperature, high pressure liquid which would then flow through the expansion valve that regulates its flow and causes the refrigerant to expand back into a low temperature, low pressure liquid/vapor, completing the heat pump cycle. The heating mode coefficient of performance for these operating conditions would be.

$$\text{COP} = \frac{\text{Energy Output}}{\text{Work Input}} = \frac{23.9 \times 10^6 \text{ BTU/hr}}{9.0 \times 10^6 \text{ BTU/hr}} = 2.65$$

Calculation of the overall central plant coefficient of performance should include the pumping and auxiliary losses, which would slightly lower the expected system COP.

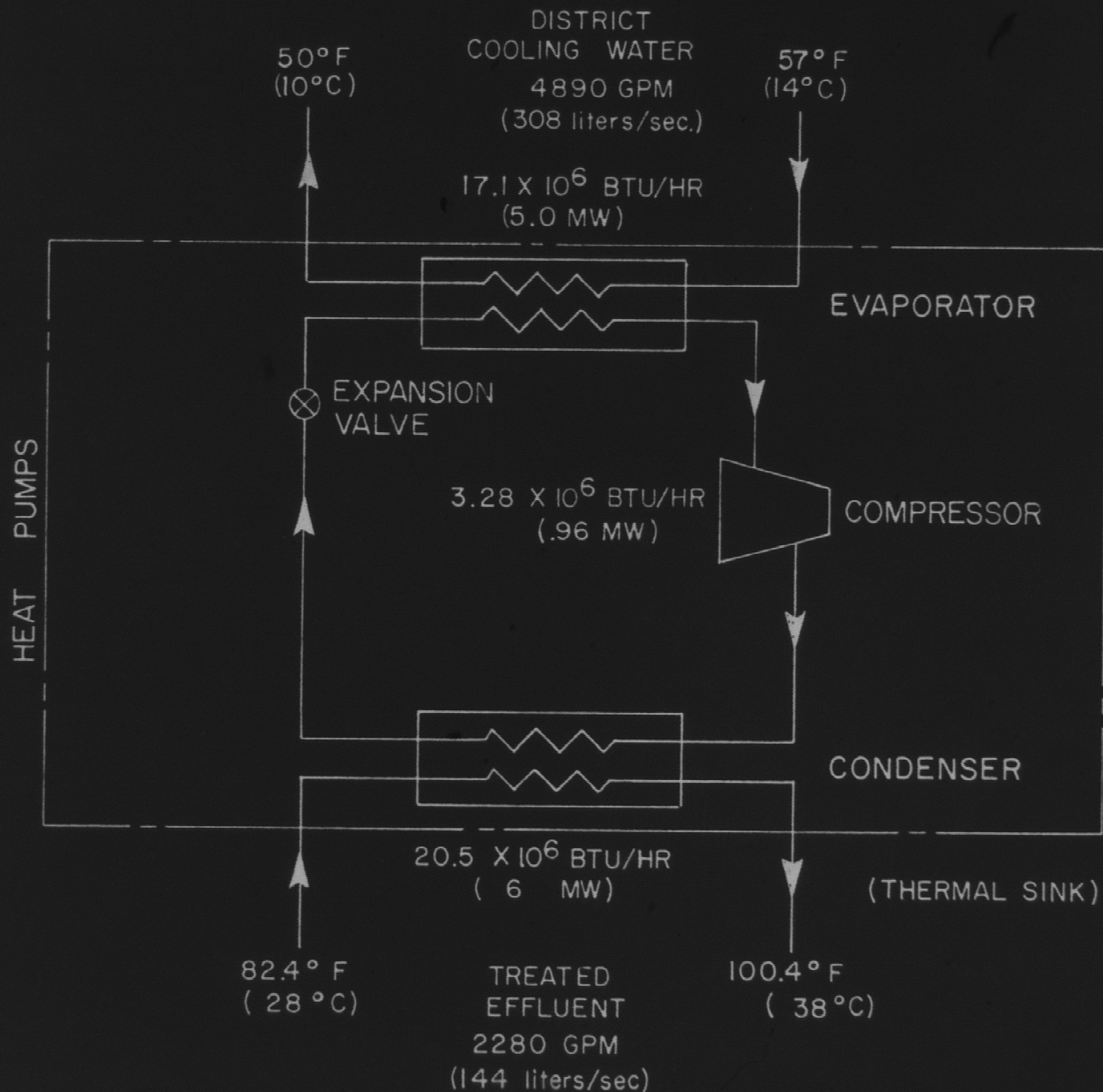
Since heat is recovered from the effluent source, the system would have a 2.65 to 1 advantage over electrical resistance heating and a significant advantage over fossil fuel fired heating systems.

The use of the heat pump as a heating only system has been proven feasible in numerous applications. However, the true advantage of the central heat pump station in the Lincoln application is the potential for installing a single mechanical system and providing both heating and cooling energy.

Connection of the effluent to the condenser, to act as the heat sink and connection of the distribution system to the evaporator, to act as the heat source will convert the heat pump into a conventional water cooled centrifugal chiller. Exhibit 2-19 illustrates the energy balance of the heat pump cycle operating in the cooling mode. The water source or district cooling water enters the evaporator heat exchanger at a

# EXHIBIT 2-19

## TYPICAL SUMMER OPERATION TWO STAGE HEAT PUMP CENTRAL PLANT



HEAT PUMP  
COEFFICIENT  
OF PERFORMANCE  
AT PEAK LOAD

$$= \frac{\text{HEAT EXTRACTED}}{\text{ENERGY INPUT}} = \frac{17.1 \times 10^6 \text{ BTU/HR}}{3.28 \times 10^6 \text{ BTU/HR}}$$

C.O.P. = 5.2

### LINCOLN ELECTRIC SYSTEM

#### TYPICAL SUMMER OPERATION TWO STAGE HEAT PUMP CENTRAL PLANT

|          |            |            |             |
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|     |    |      |          |
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|     |    |      |          |



temperature of 57°F at a flow rate of 4890 GPM. The low temperature low pressure liquid/vapor refrigerant exiting from the expansion valve would absorb  $17.1 \times 10^6$  Btu's of heat from the district cooling water through the surfaces of the evaporator causing the liquid refrigerant to boil or evaporate into a low temperature, low pressure vapor. The district cooling water would be cooled 7°F to a temperature of 50°F before being additionally cooled by auxiliary chillers and then recirculated back into the district distribution system. As the warmed refrigerant vapor is moved from the evaporator to the condenser through the compressor it absorbs  $3.28 \times 10^6$  Btu's of additional heat from the electrical drive motor as it is compressed to a high temperature, high pressure vapor. Since the vapor temperature is above the temperature of the effluent, the total of  $20.5 \times 10^6$  Btu's of heat would be transferred through the surfaces of the condenser. The temperature of the effluent would be increased from 82.4° to 100.4°F at a flow rate of 2280 GPM. This transfer of heat would cause the refrigerant vapor to condense into a warm temperature, high pressure liquid which would then flow through the expansion valve causing the refrigerant to expand back into a low temperature, low pressure liquid vapor, completing the heat pump cycle. The coefficient of performance for these operating conditions would be:

$$\text{COP} = \frac{\text{Energy Output}}{\text{Work Input}} = \frac{17.1 \times 10^6 \text{ Btu/hr}}{3.28 \times 10^6 \text{ Btu/hr}} = 5.2$$

Again, the overall coefficient of performance for the plant would be reduced somewhat by the additional central plant pumping and plant auxiliary loads, resulting in a slightly lower expected COP.

It should be noted that the cooling COP is higher than that shown for the heating cycle. The COP for a given machine is dependent upon source and discharge water conditions and operating levels. In the heating case water at a temperature of approximately 57°F has been used as a thermal source to supply hot water to the system at 185°F. In the chilling case, water at a temperature of 82.4°F has been used as a thermal sink to provide chilled water to the system at 50°F. The change in water temperature requirements for the machine from the heating to cooling cycle would have a significant effect on the plant performance or COP.

A basic element of central energy plant design is matching equipment to the load to be served. This is a complex question in the case of DH&C due the uncertainty of which existing building HVAC systems can be retrofitted and in this study, the size of the new commercial development which has been proposed. The second element of this decision process is the size relationship between base load equipment and peaking equipment. In nearly all energy plant applications, high efficiency equipment carries a high capital cost when compared to equipment used for peaking purposes.

For the Lincoln central plant the heat pump equipment has been considered as the base load or primary source for heating and cooling. Through an analysis of typical heating load duration curves, shown in Exhibit 2-20, the heat pump capacity necessary for this energy supply could be sized at approximately 50% of the system maximum heating demand and still supply over 80% of the heating energy requirements. The remaining energy needs could be supplied from hot water boilers which would serve during high energy demand, during startup, provide load following requirements, and



provide backup supply during heat pump maintenance.

A fundamental problem exists in serving both heating and cooling needs from the heat pump equipment due to the thermal capabilities of the heat pump equipment and the characteristics of the system loads. This technical problem is demonstrated in Exhibit 2-21. To effectively serve all heating needs from the central plant, both heat pumps and peaking boilers could be utilized; however, in all cases the cooling capacity of a specific heat pump will be approximately two-thirds to three-fourths of the heating capacity. If the heat pump were reduced in size and peaking boilers were used to supplement the heating capacity, the heat pump would be considerably undersized for its secondary role as system cooling equipment. Since a maximum level of both heating and cooling load are to be served, both supplemental boilers and supplemental centrifugal chillers would be required.

The relationship between maximum heating and cooling capacity for the central station is as follows:

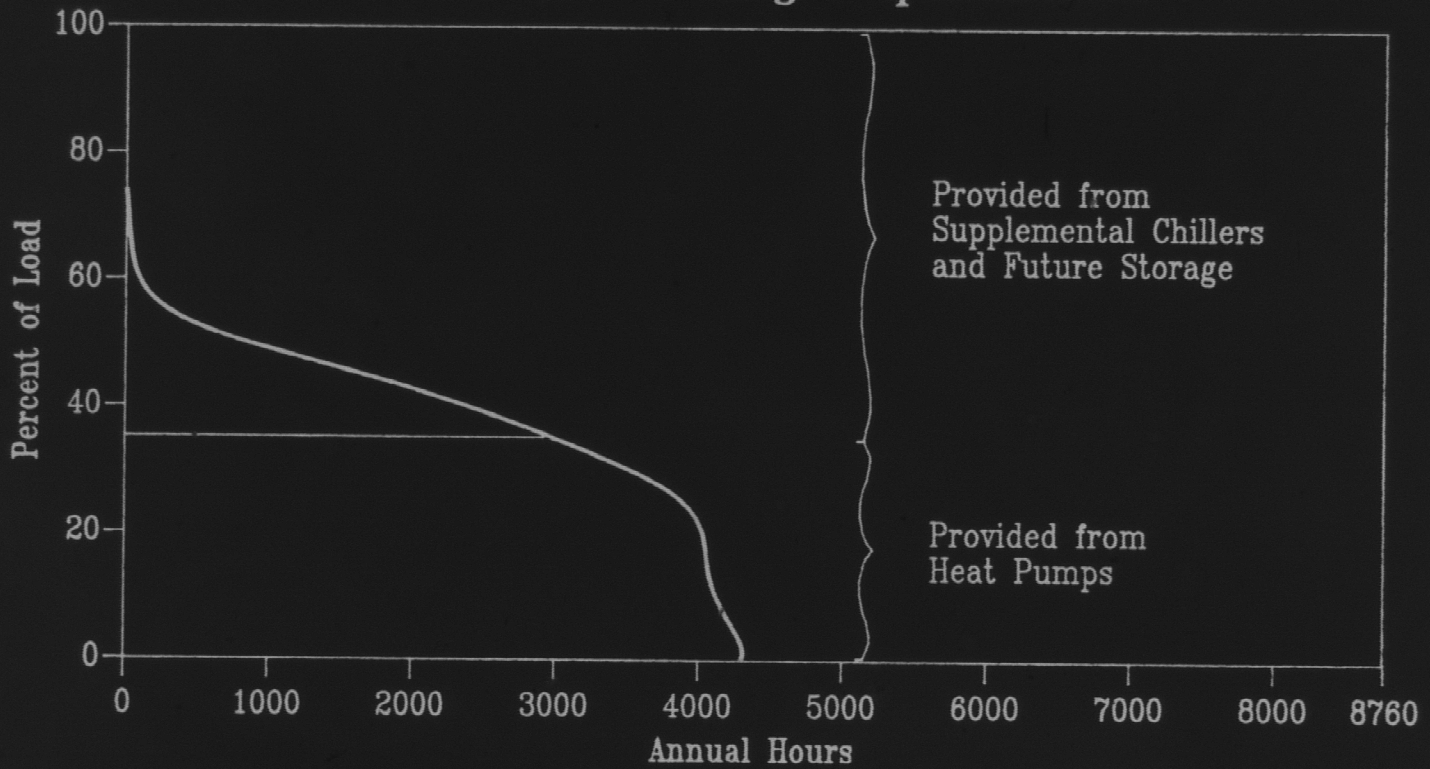
- Heating Peak Capacity -

|            |                                 |
|------------|---------------------------------|
| 50%        | Supplied from heat pumps        |
| <u>50%</u> | Supplied from peaking boilers   |
| 100%       | System size option requirements |

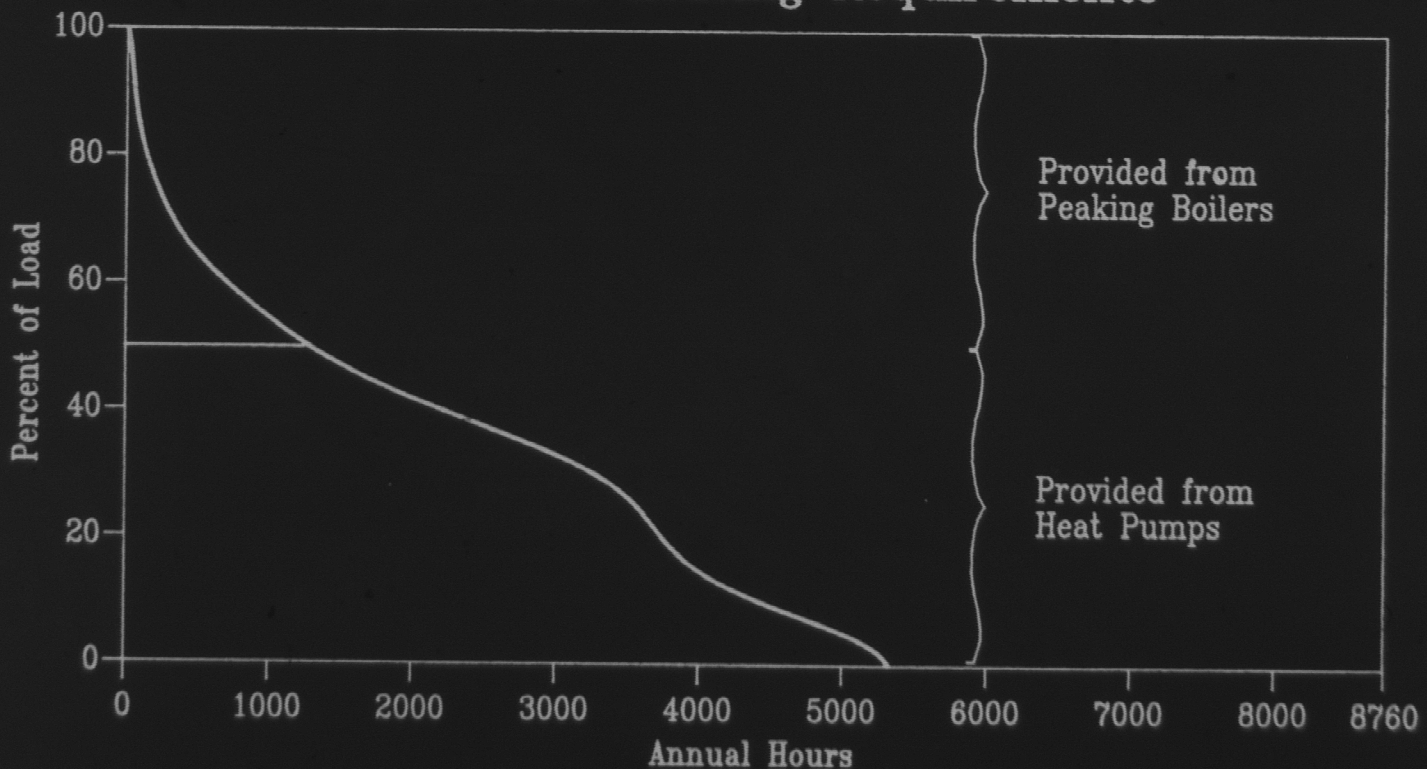
- Cooling Capacity -

|            |                                     |
|------------|-------------------------------------|
| 35%        | Supplied from heat pumps            |
| <u>65%</u> | Supplied from supplemental chillers |
| 100%       | System size option requirement      |

# Estimated Annual Load Duration Curve For Cooling Requirements

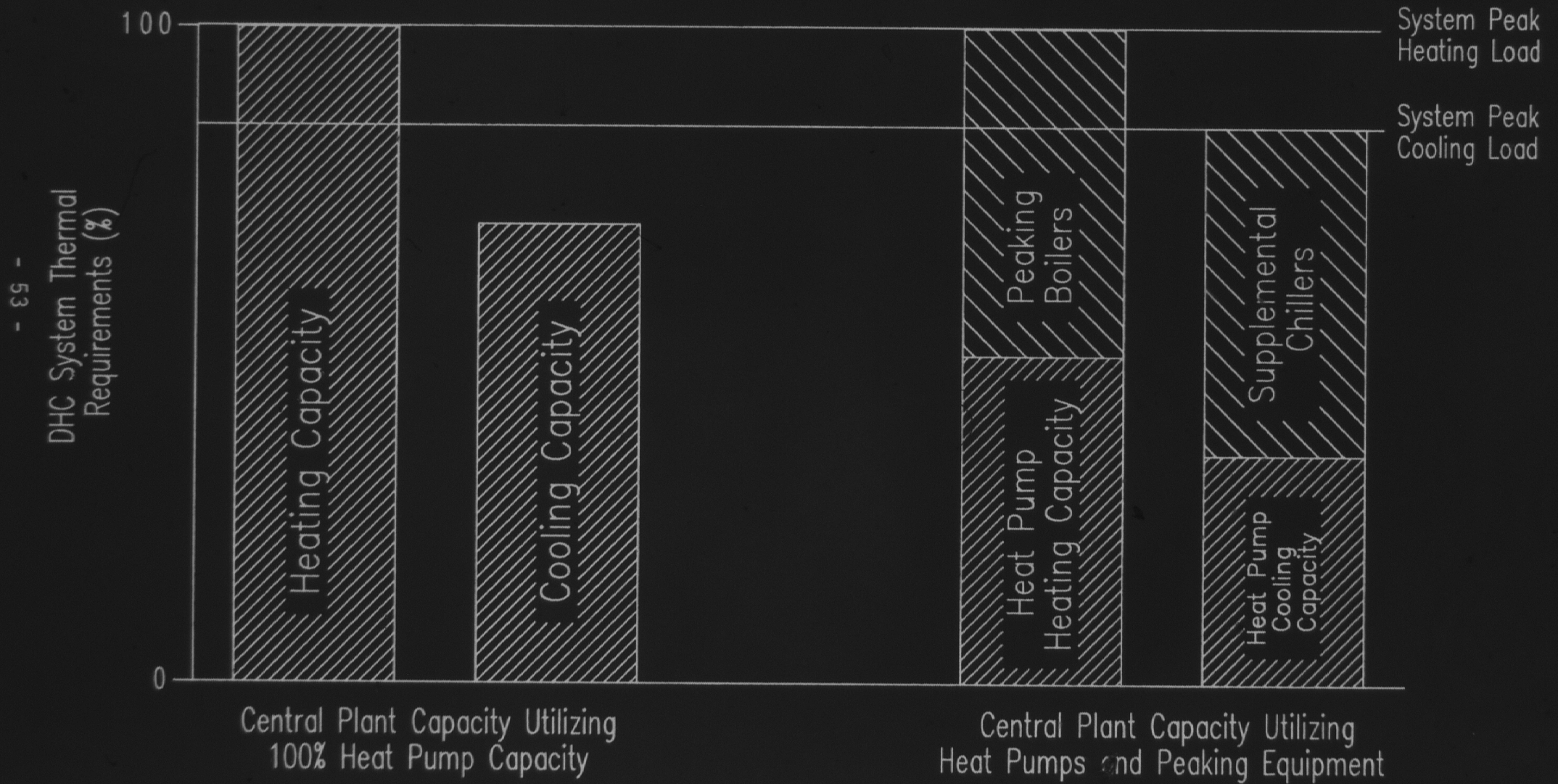


# Estimated Annual Load Duration Curve For Heating Requirements





# Central Plant Equipment Capacity Sizing Diagram



Further refinement in equipment sizing would be necessary to optimize the central plant investment cost.

The central plant configuration for the DH&C system must satisfy the following conditions:

- Provide both heating and cooling for the district.
- Follow the district heating and cooling requirements from the lowest to highest demand level.
- Provide simultaneous heating and cooling during periods of transition from heating to cooling seasons.
- Maintain a high efficiency level for both heating and cooling cycles at partial and full load.
- Provide a degree of equipment redundancy for planned and unscheduled outages.
- Provide for unmanned operation.
- Be located as close as possible to the downtown district distribution system to reduce distribution system piping costs.



Exhibits 2-25 and 2-26 are general schematic diagrams for the district heating and district cooling operations. These diagrams indicate the interconnected equipment included for the economic and operational analysis presented in this study. The following paragraphs describe in more detail the primary components required for the central plant facility.

The heat pump based central plant would contain single or multiple heat pumps and centrifugal chillers. To provide load following capabilities at least one of the compressors could be installed with a variable speed drive. This would allow matching low load levels up to the maximum output of the variable speed machine and then increasing output by bringing a fixed speed base load machine on-line and backing down the variable speed unit. The variable speed unit would then be used again for load following.

The second station component would be multiple heating boilers. The purpose of providing alternate district heating boilers is: first, to provide the capability of heat production in the event of heat pump outage; secondly, the boilers can be installed at a lower capital cost per unit of energy production and can provide peaking capacity in excess of the heat pump capability during times of high heating demand. By installing both heat pumps and boilers, the central plant would operate at high efficiency levels on the heat pump the largest percentage of the time and would provide the remainder of energy requirements through low capital cost but much lower efficiency heating boilers.

The third plant item would be the distribution system water pumps. These pumps would be installed in multiple units to provide redundancy for maintenance and pump outage. The pumps would be supplied with variable speed electric drives which would improve overall plant efficiency during partial and varying load conditions.

The fourth major component in the district heating and cooling system would be the heat and cool storage facilities. The storage systems would provide for off peak energy consumption by allowing the heat pump to charge the storage tanks with hot or cold water during low system thermal load periods. The storage capacity can be optimized to provide equipment and pipe size reductions and to enable daily electrical consumption load leveling. The parameters for storage and the systems to be used are discussed in a later section.

The fifth item required would be the equipment control and electrical equipment area. Within this area all motor starter, variable speed drive and communications equipment would be located. The actual plant structure would either be provided as part of a turnkey central plant installation or by separate building contractor. The building provided would be of a prefabricated metal structure with a overall size of approximately 4,000 square feet.

The central plant capital cost summary is shown in Exhibit 2-22. The capital cost estimates for this equipment are based on several budgetary estimates provided through turnkey heatpump plant manufacturers. The turnkey central plant budgetary estimates were plotted as shown in Exhibit



2-23. The estimates received were for various central plant sizes and the cost per unit of thermal output varied significantly between estimates.

The various plant capacities indicated in the capital cost summary allow for the incorporation of capital cost estimates for the various system sizes developed in the thermal load analysis section of the report. Plant Size 1 for the distribution system Option 1 and Plant Sizes 2 and 3 for the respective distribution options outlined in the distribution system section. Exhibit 2-24 summarizes the central plant performance assumptions used in the feasibility study.



# EXHIBIT 2-22

## Central Plant Capital Cost Summary

### Plant Size 1

|                              |                     |
|------------------------------|---------------------|
| 25.0 $10^6$ Btu/Hr (Heating) |                     |
| 25.0 $10^6$ Btu/Hr (Cooling) |                     |
| Heat Pumps (3.5 MW)          |                     |
| (Turn-Key)                   | \$ 850,000          |
| Chillers (1,114 Tons)        | 320,000             |
| Boilers (19 X $10^6$ Btu/Hr) | 170,000             |
| Building and Land            | 250,000             |
| Piping and Auxiliaries       | 150,000             |
| Cool Storage                 | 210,000             |
| Heat Storage                 | 70,000              |
| TOTAL                        | <u>\$ 2,020,000</u> |

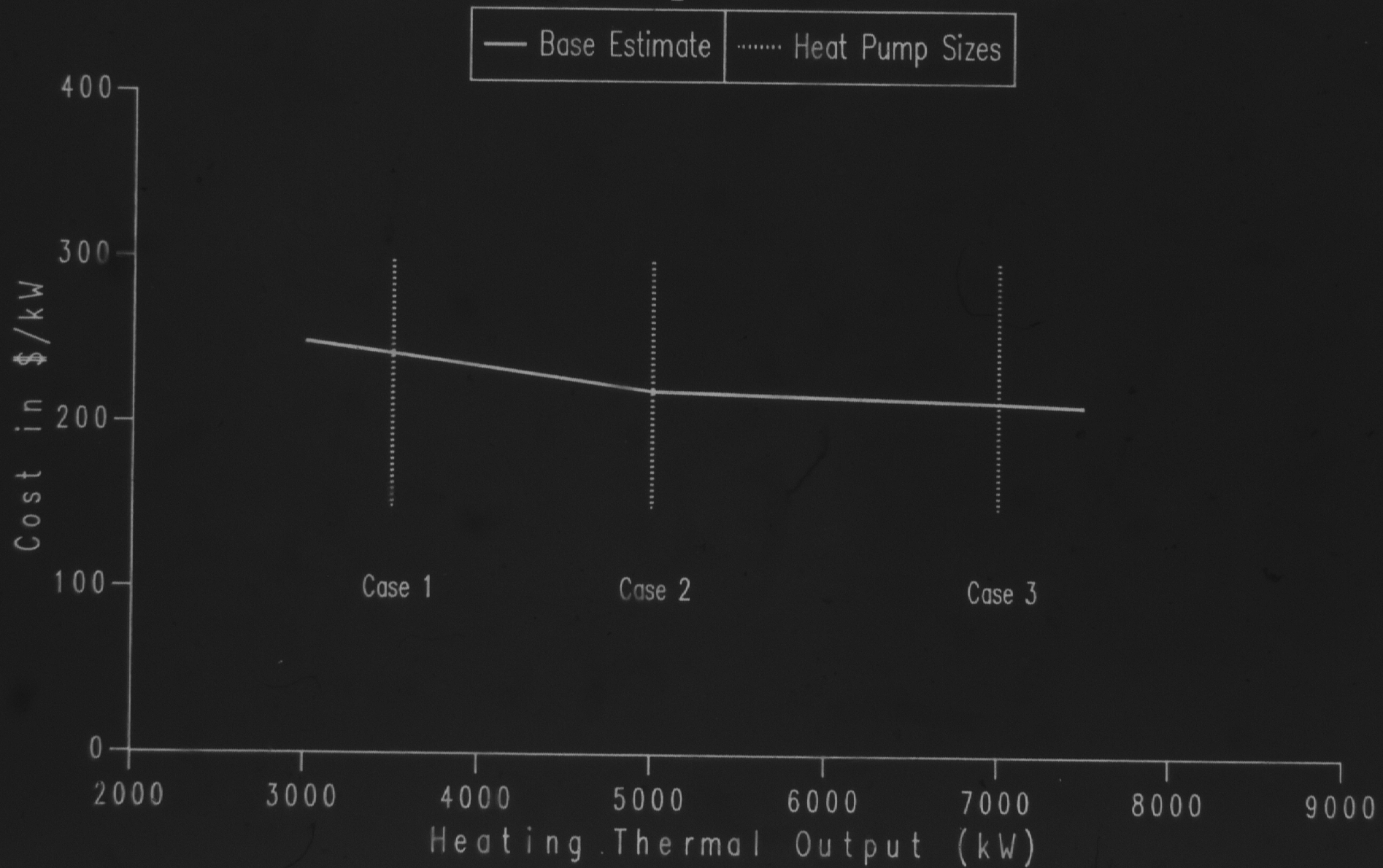
### Plant Size 2

|                                |                     |
|--------------------------------|---------------------|
| 37.5 $10^6$ Btu/Hr (Heating)   |                     |
| 37.5 $10^6$ Btu/Hr (Cooling)   |                     |
| Heat Pumps (5.0 MW)            |                     |
| (Turn-Key)                     | \$ 1,100,000        |
| Chillers (1,567 Tons)          | 480,000             |
| Boilers (37.5 X $10^6$ Btu/Hr) | 250,000             |
| Building and Land              | 380,000             |
| Piping and Auxiliaries         | 200,000             |
| Cool Storage                   | 280,000             |
| Heat Storage                   | 92,500              |
| TOTAL                          | <u>\$ 2,782,500</u> |

### Plant Size 3

|                              |                     |
|------------------------------|---------------------|
| 50.0 $10^6$ Btu/Hr (Heating) |                     |
| 50.0 $10^6$ Btu/Hr (Cooling) |                     |
| Heat Pumps (7.0 MW)          |                     |
| (Turn Key)                   | \$ 1,500,000        |
| Chillers (2,228 Tons)        | 640,000             |
| Boilers (50 X $10^6$ Btu/Hr) | 340,000             |
| Building and Land            | 400,000             |
| Piping and Auxiliaries       | 250,000             |
| Cool Storage                 | 350,000             |
| Heat Storage                 | 115,000             |
| TOTAL                        | <u>\$ 3,595,000</u> |

## Heat Pump Capital Cost Estimate





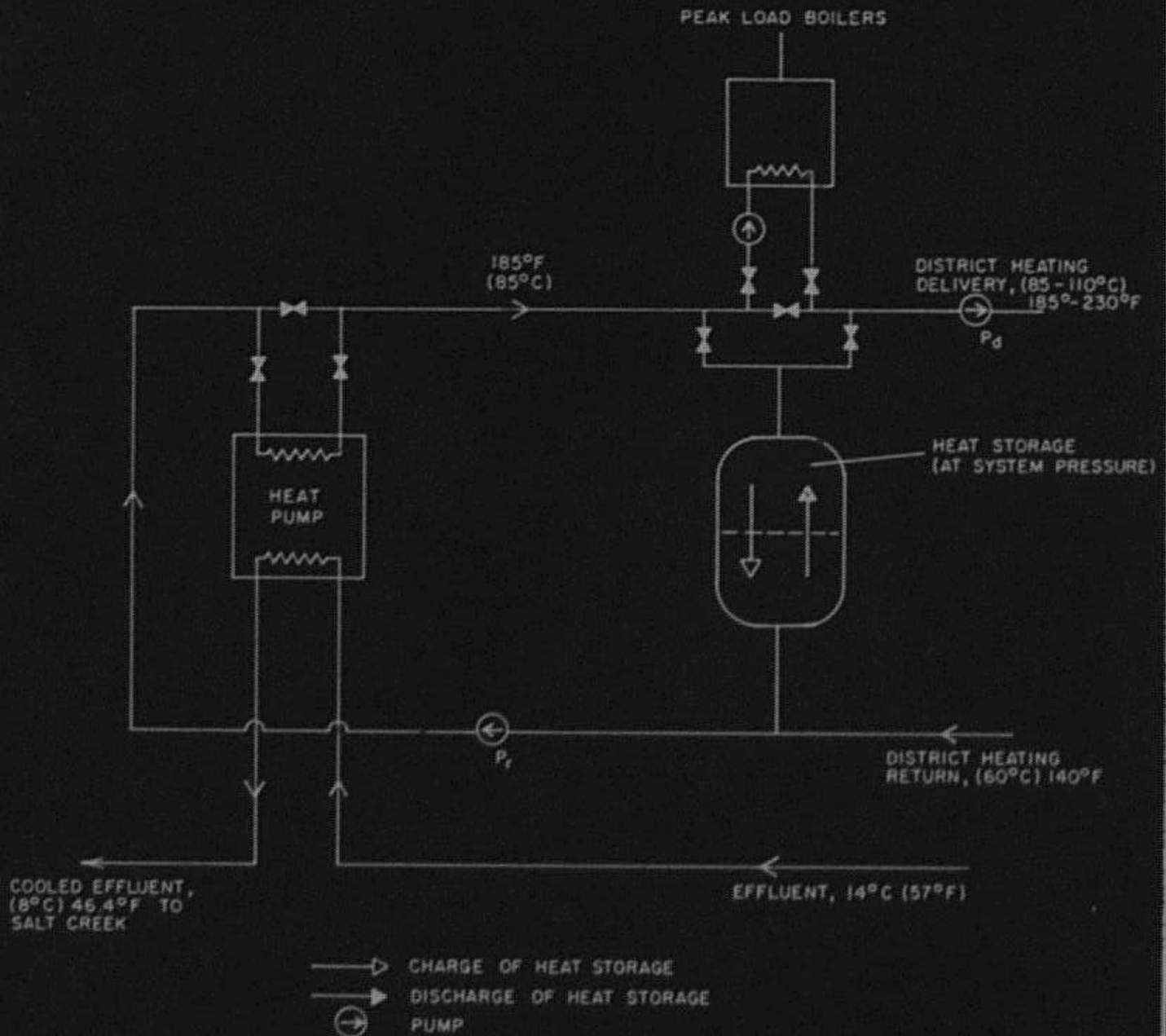
## EXHIBIT 2-24

## Central Plant Performance Parameters

|                                        | Plant<br>Size<br><u>1</u>      | Plant<br>Size<br><u>2</u>      | Plant<br>Size<br><u>3</u>      |
|----------------------------------------|--------------------------------|--------------------------------|--------------------------------|
| <b>HEATING:</b>                        |                                |                                |                                |
| Heat Pump Capacity ( $10^6$ Btu)       | 12                             | 17                             | 24                             |
| Boiler Capacity ( $10^6$ Btu)          | 19                             | 37.5                           | 50                             |
| Effluent Temp ( $^{\circ}$ F)          | 58 $^{\circ}$ -48 $^{\circ}$   | 58 $^{\circ}$ -48 $^{\circ}$   | 58 $^{\circ}$ -48 $^{\circ}$   |
| Effluent Flow (GPM)                    | 1600                           | 2400                           | 3200                           |
| Peak Distribution Temp ( $^{\circ}$ F) | 230 $^{\circ}$ -140 $^{\circ}$ | 230 $^{\circ}$ -140 $^{\circ}$ | 230 $^{\circ}$ -140 $^{\circ}$ |
| Peak Distribution Flow (GPM)           | 555                            | 830                            | 1110                           |
| Storage Capacity ( $10^6$ Btu)         | 33.4                           | 50.2                           | 66.9                           |
| <b>COOLING:</b>                        |                                |                                |                                |
| Heat Pump Capacity ( $10^6$ Btu)       | 9.5                            | 13.7                           | 19.1                           |
| Chiller Capacity ( $10^6$ Btu)         | 13.3                           | 18.8                           | 26.6                           |
| Effluent Temp ( $^{\circ}$ F)          | 67 $^{\circ}$ -85 $^{\circ}$   | 67 $^{\circ}$ -85 $^{\circ}$   | 67 $^{\circ}$ -85 $^{\circ}$   |
| Effluent Flow (GPM)                    | 1850                           | 2780                           | 3700                           |
| Distribution Temp ( $^{\circ}$ F)      | 39 $^{\circ}$ -57 $^{\circ}$   | 39 $^{\circ}$ -57 $^{\circ}$   | 39 $^{\circ}$ -57 $^{\circ}$   |
| Distribution Flow (GPM)                | 2780                           | 4170                           | 5560                           |
| Storage Capacity ( $10^6$ Btu)         | 56.1                           | 83.6                           | 112.3                          |

\* Effluent Flow Requirements would be increased by a factor of 1.5 in the cooling mode and 1.25 in the heating mode if storage capability is not incorporated into the design.

EXHIBIT 2-25  
SIMPLIFIED DISTRICT SYSTEM SCHEMATIC  
HEATING OPERATION



DIFFERENCE BETWEEN WATER FLOW RATE FOR PUMPS P<sub>d</sub> AND P<sub>r</sub> DETERMINES DIRECTION AND MAGNITUDE OF FLOW THROUGH HEAT STORAGE.

SIMPLIFIED SCHEMATIC FOR DISTRICT SYSTEM OPERATION  
DURING WINTER SEASON

LINCOLN ELECTRIC SYSTEM

SIMPLIFIED DISTRICT SYSTEM SCHEMATIC  
HEATING OPERATION

DRAWN BY

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APPROVED BY

Knapp 10-14-86

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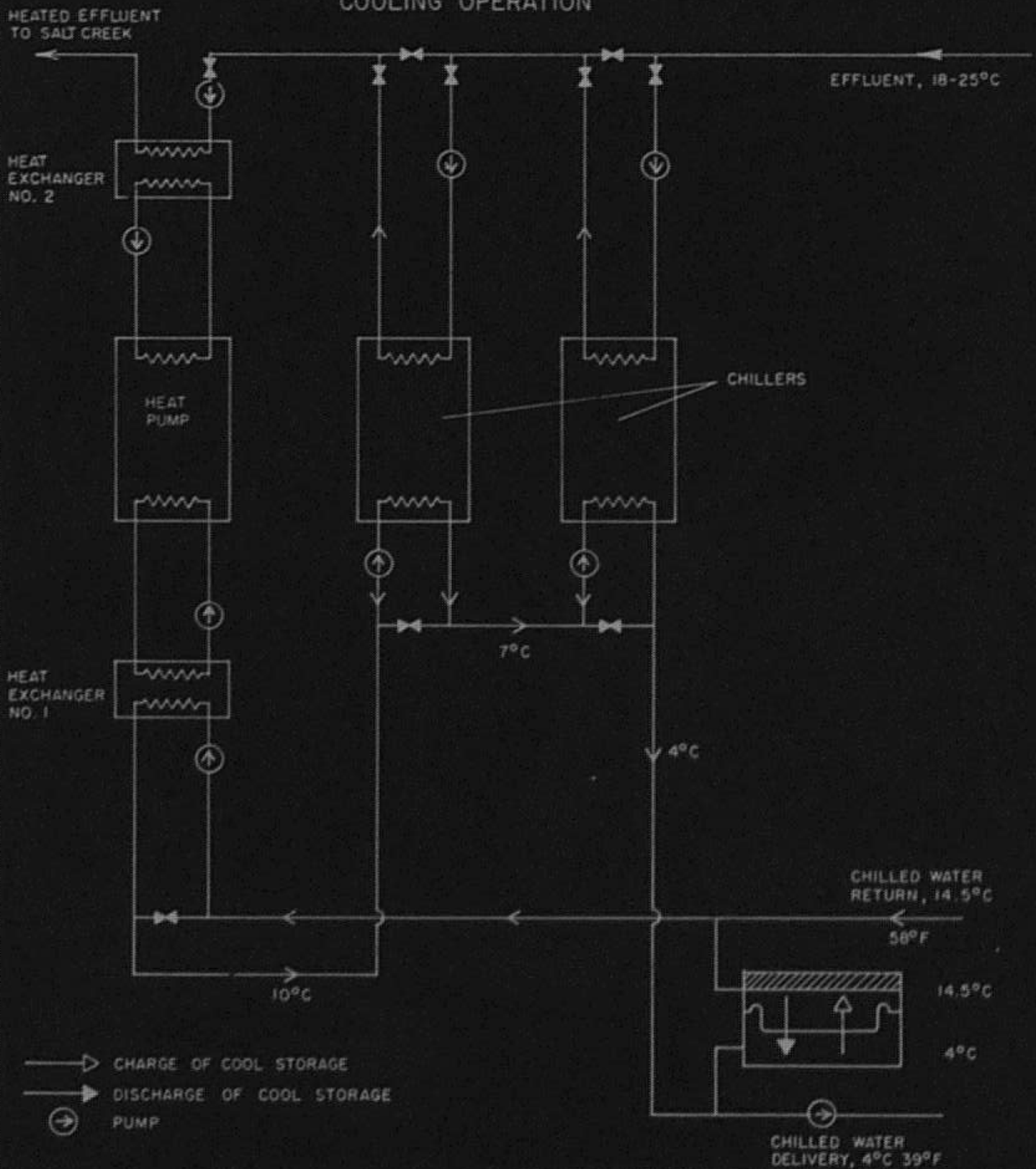
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# EXHIBIT 2-26 SIMPLIFIED DISTRICT SYSTEM SCHEMATIC COOLING OPERATION



LINCOLN ELECTRIC SYSTEM

SIMPLIFIED DISTRICT SYSTEM SCHEMATIC  
COOLING OPERATION

| DRAWN BY | CHECKED BY | CHECKED BY | APPROVED BY |
|----------|------------|------------|-------------|
|----------|------------|------------|-------------|

Knapp 10-13-86

SCALE NONE

DRAWING NO MISC-A-29

Central Plant Recommendations:

- a. Refine thermal conditions required for system operation to develop more accurate equipment cost estimates.
- b. Investigate machine sizes and speed control requirement to optimize load following and plant efficiency.
- c. Investigate single and two-stage machine applications which would best suit this application.



## 5. Thermal Storage

One of the major benefits of large district energy systems is the potential for energy storage applications. Utilizing storage systems for daily load leveling and emergency system backup provides cost control possibilities which are not available or are very expensive for the single building system owners.

For the district heating and cooling system analyzed in this study, both heat and cool storage systems have been incorporated. The general parameters for the storage systems proposed include the following:

**Storage Capacity** - Sufficient capacity is included to reduce peak electrical demand by a factor of 1.5 for cooling and 1.25 for heating. The storage systems proposed provide sufficient capacities for hours of daily peak energy storage thus reducing central plant equipment size and sewage effluent flow requirements.

**Type of Storage** - The storage systems included in this analysis are steel vessels of a sufficient size to satisfy the above storage requirements. The cool water storage tanks would be a steel vessel similar to those used as oil storage tanks. The cylindrical tank wall would be fitted with a thermal insulation of a thickness optimized as a function of cooling energy costs and temperature difference. The horizontal surface could be insulated by a layer of floating plastic foam. In order to maintain storage efficiency, blending or thermal mixing of the cold water in storage and warm return water must be minimized or

eliminated. This can be accomplished by installing a horizontal diaphragm that can move up and down within the storage tank to provide physical separation of water temperatures.

The hot water storage tanks would be steel vessels operated at atmospheric pressure. The vessels would have a cushion of steam above the water surface in order to keep out air and avoid corrosion caused by the absorption of air into the water. This steam cushion would also allow the vessel to be used as an expansion tank. The vessel could be designed with sufficient height to act as the system pressurizer if it is installed on the suction side of the main circulation pump.

**Storage System Costs** - The storage tank sizes and costs used for each size option have been summarized in Exhibit 2-27. The cool storage vessels are approximately eight times the size of the heat storage vessels, due primarily to the relative enthalpy difference between the delivery water versus the return water for the cool water and hot water system. The cold water and hot water system costs differ by only a factor of 3 due to the economy of scale and the more costly requirements for hot water storage equipment.

The storage facilities included for this feasibility study require additional optimization. Factors which must be considered to determine the ideal storage capacity include: facility input energy costs, the electrical energy rate structure, storage period requirements, storage capital costs, and the system load profile for both heating and cooling. While optimization of energy storage is beyond the scope of this analysis

it is an essential part of the final project design.

**Thermal Storage Recommendations:**

- a. Review and optimize thermal storage capacity for both heat and cool storage.
- b. Review the potential for off-peak type electrical rate structures which may provide benefit to both the electric utility and the district heating system.
- c. Determine possible locations for storage facilities. Review distributed as well as centrally located storage tanks.

## EXHIBIT 2-27

## Thermal Storage Summary

|                                          | <u>Option 1</u> | <u>Option 2</u> | <u>Option 3</u> |
|------------------------------------------|-----------------|-----------------|-----------------|
| <u>Cool Storage</u>                      |                 |                 |                 |
| Storage Capacity (kWh)                   | 16,400          | 24,500          | 32,900          |
| Storage Volume (gal)                     | 375,000         | 560,000         | 750,000         |
| Central Plant (MW)<br>Capacity Reduction | 2.35            | 3.5             | 4.7             |
| Peak Storage Period (hrs)                | 7               | 7               | 7               |
| Storage Cost (\$)                        | \$210,000       | \$280,000       | \$350,000       |
| Storage Capacity Cost (\$/kW)            | \$90            | \$80            | \$74            |
| Peaking Chiller Capacity Cost (\$/kW)    | \$100           | \$100           | \$100           |
| <u>Heat Storage</u>                      |                 |                 |                 |
| Storage Capacity (kWh)                   | 9,800           | 14,700          | 19,600          |
| Storage Volume (gal)                     | 45,000          | 70,000          | 90,000          |
| Central Plant (MW)<br>Capacity Reduction | 1.4             | 2.1             | 2.8             |
| Peak Storage Period (hrs)                | 7               | 7               | 7               |
| Storage Cost (\$)                        | \$70,000        | \$92,500        | \$115,000       |
| Storage Capacity Cost (\$/kW)            | \$50            | \$44            | \$41            |
| Peaking Boiler Capacity Cost (\$/kW)     | \$30            | \$30            | \$30            |



## 6. UNL Interconnection

On October 2, 1985, project staff met with University of Nebraska-Lincoln to discuss the operating parameters of UNL's district heating and cooling (DHC) system and the proposed DHC system in the downtown area to determine if mutually beneficial operations could be achieved through interconnection.

It was determined that UNL has a steam heating capacity from 350,000 to 375,000 lbs/hr with a peak heating demand of 180,000 lbs/hr. UNL supplies heating service to the downtown campus, the State Office Building and the State Capitol with a 8" to 10" steam supply and condensate return line running along 14th Street, rated at 250 psi and operated at 75 psi. The boilers range in age from 1930 to 1960 and are capable of burning either natural gas or #6 oil.

UNL has an installed cooling capacity of 14,000 tons at the central plant supplying the same buildings with 16" cooling water supply and return mains running down 16th Street. The equipment includes 3 steam-turbine driven centrifugal chillers and one electrically driven chiller. The chillers operate from approximately March 15 to October 15. The chilled water temperature runs from 42°F to 48°F.

UNL does experience some simultaneous heating and cooling requirements and must start a minimum 800 tons of cooling capacity to bring the system to an operating level.



UNL has experienced significant cost savings through reduced cooling demand by precooling campus buildings prior to peak load periods.

From these discussions, it was concluded that UNL has surplus heating capacity. The possibility of purchasing cooling energy during certain low load periods could reduce the need for UNL to start more chilling capacity than is necessary. Interconnection of the two systems could offer mutual peaking benefits but the interconnection costs may be prohibitive due to distances involved. This operating scenario should be further examined.

#### UNL Interconnection Recommendations

- a. Determine if surplus cooling capacity is available on proposed system for sale to UNL during light cooling loads during spring and fall.
- b. Determine interface requirements for purchase of peak heating energy from UNL.
- c. Evaluate route and capital cost of interconnection piping between systems.
- d. Determine maintenance and renovation plans for UNL central plant equipment.
- e. Evaluate potential for savings by reducing peak cooling demand by precooling buildings.

## TASK 3

### Economic Analysis

The economic analysis performed in this feasibility study was based upon an estimation of what load could potentially be served from a centralized DH&C plant. The viability of any capital intensive project is dependent upon maximizing sales volume, in this case heating and cooling energy, versus the required capital investment. The derivation of three distribution systems was discussed earlier in this report and the magnitude of service to these heating and cooling loads is the beginning point for the economic evaluation. Three system capacities were selected for capital cost estimates and it was the utilization of these specific central plant configurations which determined the economic feasibility of DH&C for the study.

The economic analysis has been performed through the use of an Interactive Financial Planning System (IFPS) model written and documented by Lincoln Electric System. The model incorporates all cost aspects of the proposed investment including component capital costs, central plant load, operations and maintenance expenses, renewals and replacement costs, and energy costs. The model utilizes ordinary language for variable names and functions and is organized in a readily interpreted format.

The IFPS model allows the user to apply any inflation or escalation factor to any cost variable and perform interactive proforma cost estimates and sensitivity analysis. A documented copy of the model and variable list

has been included in the appendix for reference.

Exhibit 3-1 outlines the specific cases that were modeled for the economic analysis. Three ownership methods were evaluated for each of the three system size options selected. These ownership methods were 1) Public ownership, 2) Private ownership and, 3) Leverage Leasing. The public ownership method included two capital and operating cost summaries to evaluate the effects of reducing debt coverage requirements. The private ownership and leverage lease methods included a capital and operating cost summary and a pro forma income statement. Exhibit 3-2 summarizes the parameters associated with each ownership method and the economic variables applied to each case.

Each of the capital and operating cost summaries includes:

- Case Assumptions
- Annualized Proforma Costs
- Per unit End Use Customer cost estimates.

A sensitivity analysis was performed on a number of alternate variables and it was determined that the two variables having the greatest effect on per unit energy cost were the overall system capital cost and total energy sales. This is a reasonable conclusion and holds true for all capital intensive production facilities.

The results of the individual cases and sensitivity analyses are included in Tables 1 thru Table 27 at the end of this section and have been indexed to Exhibit 3-1 for reference.

The overall variation in end use average energy cost is summarized in Exhibit 3-3. The costs range from \$11.55/10<sup>6</sup> Btu to \$19.23/10<sup>6</sup> Btu, with the lowest cost demonstrated for size option 3/public ownership. Exhibit 3-4 provides a comparison of the components of the energy costs for size option 2, which is the most likely DH&C option and a conventional heating and cooling system which would be the alternative to interconnecting to the DH&C system.

The capital costs and operating parameters for two alternate conventional heating and cooling systems have been summarized in Exhibit 3-5.

Alternate 1 would include a natural gas fired hot water boiler and standard centrifugal chiller while Alternate 2 would incorporate an electric hot water boiler and standard centrifugal chiller.

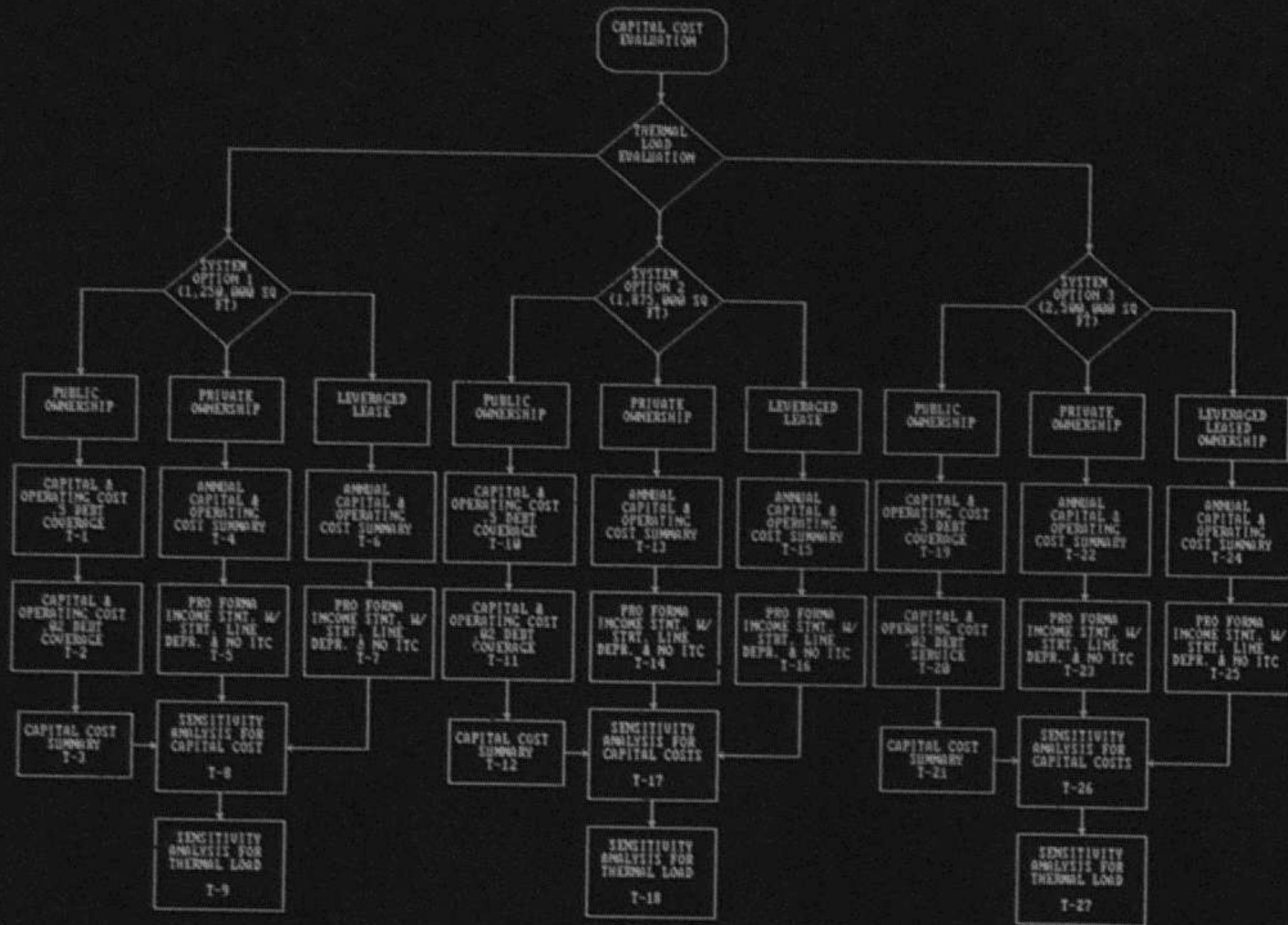
Along with the strict present worth comparison, several significant benefits could be demonstrated with the DH&C option. These benefits would include the reduction in energy cost sensitivity to input energy rate escalations due to the breakdown of the overall per unit cost. For the DH&C alternative, energy costs comprise a smaller fraction of the total energy related expense than the energy component of alternative systems. The central heating and cooling plant operation could be transferred from the individual building owner to the DH&C district operating agent. The value of this benefit would be quite variable dependent upon each building



operation but is a significant consideration.

The benefits to and drawbacks of DH&C interconnection have been listed for reference in Exhibit 3-6 without regard to cost comparisons.





## EXHIBIT 3-2

### Ownership Method Parameters Summary

#### PUBLIC OWNERSHIP -

|                   |                                                                                    |                     |
|-------------------|------------------------------------------------------------------------------------|---------------------|
| Investment Term - | 30 Years                                                                           |                     |
| Interest Rate -   | 7.5%/Year                                                                          |                     |
| Debt Coverage -   | <u>Case 1</u><br>50%                                                               | <u>Case 2</u><br>2% |
| Description -     | 100% debt financed through bond issues and operated as a nonprofit public utility. |                     |

#### PRIVATE OWNERSHIP -

|                         |                                                                       |  |
|-------------------------|-----------------------------------------------------------------------|--|
| Investment Term -       | 30 Years                                                              |  |
| Interest Rate -         | 11.5%/Year                                                            |  |
| Investment Tax Credit - | 0%                                                                    |  |
| Depreciation -          | Straight Line                                                         |  |
| Tax Rate -              | 34%                                                                   |  |
| Description -           | 20% equity, 80% debt financed and operated as investor owned utility. |  |

#### LEVERAGE LEASE -

|                         |                                                                                                                                                              |  |
|-------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------|--|
| Investment Term -       | 30 Years                                                                                                                                                     |  |
| Interest Rate -         | 11.5%/Year                                                                                                                                                   |  |
| Investment Tax Credit - | 0%                                                                                                                                                           |  |
| Depreciation -          | Straight Line                                                                                                                                                |  |
| Tax Rate -              | 34%                                                                                                                                                          |  |
| Description -           | 20% equity secured as a nonrecourse loan with 10% return and 80% debt financed at 11.5% interest. Lessee would operate system as a nonprofit public utility. |  |

# EXHIBIT 3-3

## System Size/Ownership Option End Use Energy Cost Summary

|                                                   | 1987<br>ENERGY COST<br>\$/10 <sup>6</sup> Btu |
|---------------------------------------------------|-----------------------------------------------|
| SIZE OPTION 1 (1,250,000 Ft <sup>2</sup> ) -      |                                               |
| Public Ownership<br>(1.5 Debt Coverage)           | \$16.85                                       |
| Public Ownership<br>(1.02 Debt Coverage)          | 14.06                                         |
| Private Ownership<br>(w/o ITC & Strt. Line Depr.) | 19.23                                         |
| Leveraged Lease                                   | 16.36                                         |
| SIZE OPTION 2 (1,875,000 Ft <sup>2</sup> )        |                                               |
| Public Ownership<br>(1.5 Debt Coverage)           | 14.47                                         |
| Public Ownership<br>(1.02 Debt Coverage)          | 12.18                                         |
| Private Ownership<br>(w/o ITC & Strt. Line Depr.) | 16.54                                         |
| Leveraged Lease                                   | 14.06                                         |
| SIZE OPTION 3 (2,500,000 Ft <sup>2</sup> )        |                                               |
| Public Ownership<br>(1.5 Debt Coverage)           | 13.71                                         |
| Public Ownership<br>(1.02 Debt Coverage)          | 11.55                                         |
| Private Ownership<br>(w/o ITC & Strt. Line Depr.) | 15.67                                         |
| Leveraged Lease                                   | 13.32                                         |

# EXHIBIT 3-4

## OPTION 2 (1,875,000 Square Feet) 1987 Energy Cost Comparison For Typical New Commercial Building Lincoln, Nebraska

### Average Heating and Cooling Cost \$/10<sup>6</sup> Btu

|                                             | Conventional<br>System<br>\$/10 <sup>6</sup> Btu | Private<br>Ownership<br>\$/10 <sup>6</sup> Btu | Public<br>Ownership(8)<br>\$/10 <sup>6</sup> Btu | Public<br>Ownership(9)<br>\$/10 <sup>6</sup> Btu | Leveraged<br>Lease Ownership<br>\$/10 <sup>6</sup> Btu |
|---------------------------------------------|--------------------------------------------------|------------------------------------------------|--------------------------------------------------|--------------------------------------------------|--------------------------------------------------------|
| Debt Service                                | \$9.03 <sup>(1)</sup>                            | \$5.55 <sup>(2)</sup>                          | \$4.77 <sup>(3)</sup>                            | \$4.77 <sup>(3)</sup>                            | \$6.74 <sup>(3)</sup>                                  |
| Energy                                      | 6.62 <sup>(4)</sup>                              | 4.58 <sup>(5)</sup>                            | 4.58 <sup>(5)</sup>                              | 4.58 <sup>(5)</sup>                              | 4.58 <sup>(5)</sup>                                    |
| O&M                                         | 4.21 <sup>(10)</sup>                             | 3.63                                           | 2.64                                             | 2.64                                             | 2.64                                                   |
| Debt Coverage                               | -0-                                              | -0-                                            | 2.38                                             | .10                                              | -0-                                                    |
| Mech. Room<br>Space Cost                    | .69 <sup>(6)</sup>                               | -0-                                            | -0-                                              | -0-                                              | -0-                                                    |
| Insurance                                   | .10                                              | .10                                            | .10                                              | .10                                              | .10                                                    |
| Total Cost<br>\$/10 <sup>6</sup> Btu (1987) | \$20.65                                          | \$13.86                                        | \$14.47                                          | \$12.19                                          | \$14.06                                                |

### Annual Cost \$/Sq. Ft.<sup>(7)</sup>

|                          | Conventional<br>System<br>\$/Sq. Ft. | Private<br>Ownership<br>\$/Sq. Ft. | Public<br>Ownership(8)<br>\$/Sq. Ft. | Public<br>Ownership(9)<br>\$/Sq. Ft. | Leveraged<br>Lease Ownership<br>\$/Sq. Ft. |
|--------------------------|--------------------------------------|------------------------------------|--------------------------------------|--------------------------------------|--------------------------------------------|
| Debt Service             | \$ .45                               | \$ .28                             | \$ .24                               | \$ .24                               | \$ .34                                     |
| Energy                   | .33                                  | .23                                | .23                                  | .23                                  | .23                                        |
| O&M and RAR              | .21                                  | .18                                | .12                                  | .12                                  | .12                                        |
| Debt Coverage            | -0-                                  | -0-                                | .12                                  | -0-                                  | -0-                                        |
| Mech. Room<br>Space Cost | .03                                  | -0-                                | -0-                                  | -0-                                  | -0-                                        |
| Insurance                | .01                                  | .01                                | .01                                  | .01                                  | .01                                        |
| Total Cost<br>\$/Sq. Ft. | \$1.03                               | \$ .70                             | \$ .72                               | \$ .60                               | \$ .70                                     |

- (1) Capital Cost at \$3.60/Ft.<sup>2</sup>, amortized 30 years at 12%.
- (2) Capital Cost Included in DHAC End User Rate, see detailed report.
- (3) Capital Cost Included in DHAC End User Rate, see detailed report.
- (4) Natural Gas fired boiler at 70% average seasonal efficiency and Centrifugal Chiller at 3.0 seasonal average COP.
- (5) See detailed report for Heat Pump Energy Production.
- (6) Value of space in new construction for heating and cooling plant at \$30 per Sq. Ft. for 1000 Sq. Ft. per 100,000 of structure.
- (7) Annual Energy Requirements of 50,000 Btu/Sq. Foot.
- (8) Uses 1.5 Debt Coverage
- (9) 1.02 Debt Coverage
- (10) O&M cost includes operator time plus 2% for maintenance and 2% for renewals and replacements base on a percentage of capital investment.



### EXHIBIT 3-5

#### Alternate Conventional Heating and Cooling System Parameters

##### ALTERNATE 1 -

Equipment - Gas fired hot water boiler ( $6 \times 10^6$  BTU/hr)  
Electric centrifugal water chiller (450 Ton)

Efficiency - 70% for Boiler  
3.0 COP for chiller seasonal average

Mechanical Plant in Capital Cost - \$3.00/Ft.<sup>2</sup>

Contingency, Engineering, O&P (20%) - \$ .60/Ft.<sup>2</sup>

TOTAL \$3.60/Ft.<sup>2</sup>

##### ALTERNATE 2 -

Equipment - Electric hot water boiler (1.7 MW)  
Electric centrifugal water chiller (450 Ton)

Efficiency - 99% for boiler  
3.0 COP for chiller seasonal average

Mechanical Plant in Capital Cost - \$3.00/Ft.<sup>2</sup>

Contingency, Engineering, O&P (20%) - \$ .60/Ft.<sup>2</sup>

TOTAL \$3.60/Ft.<sup>2</sup>



## EXHIBIT 3-6

### Benefits Comparison DH&C vs. Conventional System

#### DH&C Benefits

- Reduced energy cost sensitivity
- Transfer of operations responsibility
- Higher operational efficiency
- Opportunity for savings through load management
- Opportunity for savings through energy storage
- Individual building space savings
- Added economic development tool
- Energy from plentiful coal supply
- Reduction in air emissions
- Overall improvement in environmental quality
- Optimization of existing electrical resources
- Avoidance of boiler and chilling equipment investment for new buildings
- Alternative to replacing existing plant equipment for existing building owners
- System can take advantage of "diversity" to supply loads with less installed capacity

#### DH&C Drawbacks

- Requires comparatively large capital investment
- Requires early commitment from customers
- Minimal savings for existing buildings with recently installed boiler and chilling equipment
- Potential exists for additional underground utility conflicts

## TASK 4

### Marketing

The Lincoln DH&C customer marketing effort would consist of two parts. The first and essential part is establishing service to a relatively large new customer base. In the Lincoln system this initial customer load would be the Lincoln Town Center Development. Due to the capital investment required to construct the central plant facility the system would require an initial load of significant size in order for the overall production costs to remain competitive with existing fuels. The second part of the marketing effort would be directed toward expansion of the system to serve existing buildings in the downtown area.

The marketing of district energy to the Lincoln Town Center Development would revolve around the following factors:

- Establishing that the overall cost of district supplied energy is competitive with conventional heating and cooling systems.
- Presenting the savings which could be expected from transferring the responsibility for equipment operation and maintenance from the customer to the District. These costs would be shown as an integral part of the energy charges from the District. In many cases the customer may not be aware of actual annual O&M costs.
- Demonstrate savings in floor space which the Customer might expect

by utilizing District energy rather than installing individual boiler and chiller equipment in buildings.

- Through the use of energy cost estimates indicate the reduced sensitivity of annual energy costs due to conventional fuel escalation factors.

The second marketing effort directed toward the existing buildings in the downtown area would be based on the above factors and the following additional concerns:

- Providing the building owners with an opportunity to replace old or high maintenance equipment through interconnection to the District.
- Demonstrate potential savings in insurance costs through the elimination of fossil fired equipment from the buildings.
- Presenting the potential for future savings through District sponsored energy savings programs. These may include load management, energy storage, and possibly the utilization of customer owned chilling and heating equipment for peaking purposes.

Prior to interconnection to the District several factors would be evaluated. These would include:

- The location of the customer with respect to the established distribution system. The cost of piping installation may or may not

exceed the benefit available to both the customer and the District.

- A detailed energy audit should be performed on the existing buildings to accurately determine the projected heating and cooling demand and energy required by the customer.
- An evaluation of potential conservation efforts which the customer may undertake to reduce energy demand and consumption.
- An analysis would be performed to determine if the customer's existing cooling or heating equipment might be of benefit to the District for use during high demand periods.
- A review of building HVAC retrofit options could be performed in order to establish the actual conversion costs which the customer would expect during interconnection to the District.

A number of options exist for providing the preliminary evaluation and financing of customer interconnections. These tasks could be performed through:

- Customer retrofit evaluation with customer financing.
- District retrofit evaluation with contracted repayment.
- Third Party retrofit evaluation with contracted repayment.



- Third Party retrofit evaluation with shared customer savings repayment.

While each of these arrangements would be feasible, the third and fourth option would appear to present the most straight forward approach. The third party program envisioned for customer marketing could be structured as detailed in Exhibit 4-1.

Following a customer request for interconnection the first step would include a Preliminary Analysis. This preliminary review could be provided by the District through a third party at no cost to the customer. The results of this analysis would provide a determination of interconnection viability and an estimate of retrofit capital costs. Considering the results of the preliminary analysis the customer would have two options. These would be to either proceed to a comprehensive engineering evaluation or go no further with the interconnection plan.

If a comprehensive evaluation were chosen the customer would be responsible for the costs associated with this review. After reviewing the results of the second evaluation the customer would again decide whether to proceed or go no further with the interconnection plan.

If the Customer would choose to proceed, the final financing and engineering work would be performed and the retrofit work and interconnection would be completed.

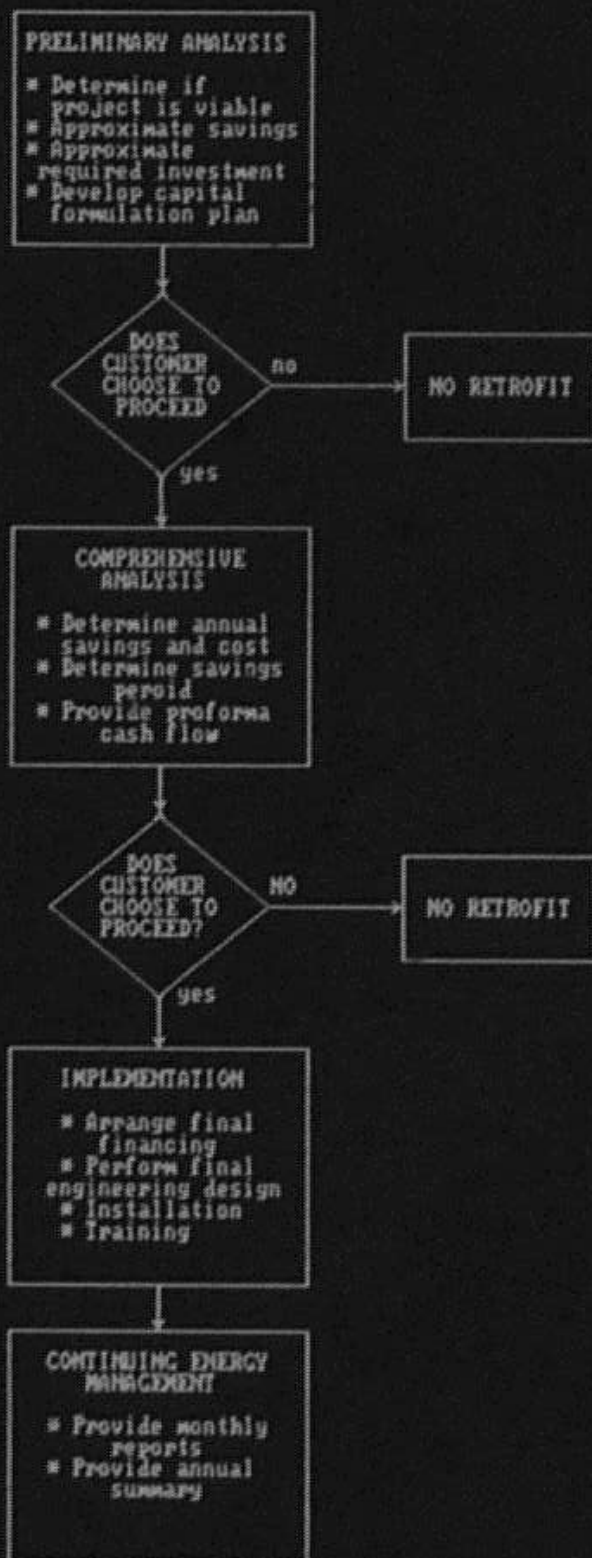
As stated previously the utilization of third party evaluation and



contracted or share cost savings repayment would appear most feasible for the retrofit work.

A number of third party organizations exists which would be capable of the necessary engineering evaluation, design and the arrangement of financing for equipment modification and building retrofit projects.

EXHIBIT 4-1  
DISTRICT HEATING & COOLING  
EXISTING BUILDING MARKETING  
FLOW CHART



## TASK 5

### Financial Feasibility

#### 1. General Financing

Financing has always been a crucial element in the development of any project and has become particularly important in recent years due to interest rate fluctuations. In a District Heating and Cooling project the financing can be particularly important in that it may act as a mitigating factor relative to high capital costs and lengthy development schedules. The type of financing structure used and the implications derived from that financing will vary greatly depending upon who is the ultimate owner/operator.

In determining who should be the ultimate owner/operator there are two major factors to be considered. They are as follows:

- a. In a private sector ownership scenario, the tax benefits along with a built-in profit margin, must provide an investor with an adequate return on his investment plus a reasonable return for the risk taken on the leverage portion of the total project cost.
- b. In a public sector financing scenario, the public body must secure the necessary tax exempt revenue bond-type financing to cover a major percentage of the capital costs and still allow the system to

operate competitively with an acceptable debt service coverage ratio.

The following descriptions provide a more detailed examination of the inherent characteristics of both types of ownership.

## 2. Private Debt Financing

Relative to private debt financing, the scenario that was examined involved a variety of factors including interest rate, depreciation, and tax rate. A range of interest rates within which a private developer might expect to obtain financing in the present economy was examined. Ultimately the rate itself would reflect not only the economy but also the credit worthiness of the borrower and the viability of the project as a whole. Passage of H.R. 3838, "The Tax Reform Act of 1986," eliminated the investment tax credit and replaced the accelerated form of depreciation with 30-year straight line depreciation. The maximum tax liability was calculated at thirty-four percent (34%). In the private ownership scenarios the underlying assumption was that the investor(s) would occupy a twenty percent (20%) equity position in the project.

There are a variety of forms that can be utilized by the private borrower(s) such as 1) mortgage bonds, which are secured by tangible assets of the system, and whose interest earnings are taxable; 2) debentures or general credit bonds, which are unsecured commercial loans given to established credit worthy investor(s) usually with a negative pledge which prohibits the borrower from pledging its assets to other



creditors and whose interests earnings are taxable; and 3) tax exempt industrial revenue bonds, which are issued by a public authority to finance a loan to the private developer in exchange for a capital note and pledge of the project's revenues sufficient to satisfy bond interest and principle payments while also providing a tax exempt interest expense to the developer and tax free interest income to the bond buyer. There is currently a degree of uncertainty surrounding the public tax exempt financing approach. Many aspects of the tax exempt issue will be clarified with the development of regulations implementing the new tax law during the next few months.

A leverage lease approach is an additional form of financing which could be used. Leveraged leases have been developed to finance large capital projects having economic lives as long as twenty or thirty years. A leverage lease is often used in joint ventures involving three parties: 1) a leasee (the energy customers or perhaps a local government), 2) a lessor (a developer with minor equity), and 3) a long-term institutional lender (such as a bank). The lessor provides ten to thirty percent of the required equity and the remainder is borrowed from the lending institution, on a non-recourse basis to the lessor. Repayment to the lender is made from project revenues secured by credit of energy customers through take or pay contracts and/or a first lien on the production and distribution facility backed by equipment collateral. The lessor has no personal liability if the lessee defaults, but can claim all of the tax benefits of ownership. Leverage given by the non-recourse debt also magnifies the effects of tax shelter relative to the lessors equity investment, thus allowing the lessee's payment to the lessor to be



arranged lower than for the non-leveraged lease, thereby lowering cash flow requirements for the project. It was also assumed that all of the interest expense could be used by the individual investor(s) as they occur to offset tax liabilities from other ventures. If multiple investors are involved the credits would accrue on a prorata basis with ownership. If credits and expense cannot be utilized the rate of return would be lower or the energy cost would increase in order to make up the tax credit loss.

### 3. Investor Interest

In order to reduce investment risk and subsequently lower interest rates, the lender may require that customers execute unconditional take or pay contracts for the life of the project regardless of the energy taken, to guarantee minimum payments for lease rental maintenance, insurance, and taxes. Long term financing will provide a uniform capital component of the energy price for the life of the project.

The investor interest will of course be directly related to the return on investment that the investor might expect but equally important is the perceived amount of risk involved in the project. Consequently if the private sector approach were taken, it would be necessary that adequate guarantees from the legal bodies of authority be given either by long term franchising agreements or other type of agreement which will allow the private entity a high degree of assurance that they will be able to operate in the proposed manner. This of course would require a certain degree of political consensus in the community for the project as well as a demonstrative need or market for the project.

#### 4. Public Debt Financing

In the scenarios involving public debt financing, the interest rate was based upon the likelihood of a public entity's ability to obtain some type of bonding, and the ability to operate the system with a debt service coverage ratio at an acceptable user rate level. The type of structure that public financing might take could involve: 1) bonds, 2) guaranteed loans, or 3) the possibility of a lease purchase agreement. The most likely type of bond that would be utilized by a public entity is a revenue bond. Revenue bonds utilize a project's revenues as the only security for the bond holders, and consequently the interest rates on these bonds are determined by the project's risks and its projected cash flows. Given the potential riskiness of a district heating and cooling project's early stages and the limited cash flow during initial years of market penetration, the interest rates on revenue bonds could be relatively high. However, as with other types of bonds, there is an ability to improve the marketability of the revenue bonds by adding other securities, such as the mortgage on the project's facility or pledging other revenues or taxing powers. As a result, the participation by the Lincoln Electric System or the City to tie in any potential revenue bonds for this project with other revenue bonds in some manner might provide a substantially better interest rate.

Another alternative available to the public sector, which was examined to some degree in the private sector financing section, is leasing or a leased-purchase approach to the facilities and equipment. A lease of this

nature can either take the form of a traditional lease or a leverage lease with third-party financing, which was discussed in the earlier section. Leasing may provide a public entity project with the availability of raising capital in situations where traditional borrowing directly from a bank may be prohibited by law or where the size of the project is such that the issuing of bonds would not be warranted. Leveraged leases are however complex from legal and tax perspectives with a number of involved parties. Before a leasing arrangement can be entered into it would be necessary to carefully examine recent tax rulings and the requirements for regulatory approval.

#### **Financial Feasibility Recommendations**

- a. Monitor changes to IRS tax rulings and regulatory requirements pertaining to leverage leasing.
- b. Monitor changes to IRS tax rulings pertaining to tax exempt status of municipal bonds.



1,250,000 SQ. FT.

LINCOLN DISTRICT HEATING SYSTEM  
CAPITAL AND OPERATING COST  
PUBLIC CASE

## \*\*\* ASSUMPTIONS \*\*\*

TOTAL MBRTUS PRODUCED 62,500  
COOLING ENERGY OUTPUT 25,000  
HEATING ENERGY OUTPUT 37,500  
HEAT PUMP COST 850,000  
PROJECT LIFE 30  
FINANCED PORTION 4,290,370  
SALVAGE VALUE 50,000  
COOLING COP 4.800  
HEATING COP 2.400  
HEATING RATE .030  
COOLING RATE .060  
FINANCED INTEREST RATE .075

DATE GENERATED: 10/01/86

## ANNUAL COSTS

|                        | 1987       | 1988       | 1989       | 1990       | 1991       | 1992       | 1993       | 1994       | 1995       | 1996       |
|------------------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|
| PUMPING COST           | \$ 40,217  | \$ 40,217  | \$ 40,217  | \$ 40,217  | \$ 41,021  | \$ 41,841  | \$ 42,678  | \$ 43,532  | \$ 44,402  | \$ 45,291  |
| PLANT ENERGY COST      | \$ 228,905 | \$ 228,905 | \$ 228,905 | \$ 228,905 | \$ 233,483 | \$ 238,152 | \$ 242,915 | \$ 247,774 | \$ 252,729 | \$ 257,784 |
| CUSTOMER CHARGE        | \$ 3,240   | \$ 3,240   | \$ 3,240   | \$ 3,240   | \$ 3,240   | \$ 3,240   | \$ 3,240   | \$ 3,240   | \$ 3,240   | \$ 3,240   |
| MAINTENANCE COST       | \$ 76,020  | \$ 76,020  | \$ 76,020  | \$ 76,020  | \$ 76,020  | \$ 76,020  | \$ 76,020  | \$ 76,020  | \$ 76,020  | \$ 76,020  |
| OPERATOR COST          | \$ 79,875  | \$ 83,070  | \$ 86,393  | \$ 89,849  | \$ 93,442  | \$ 97,180  | \$ 101,067 | \$ 105,110 | \$ 109,314 | \$ 113,687 |
| INSURANCE              | \$ 30,000  | \$ 30,000  | \$ 30,000  | \$ 30,000  | \$ 30,000  | \$ 30,000  | \$ 30,000  | \$ 30,000  | \$ 30,000  | \$ 30,000  |
| SELLING ADMIN          | \$ 50,000  | \$ 50,000  | \$ 25,000  | \$ 25,000  | \$ 25,000  | \$ 25,000  | \$ 25,000  | \$ 25,000  | \$ 25,000  | \$ 25,000  |
| O & M                  | \$ 508,257 | \$ 511,452 | \$ 489,775 | \$ 493,231 | \$ 502,206 | \$ 511,433 | \$ 520,920 | \$ 530,676 | \$ 540,705 | \$ 551,022 |
| DEBT SERVICE (7.5%)    | \$ 363,271 | \$ 363,271 | \$ 363,271 | \$ 363,271 | \$ 363,271 | \$ 363,271 | \$ 363,271 | \$ 363,271 | \$ 363,271 | \$ 363,271 |
| OPERATION+DEBT SERVICE | \$ 871,528 | \$ 874,723 | \$ 853,046 | \$ 856,502 | \$ 865,477 | \$ 874,704 | \$ 884,191 | \$ 893,947 | \$ 903,976 | \$ 914,293 |
| R&R (DEBT COVERAGE)    | \$ 7,266   | \$ 7,266   | \$ 7,266   | \$ 7,266   | \$ 7,266   | \$ 7,266   | \$ 7,266   | \$ 7,266   | \$ 7,266   | \$ 7,266   |
| TOTAL ANNUAL COST      | \$ 878,794 | \$ 881,989 | \$ 860,312 | \$ 863,768 | \$ 872,743 | \$ 881,970 | \$ 891,457 | \$ 901,213 | \$ 911,242 | \$ 921,559 |
| COST PER MILLION BTUS  |            |            |            |            |            |            |            |            |            |            |
| DEBT SERVICE           | \$ 5.81    | \$ 5.81    | \$ 5.81    | \$ 5.81    | \$ 5.81    | \$ 5.81    | \$ 5.81    | \$ 5.81    | \$ 5.81    | \$ 5.81    |
| ENERGY COST            | \$ 4.31    | \$ 4.31    | \$ 4.31    | \$ 4.31    | \$ 4.39    | \$ 4.48    | \$ 4.57    | \$ 4.66    | \$ 4.75    | \$ 4.85    |
| O & M                  | \$ 3.83    | \$ 3.88    | \$ 3.53    | \$ 3.59    | \$ 3.64    | \$ 3.70    | \$ 3.77    | \$ 3.83    | \$ 3.90    | \$ 3.97    |
| R&R (DEBT COVERAGE)    | \$ .12     | \$ .12     | \$ .12     | \$ .12     | \$ .12     | \$ .12     | \$ .12     | \$ .12     | \$ .12     | \$ .12     |
| TOTAL PER UNIT COST    | \$14.06    | \$14.11    | \$13.76    | \$13.82    | \$13.96    | \$14.11    | \$14.26    | \$14.42    | \$14.58    | \$14.74    |
| COOLING PORTION        | \$17.82    | \$17.88    | \$17.49    | \$17.55    | \$17.71    | \$17.87    | \$18.04    | \$18.21    | \$18.39    | \$18.57    |
| HEATING PORTION        | \$11.55    | \$11.60    | \$11.28    | \$11.33    | \$11.47    | \$11.60    | \$11.75    | \$11.89    | \$12.04    | \$12.20    |

TABLE 1

SIZE OPTION 1  
1,250,000 SQ. FT.

LINCOLN DISTRICT HEATING SYSTEM  
CAPITAL AND OPERATING COST  
PUBLIC CASE

\*\*\* ASSUMPTIONS \*\*\*

TOTAL MMBTUS PRODUCED 62,500  
COOLING ENERGY OUTPUT 25,000  
HEATING ENERGY OUTPUT 37,500  
HEAT PUMP COST 850,000  
PROJECT LIFE 30  
FINANCED PORTION 4,290,370  
SALVAGE VALUE 50,000  
COOLING COP 4.800  
HEATING COP 2.400  
HEATING RATE .030  
COOLING RATE .060  
FINANCED INTEREST RATE .075  
DATE GENERATED: 10/01/86

ANNUAL COSTS

|                        | 1987        | 1988        | 1989        | 1990        | 1991        | 1992        | 1993        | 1994        | 1995        | 1996        |
|------------------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|
| PUMPING COST           | \$ 40,217   | \$ 40,217   | \$ 40,217   | \$ 40,217   | \$ 41,021   | \$ 41,841   | \$ 42,678   | \$ 43,532   | \$ 44,402   | \$ 45,291   |
| PLANT ENERGY COST      | \$ 228,905  | \$ 228,905  | \$ 228,905  | \$ 228,905  | \$ 233,483  | \$ 238,152  | \$ 242,915  | \$ 247,774  | \$ 252,729  | \$ 257,784  |
| CUSTOMER CHARGE        | \$ 3,240    | \$ 3,240    | \$ 3,240    | \$ 3,240    | \$ 3,240    | \$ 3,240    | \$ 3,240    | \$ 3,240    | \$ 3,240    | \$ 3,240    |
| MAINTENANCE COST       | \$ 76,020   | \$ 76,020   | \$ 76,020   | \$ 76,020   | \$ 76,020   | \$ 76,020   | \$ 76,020   | \$ 76,020   | \$ 76,020   | \$ 76,020   |
| OPERATOR COST          | \$ 79,875   | \$ 83,070   | \$ 86,393   | \$ 89,849   | \$ 93,442   | \$ 97,180   | \$ 101,067  | \$ 105,110  | \$ 109,314  | \$ 113,687  |
| INSURANCE              | \$ 30,000   | \$ 30,000   | \$ 30,000   | \$ 30,000   | \$ 30,000   | \$ 30,000   | \$ 30,000   | \$ 30,000   | \$ 30,000   | \$ 30,000   |
| SELLING ADMIN          | \$ 50,000   | \$ 50,000   | \$ 25,000   | \$ 25,000   | \$ 25,000   | \$ 25,000   | \$ 25,000   | \$ 25,000   | \$ 25,000   | \$ 25,000   |
| O & M                  | \$ 508,257  | \$ 511,452  | \$ 489,775  | \$ 493,231  | \$ 502,206  | \$ 511,433  | \$ 520,920  | \$ 530,676  | \$ 540,705  | \$ 551,022  |
| DEBT SERVICE (7.5%)    | \$ 363,271  | \$ 363,271  | \$ 363,271  | \$ 363,271  | \$ 363,271  | \$ 363,271  | \$ 363,271  | \$ 363,271  | \$ 363,271  | \$ 363,271  |
| OPERATION+DEBT SERVICE | \$ 871,528  | \$ 874,723  | \$ 853,046  | \$ 856,502  | \$ 865,477  | \$ 874,704  | \$ 884,191  | \$ 893,947  | \$ 903,976  | \$ 914,293  |
| R&R (DEBT COVERAGE)    | \$ 181,636  | \$ 181,636  | \$ 181,636  | \$ 181,636  | \$ 181,636  | \$ 181,636  | \$ 181,636  | \$ 181,636  | \$ 181,636  | \$ 181,636  |
| TOTAL ANNUAL COST      | \$1,053,164 | \$1,056,359 | \$1,034,682 | \$1,038,138 | \$1,047,113 | \$1,056,340 | \$1,065,827 | \$1,075,583 | \$1,085,612 | \$1,095,929 |
| COST PER MILLION BTUS  |             |             |             |             |             |             |             |             |             |             |
| DEBT SERVICE           | \$ 5.81     | \$ 5.81     | \$ 5.81     | \$ 5.81     | \$ 5.81     | \$ 5.81     | \$ 5.81     | \$ 5.81     | \$ 5.81     | \$ 5.81     |
| ENERGY COST            | \$ 4.31     | \$ 4.31     | \$ 4.31     | \$ 4.31     | \$ 4.39     | \$ 4.48     | \$ 4.57     | \$ 4.66     | \$ 4.75     | \$ 4.85     |
| O & M                  | \$ 3.83     | \$ 3.88     | \$ 3.53     | \$ 3.59     | \$ 3.64     | \$ 3.70     | \$ 3.77     | \$ 3.83     | \$ 3.90     | \$ 3.97     |
| R&R (DEBT COVERAGE)    | \$ 2.91     | \$ 2.91     | \$ 2.91     | \$ 2.91     | \$ 2.91     | \$ 2.91     | \$ 2.91     | \$ 2.91     | \$ 2.91     | \$ 2.91     |
| TOTAL PER UNIT COST    | \$16.85     | \$16.90     | \$16.55     | \$16.61     | \$16.75     | \$16.90     | \$17.05     | \$17.21     | \$17.37     | \$17.53     |
| COOLING PORTION        | \$22.01     | \$22.06     | \$21.68     | \$21.74     | \$21.90     | \$22.06     | \$22.22     | \$22.40     | \$22.57     | \$22.75     |
| HEATING PORTION        | \$13.41     | \$13.46     | \$13.14     | \$13.19     | \$13.33     | \$13.46     | \$13.61     | \$13.75     | \$13.90     | \$14.06     |

TABLE 2



CAPITAL COSTS SUMMARY  
 SIZE OPTION 1  
 -----

|                          |             |             |
|--------------------------|-------------|-------------|
| SOURCE PIPE              | \$ 440,000  |             |
| PIPE INSTALLATION        | \$ 220,000  |             |
| SOURCE PUMP STATION      | \$ 200,000  |             |
|                          | -----       |             |
| SOURCE SYSTEM COST       | \$ 860,000  |             |
| DISTRIBUTION PIPE        | \$ 921,000  |             |
| HEAT PUMP                | \$ 850,000  |             |
| CENTRAL PLANT BOILER     | \$ 170,000  |             |
| CENTRAL PLANT CHILLER    | \$ 320,000  |             |
| LAND & BUILDING          | \$ 250,000  |             |
| PIPING & AUX.            | \$ 150,000  |             |
| STORAGE                  | \$ 280,000  |             |
|                          | -----       |             |
| CENTRAL PLANT SYSTEM     | \$2,020,000 |             |
| TOTAL CAPITAL COST       |             | \$3,801,000 |
| TAXES                    | \$ 104,528  |             |
| A&G                      | \$ 0        |             |
| ENGINEERING              | \$ 195,277  |             |
| CONTINGENCY              | \$ 195,277  |             |
| SALVAGE VALUE            | \$ -5,712   |             |
|                          | -----       |             |
| MISC                     |             | \$ 489,370  |
|                          |             | -----       |
| TOTAL INITIAL COST       |             | \$4,290,370 |
|                          |             | =====       |
| DATE GENERATED: 10/01/86 |             |             |

TABLE 3

1,250,000 SQ. FT.

LINCOLN DISTRICT HEATING SYSTEM  
CAPITAL AND OPERATING COST  
PRIVATE OWNERSHIP

DATE: 10/10/86

\*\*\* ASSUMPTIONS \*\*\*

TOTAL MMBTUS PRODUCED 62,500  
COOLING ENERGY OUTPUT 25,000  
HEATING ENERGY OUTPUT 37,500  
HEAT PUMP COST 850,000  
YEARS AMORTIZED OVER 30  
SALVAGE VALUE 50,000  
COOLING COP 4.800  
HEATING COP 2.400  
HEATING RATE .030  
COOLING RATE .060  
INTEREST RATE .115

ANNUAL COSTS

|                       | 1987        | 1988        | 1989       | 1990       | 1991        | 1992        | 1993        | 1994        | 1995        | 1996        |
|-----------------------|-------------|-------------|------------|------------|-------------|-------------|-------------|-------------|-------------|-------------|
| DEBT SERVICE          | \$ 423,066  | \$ 423,066  | \$ 423,066 | \$ 423,066 | \$ 423,066  | \$ 423,066  | \$ 423,066  | \$ 423,066  | \$ 423,066  | \$ 423,066  |
| PUMPING COST          | \$ 40,217   | \$ 40,217   | \$ 40,217  | \$ 40,217  | \$ 41,021   | \$ 41,841   | \$ 42,678   | \$ 43,532   | \$ 44,402   | \$ 45,291   |
| PLANT ENERGY COST     | \$ 228,905  | \$ 228,905  | \$ 228,905 | \$ 228,905 | \$ 233,483  | \$ 238,152  | \$ 242,915  | \$ 247,774  | \$ 252,729  | \$ 257,784  |
| CUSTOMER CHARGE       | \$ 3,240    | \$ 3,240    | \$ 3,240   | \$ 3,240   | \$ 3,240    | \$ 3,240    | \$ 3,240    | \$ 3,240    | \$ 3,240    | \$ 3,240    |
| MAINTENANCE COST      | \$ 76,020   | \$ 76,020   | \$ 76,020  | \$ 76,020  | \$ 76,020   | \$ 76,020   | \$ 76,020   | \$ 76,020   | \$ 76,020   | \$ 76,020   |
| OPERATOR COST         | \$ 79,875   | \$ 83,070   | \$ 86,393  | \$ 89,849  | \$ 93,443   | \$ 97,181   | \$ 101,068  | \$ 105,111  | \$ 109,315  | \$ 113,688  |
| SELLING ADMIN         | \$ 50,000   | \$ 50,000   | \$ 25,000  | \$ 25,000  | \$ 25,000   | \$ 25,000   | \$ 25,000   | \$ 25,000   | \$ 25,000   | \$ 25,000   |
| INSURANCE             | \$ 30,000   | \$ 30,000   | \$ 30,000  | \$ 30,000  | \$ 30,000   | \$ 30,000   | \$ 30,000   | \$ 30,000   | \$ 30,000   | \$ 30,000   |
| REPLACEMENT & RENEWAL | \$ 76,020   | \$ 76,020   | \$ 76,020  | \$ 76,020  | \$ 76,020   | \$ 76,020   | \$ 76,020   | \$ 76,020   | \$ 76,020   | \$ 76,020   |
| TOTAL ANNUAL COST     | \$1,007,343 | \$1,010,538 | \$ 988,861 | \$ 992,317 | \$1,001,293 | \$1,010,520 | \$1,020,007 | \$1,029,763 | \$1,039,792 | \$1,050,109 |

COST PER MILLION BTUS

|                      |         |         |         |         |         |         |         |         |         |         |
|----------------------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|
| DEBT SERVICE         | \$ 6.77 | \$ 6.77 | \$ 6.77 | \$ 6.77 | \$ 6.77 | \$ 6.77 | \$ 6.77 | \$ 6.77 | \$ 6.77 | \$ 6.77 |
| ENERGY COST          | \$ 4.31 | \$ 4.31 | \$ 4.31 | \$ 4.31 | \$ 4.39 | \$ 4.48 | \$ 4.57 | \$ 4.66 | \$ 4.75 | \$ 4.85 |
| FIXED OPERATING COST | \$ 5.04 | \$ 5.09 | \$ 4.75 | \$ 4.80 | \$ 4.86 | \$ 4.92 | \$ 4.98 | \$ 5.05 | \$ 5.11 | \$ 5.18 |
| TOTAL PER UNIT COST  | \$16.12 | \$16.17 | \$15.82 | \$15.88 | \$16.02 | \$16.17 | \$16.32 | \$16.48 | \$16.64 | \$16.80 |

TABLE 4

SIZE OPTION 1  
1,250,000 SQ. FT.

LINCOLN DISTRICT HEATING SYSTEM  
INCOME STATEMENT  
PRIVATE CASE

DATE: 10/10/86

|                            | 1987        | 1988        | 1989        | 1990        | 1991        | 1992        | 1993        | 1994        | 1995        | 1996        |
|----------------------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|
| SALES                      | \$1,201,761 | \$1,205,572 | \$1,171,801 | \$1,175,896 | \$1,186,533 | \$1,197,467 | \$1,183,209 | \$1,194,526 | \$1,206,159 | \$1,197,125 |
| VARIABLE COST:             |             |             |             |             |             |             |             |             |             |             |
| ENERGY COST                | \$ 269,122  | \$ 269,122  | \$ 269,122  | \$ 269,122  | \$ 274,504  | \$ 279,993  | \$ 285,593  | \$ 291,306  | \$ 297,131  | \$ 303,075  |
| CONTRIBUTION MARGIN        | \$ 932,639  | \$ 936,450  | \$ 902,679  | \$ 906,774  | \$ 912,029  | \$ 917,474  | \$ 897,616  | \$ 903,220  | \$ 909,028  | \$ 894,050  |
| FIXED COSTS:               |             |             |             |             |             |             |             |             |             |             |
| DEBT SERVICE               | \$ 423,066  | \$ 423,066  | \$ 423,066  | \$ 423,066  | \$ 423,066  | \$ 423,066  | \$ 423,066  | \$ 423,066  | \$ 423,066  | \$ 423,066  |
| MAINTENANCE COST           | \$ 76,020   | \$ 76,020   | \$ 76,020   | \$ 76,020   | \$ 76,020   | \$ 76,020   | \$ 76,020   | \$ 76,020   | \$ 76,020   | \$ 76,020   |
| OPERATOR COST              | \$ 79,875   | \$ 83,070   | \$ 86,393   | \$ 89,849   | \$ 93,443   | \$ 97,181   | \$ 101,068  | \$ 105,111  | \$ 109,315  | \$ 113,688  |
| REPLACEMENT RENEWAL        | \$ 76,020   | \$ 76,020   | \$ 76,020   | \$ 76,020   | \$ 76,020   | \$ 76,020   | \$ 76,020   | \$ 76,020   | \$ 76,020   | \$ 76,020   |
| SELLING & ADMIN.           | \$ 50,000   | \$ 50,000   | \$ 25,000   | \$ 25,000   | \$ 25,000   | \$ 25,000   | \$ 25,000   | \$ 25,000   | \$ 25,000   | \$ 25,000   |
| INSURANCE                  | \$ 30,000   | \$ 30,000   | \$ 30,000   | \$ 30,000   | \$ 30,000   | \$ 30,000   | \$ 30,000   | \$ 30,000   | \$ 30,000   | \$ 30,000   |
| CUSTOMER CHARGE            | \$ 3,240    | \$ 3,240    | \$ 3,240    | \$ 3,240    | \$ 3,240    | \$ 3,240    | \$ 3,240    | \$ 3,240    | \$ 3,240    | \$ 3,240    |
| TOTAL FIXED COSTS          | \$ 738,221  | \$ 741,416  | \$ 719,739  | \$ 723,195  | \$ 726,789  | \$ 730,527  | \$ 734,414  | \$ 738,457  | \$ 742,661  | \$ 747,034  |
| OPERATING INCOME           | \$ 194,418  | \$ 195,034  | \$ 182,940  | \$ 183,579  | \$ 185,240  | \$ 186,947  | \$ 163,202  | \$ 164,763  | \$ 166,367  | \$ 147,016  |
| LESS:                      |             |             |             |             |             |             |             |             |             |             |
| DEPRECIATION               | \$ 114,613  | \$ 114,613  | \$ 114,613  | \$ 114,613  | \$ 114,613  | \$ 114,613  | \$ 114,613  | \$ 114,613  | \$ 114,613  | \$ 114,613  |
| TAXABLE INCOME             | \$ 79,805   | \$ 80,421   | \$ 68,327   | \$ 68,966   | \$ 70,627   | \$ 72,334   | \$ 48,589   | \$ 50,150   | \$ 51,754   | \$ 32,403   |
| INCOME TAX                 | \$ 27,134   | \$ 27,343   | \$ 23,231   | \$ 23,448   | \$ 24,013   | \$ 24,594   | \$ 16,520   | \$ 17,051   | \$ 17,596   | \$ 11,017   |
| NET INCOME                 | \$ 52,671   | \$ 53,078   | \$ 45,096   | \$ 45,518   | \$ 46,614   | \$ 47,740   | \$ 32,069   | \$ 33,099   | \$ 34,158   | \$ 21,386   |
| POSITIVE NET INCOME        | \$ 52,671   | \$ 53,078   | \$ 45,096   | \$ 45,518   | \$ 46,614   | \$ 47,740   | \$ 32,069   | \$ 33,099   | \$ 34,158   | \$ 21,386   |
| INVESTMENT TAX CREDIT      | \$ 0        | \$ 0        | \$ 0        | \$ 0        | \$ 0        | \$ 0        | \$ 0        | \$ 0        | \$ 0        | \$ 0        |
| TAX VALUE DEPR             | \$ 38,969   | \$ 38,969   | \$ 38,969   | \$ 38,969   | \$ 38,969   | \$ 38,969   | \$ 38,969   | \$ 38,969   | \$ 38,969   | \$ 38,969   |
| EQUITY                     | \$ 16,150   | \$ 18,007   | \$ 20,078   | \$ 22,386   | \$ 24,961   | \$ 27,831   | \$ 31,032   | \$ 34,601   | \$ 38,580   | \$ 43,017   |
| EFFECTIVE NET INCOME       | \$ 107,790  | \$ 110,054  | \$ 104,142  | \$ 106,873  | \$ 110,544  | \$ 114,541  | \$ 102,070  | \$ 106,669  | \$ 111,706  | \$ 103,372  |
| RATE OF RETURN             | .126        | .128        | .121        | .124        | .129        | .133        | .119        | .124        | .130        | .120        |
| SELLING PRICE              | \$19.23     |             |             |             |             |             |             |             |             |             |
| TOTAL INVESTMENT           | \$4,294,173 |             |             |             |             |             |             |             |             |             |
| CAPITAL PORTION            | \$ 858,835  |             |             |             |             |             |             |             |             |             |
| FINANCED PORTION           | \$3,435,338 |             |             |             |             |             |             |             |             |             |
| POINTS COST                | \$ 103,061  |             |             |             |             |             |             |             |             |             |
| FIRST YEAR DEPR.           | \$ 114,613  |             |             |             |             |             |             |             |             |             |
| TOTAL MMBTU'S SOLD         | 62,500      |             |             |             |             |             |             |             |             |             |
| PERCENTAGE MARKUP          | .19         |             |             |             |             |             |             |             |             |             |
| INVESTMENT TAX CREDIT      | .00         |             |             |             |             |             |             |             |             |             |
| INCOME TAX RATE            | .34         |             |             |             |             |             |             |             |             |             |
| STRAIGHT LINE DEPRECIATION |             |             |             |             |             |             |             |             |             |             |

TABLE 5



1,250,000 SQ. FT.

LINCOLN DISTRICT HEATING SYSTEM  
CAPITAL AND OPERATING COST  
LEVERAGED LEASE CASE

DATE: 10/10/86

\*\*\* ASSUMPTIONS \*\*\*

|                       |         |
|-----------------------|---------|
| TOTAL MMBTUS PRODUCED | 62,500  |
| COOLING ENERGY OUTPUT | 25,000  |
| HEATING ENERGY OUTPUT | 37,500  |
| HEAT PUMP COST        | 850,000 |
| YEARS AMORTIZED OVER  | 30      |
| COOLING COP           | 4.800   |
| HEATING COP           | 2.400   |
| HEATING RATE          | .030    |
| COOLING RATE          | .060    |
| DEBT INTEREST RATE    | .115    |
| RETURN ON EQUITY      | .100    |

ANNUAL COSTS

|                   | 1987        | 1988        | 1989        | 1990        | 1991        | 1992        | 1993        | 1994        | 1995        | 1996        |
|-------------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|
| DEBT SERVICE      | \$ 514,170  | \$ 514,170  | \$ 514,170  | \$ 514,170  | \$ 514,170  | \$ 514,170  | \$ 514,170  | \$ 514,170  | \$ 514,170  | \$ 514,170  |
| PUMPING COST      | \$ 40,217   | \$ 40,217   | \$ 40,217   | \$ 40,217   | \$ 41,021   | \$ 41,841   | \$ 42,678   | \$ 43,532   | \$ 44,402   | \$ 45,291   |
| PLANT ENERGY COST | \$ 228,905  | \$ 228,905  | \$ 228,905  | \$ 228,905  | \$ 233,483  | \$ 238,152  | \$ 242,915  | \$ 247,774  | \$ 252,729  | \$ 257,784  |
| CUSTOMER CHARGE   | \$ 3,240    | \$ 3,240    | \$ 3,240    | \$ 3,240    | \$ 3,240    | \$ 3,240    | \$ 3,240    | \$ 3,240    | \$ 3,240    | \$ 3,240    |
| MAINTENANCE COST  | \$ 76,020   | \$ 76,020   | \$ 76,020   | \$ 76,020   | \$ 76,020   | \$ 76,020   | \$ 76,020   | \$ 76,020   | \$ 76,020   | \$ 76,020   |
| OPERATOR COST     | \$ 79,875   | \$ 83,070   | \$ 86,393   | \$ 89,849   | \$ 93,443   | \$ 97,181   | \$ 101,068  | \$ 105,111  | \$ 109,315  | \$ 113,688  |
| SELLING ADMIN     | \$ 50,000   | \$ 50,000   | \$ 25,000   | \$ 25,000   | \$ 25,000   | \$ 25,000   | \$ 25,000   | \$ 25,000   | \$ 25,000   | \$ 25,000   |
| INSURANCE         | \$ 30,000   | \$ 30,000   | \$ 30,000   | \$ 30,000   | \$ 30,000   | \$ 30,000   | \$ 30,000   | \$ 30,000   | \$ 30,000   | \$ 30,000   |
| TOTAL ANNUAL COST | \$1,022,427 | \$1,025,622 | \$1,003,945 | \$1,007,401 | \$1,016,377 | \$1,025,604 | \$1,035,091 | \$1,044,847 | \$1,054,876 | \$1,065,193 |

COST PER MILLION BTUS

|                      |         |         |         |         |         |         |         |         |         |         |
|----------------------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|
| DEBT SERVICE         | \$ 8.23 | \$ 8.23 | \$ 8.23 | \$ 8.23 | \$ 8.23 | \$ 8.23 | \$ 8.23 | \$ 8.23 | \$ 8.23 | \$ 8.23 |
| ENERGY COST          | \$ 4.31 | \$ 4.31 | \$ 4.31 | \$ 4.31 | \$ 4.39 | \$ 4.48 | \$ 4.57 | \$ 4.66 | \$ 4.75 | \$ 4.85 |
| FIXED OPERATING COST | \$ 3.83 | \$ 3.88 | \$ 3.53 | \$ 3.59 | \$ 3.64 | \$ 3.70 | \$ 3.77 | \$ 3.83 | \$ 3.90 | \$ 3.97 |
| TOTAL PER UNIT COST  | \$16.36 | \$16.41 | \$16.06 | \$16.12 | \$16.26 | \$16.41 | \$16.56 | \$16.72 | \$16.88 | \$17.04 |

TABLE 6

SIZE OPTION 1  
1,250,000 SQ. FT.

LINCOLN DISTRICT HEATING SYSTEM  
INCOME STATEMENT  
LEVERAGED LEASE CASE

DATE: 10/10/86

LESSEE OPERATING STATEMENT:

|                     | 1987        | 1988        | 1989        | 1990        | 1991        | 1992        | 1993        | 1994        | 1995        | 1996        |
|---------------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|
| SALES               | \$1,022,427 | \$1,025,622 | \$1,003,945 | \$1,007,401 | \$1,016,377 | \$1,025,604 | \$1,035,091 | \$1,044,847 | \$1,054,976 | \$1,065,193 |
| VARIABLE COST:      |             |             |             |             |             |             |             |             |             |             |
| ENERGY COST         | \$ 269,122  | \$ 269,122  | \$ 269,122  | \$ 269,122  | \$ 274,504  | \$ 279,993  | \$ 285,593  | \$ 291,306  | \$ 297,131  | \$ 303,075  |
| CONTRIBUTION MARGIN | \$ 753,305  | \$ 756,500  | \$ 734,823  | \$ 738,279  | \$ 741,873  | \$ 745,611  | \$ 749,498  | \$ 753,541  | \$ 757,745  | \$ 762,118  |
| FIXED COSTS:        |             |             |             |             |             |             |             |             |             |             |
| LEASE PAYMENT       | \$ 514,170  | \$ 514,170  | \$ 514,170  | \$ 514,170  | \$ 514,170  | \$ 514,170  | \$ 514,170  | \$ 514,170  | \$ 514,170  | \$ 514,170  |
| MAINTENANCE COST    | \$ 76,020   | \$ 76,020   | \$ 76,020   | \$ 76,020   | \$ 76,020   | \$ 76,020   | \$ 76,020   | \$ 76,020   | \$ 76,020   | \$ 76,020   |
| OPERATOR COST       | \$ 79,875   | \$ 83,070   | \$ 86,393   | \$ 89,849   | \$ 93,443   | \$ 97,181   | \$ 101,068  | \$ 105,111  | \$ 109,315  | \$ 113,688  |
| SELLING & ADMIN.    | \$ 50,000   | \$ 50,000   | \$ 25,000   | \$ 25,000   | \$ 25,000   | \$ 25,000   | \$ 25,000   | \$ 25,000   | \$ 25,000   | \$ 25,000   |
| INSURANCE           | \$ 30,000   | \$ 30,000   | \$ 30,000   | \$ 30,000   | \$ 30,000   | \$ 30,000   | \$ 30,000   | \$ 30,000   | \$ 30,000   | \$ 30,000   |
| CUSTOMER CHARGE     | \$ 3,240    | \$ 3,240    | \$ 3,240    | \$ 3,240    | \$ 3,240    | \$ 3,240    | \$ 3,240    | \$ 3,240    | \$ 3,240    | \$ 3,240    |
| TOTAL FIXED COSTS   | \$ 753,305  | \$ 756,500  | \$ 734,823  | \$ 738,279  | \$ 741,873  | \$ 745,611  | \$ 749,498  | \$ 753,541  | \$ 757,745  | \$ 762,118  |
| OPERATING INCOME    | \$ 0        | \$ 0        | \$ 0        | \$ 0        | \$ 0        | \$ 0        | \$ 0        | \$ 0        | \$ 0        | \$ 0        |

LESSOR STATEMENT:

|                        |            |            |            |            |            |            |            |            |            |            |
|------------------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|
| DEBT PAYMENT           | \$ 423,065 | \$ 423,065 | \$ 423,065 | \$ 423,065 | \$ 423,065 | \$ 423,065 | \$ 423,065 | \$ 423,065 | \$ 423,065 | \$ 423,065 |
| EQUITY PAYMENT         | \$ 91,105  | \$ 91,105  | \$ 91,105  | \$ 91,105  | \$ 91,105  | \$ 91,105  | \$ 91,105  | \$ 91,105  | \$ 91,105  | \$ 91,105  |
| TOTAL DEBT SERVICE     | \$ 514,170 | \$ 514,170 | \$ 514,170 | \$ 514,170 | \$ 514,170 | \$ 514,170 | \$ 514,170 | \$ 514,170 | \$ 514,170 | \$ 514,170 |
| NET BENEFIT TO LESSOR: |            |            |            |            |            |            |            |            |            |            |
| INVESTMENT TAX CREDIT  | \$ 0       | \$ 0       | \$ 0       | \$ 0       | \$ 0       | \$ 0       | \$ 0       | \$ 0       | \$ 0       | \$ 0       |
| TAX VALUE DEPRECIATION | \$ 38,969  | \$ 38,969  | \$ 38,969  | \$ 38,969  | \$ 38,969  | \$ 38,969  | \$ 38,969  | \$ 38,969  | \$ 38,969  | \$ 38,969  |
| GAIN IN EQUITY         | \$ 21,371  | \$ 23,750  | \$ 26,396  | \$ 29,336  | \$ 32,606  | \$ 36,241  | \$ 40,282  | \$ 44,776  | \$ 49,772  | \$ 55,328  |
| EFFECTIVE NET INCOME   | \$ 60,340  | \$ 62,719  | \$ 65,365  | \$ 68,305  | \$ 71,575  | \$ 75,210  | \$ 79,251  | \$ 83,745  | \$ 88,741  | \$ 94,297  |
|                        | =====      | =====      | =====      | =====      | =====      | =====      | =====      | =====      | =====      | =====      |

|                            |             |
|----------------------------|-------------|
| TOTAL INVESTMENT           | \$4,294,173 |
| EQUITY PORTION             | \$ 858,835  |
| DEBT PORTION               | \$3,435,338 |
| POINTS COST                | \$ 103,061  |
| FIRST YEAR DEPR.           | \$ 114,613  |
| TOTAL MMBTU'S SOLD         | 62,500      |
| INTEREST ON DEBT           | .12         |
| RETURN ON EQUITY           | .10         |
| INVESTMENT TAX CREDIT      | .00         |
| INCOME TAX RATE            | .34         |
| STRAIGHT LINE DEPRECIATION |             |

TABLE 7



# Sensitivity of Energy Cost to Equipment Cost Option 1 - 1,250,000 Sq. Ft.

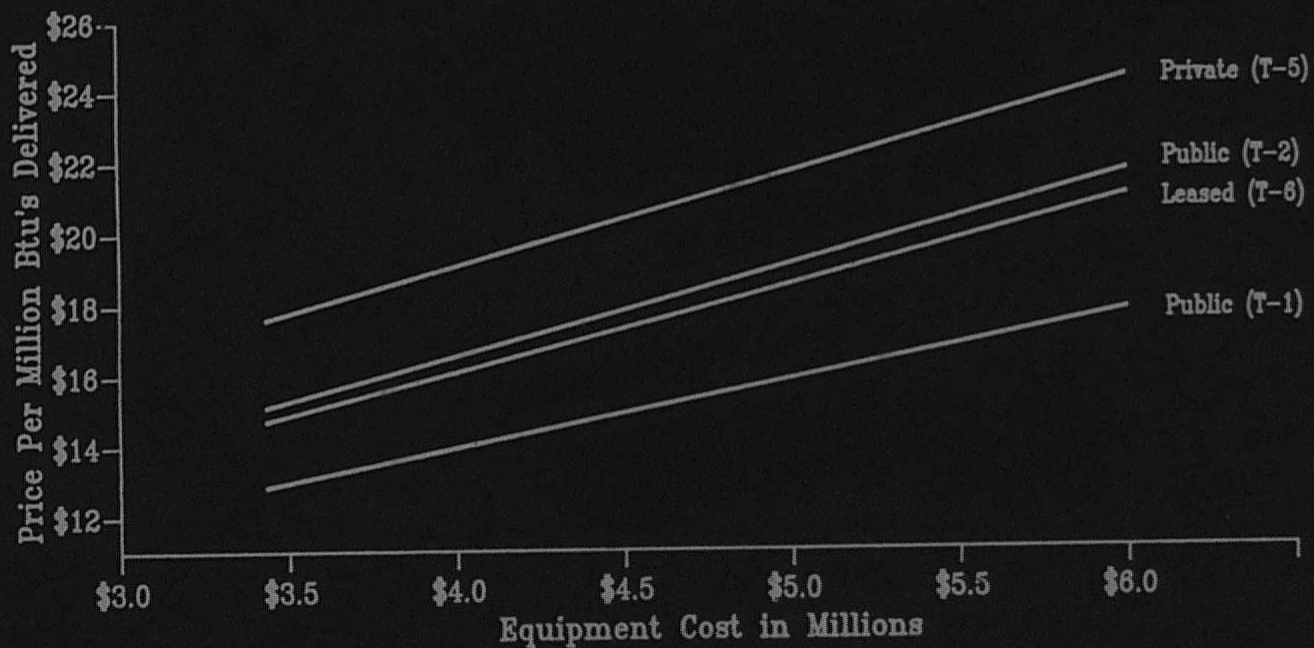


TABLE 8

# Sensitivity of Energy Cost to Thermal Energy Delivered Option 1 - 1,250,000 Sq. Ft.

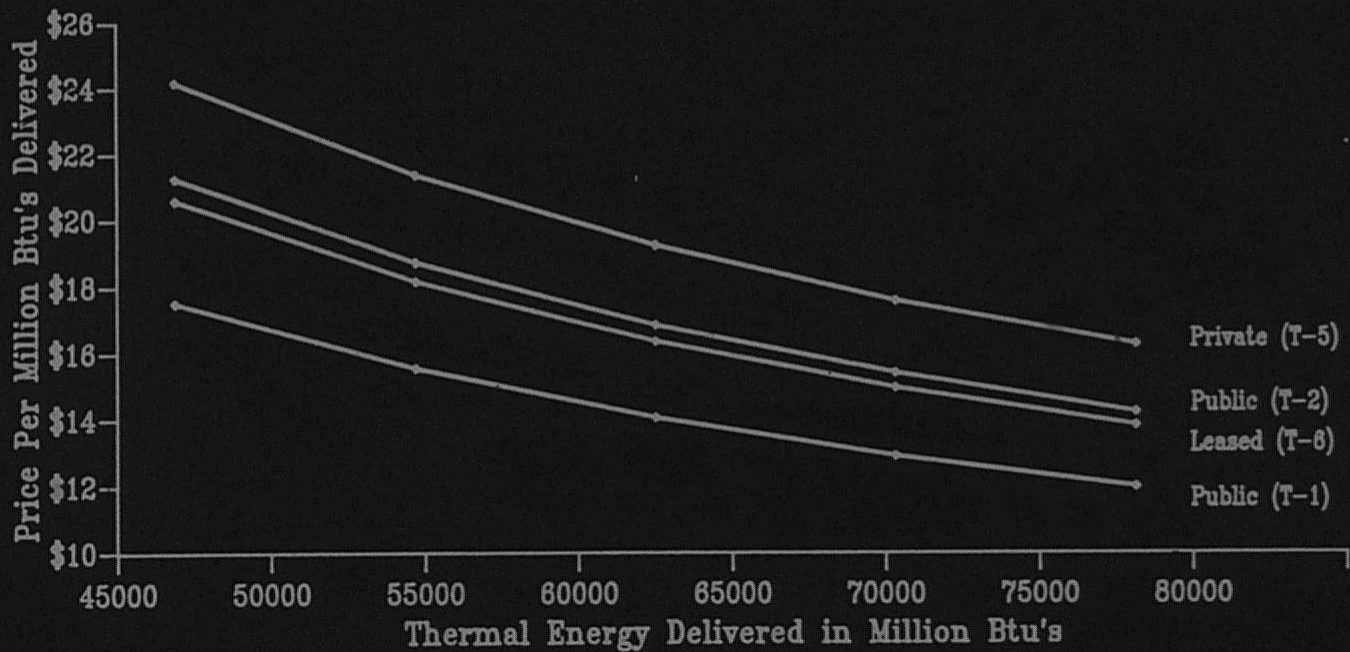


TABLE 9

1,875,000 SQ. FT.

LINCOLN DISTRICT HEATING SYSTEM  
CAPITAL AND OPERATING COST  
PUBLIC CASE

\*\*\* ASSUMPTIONS \*\*\*

TOTAL MMBTUS PRODUCED 93,750  
COOLING ENERGY OUTPUT 37,500  
HEATING ENERGY OUTPUT 56,250  
HEAT PUMP COST 1,100,000  
PROJECT LIFE 30  
FINANCED PORTION 5,276,514  
SALVAGE VALUE 50,000  
COOLING COP 4.800  
HEATING COP 2.400  
HEATING RATE .030  
COOLING RATE .060  
FINANCED INTEREST RATE .075  
DATE GENERATED: 10/01/86

ANNUAL COSTS

|                        | 1987        | 1988        | 1989        | 1990        | 1991        | 1992        | 1993        | 1994        | 1995        | 1996        |
|------------------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|
| PUMPING COST           | \$ 86,356   | \$ 86,356   | \$ 86,356   | \$ 86,356   | \$ 88,083   | \$ 89,845   | \$ 91,642   | \$ 93,475   | \$ 95,344   | \$ 97,251   |
| PLANT ENERGY COST      | \$ 343,357  | \$ 343,357  | \$ 343,357  | \$ 343,357  | \$ 350,224  | \$ 357,228  | \$ 364,373  | \$ 371,660  | \$ 379,094  | \$ 386,675  |
| CUSTOMER CHARGE        | \$ 3,240    | \$ 3,240    | \$ 3,240    | \$ 3,240    | \$ 3,240    | \$ 3,240    | \$ 3,240    | \$ 3,240    | \$ 3,240    | \$ 3,240    |
| MAINTENANCE COST       | \$ 93,470   | \$ 93,470   | \$ 93,470   | \$ 93,470   | \$ 93,470   | \$ 93,470   | \$ 93,470   | \$ 93,470   | \$ 93,470   | \$ 93,470   |
| OPERATOR COST          | \$ 79,875   | \$ 83,070   | \$ 86,393   | \$ 89,849   | \$ 93,442   | \$ 97,180   | \$ 101,067  | \$ 105,110  | \$ 109,314  | \$ 113,687  |
| INSURANCE              | \$ 30,000   | \$ 30,000   | \$ 30,000   | \$ 30,000   | \$ 30,000   | \$ 30,000   | \$ 30,000   | \$ 30,000   | \$ 30,000   | \$ 30,000   |
| SELLING ADMIN          | \$ 50,000   | \$ 50,000   | \$ 25,000   | \$ 25,000   | \$ 25,000   | \$ 25,000   | \$ 25,000   | \$ 25,000   | \$ 25,000   | \$ 25,000   |
| O & M                  | \$ 686,298  | \$ 689,493  | \$ 667,816  | \$ 671,272  | \$ 683,459  | \$ 695,963  | \$ 708,792  | \$ 721,955  | \$ 735,462  | \$ 749,323  |
| DEBT SERVICE (7.5%)    | \$ 446,769  | \$ 446,769  | \$ 446,769  | \$ 446,769  | \$ 446,769  | \$ 446,769  | \$ 446,769  | \$ 446,769  | \$ 446,769  | \$ 446,769  |
| OPERATION+DEBT SERVICE | \$1,133,067 | \$1,136,262 | \$1,114,585 | \$1,118,041 | \$1,130,228 | \$1,142,732 | \$1,155,561 | \$1,168,724 | \$1,182,231 | \$1,196,092 |
| R&R (DEBT COVERAGE)    | \$ 8,936    | \$ 8,936    | \$ 8,936    | \$ 8,936    | \$ 8,936    | \$ 8,936    | \$ 8,936    | \$ 8,936    | \$ 8,936    | \$ 8,936    |
| TOTAL ANNUAL COST      | \$1,142,003 | \$1,145,198 | \$1,123,521 | \$1,126,977 | \$1,139,164 | \$1,151,668 | \$1,164,497 | \$1,177,660 | \$1,191,167 | \$1,205,028 |
| COST PER MILLION BTUS  |             |             |             |             |             |             |             |             |             |             |
| DEBT SERVICE           | \$ 4.77     | \$ 4.77     | \$ 4.77     | \$ 4.77     | \$ 4.77     | \$ 4.77     | \$ 4.77     | \$ 4.77     | \$ 4.77     | \$ 4.77     |
| ENERGY COST            | \$ 4.58     | \$ 4.58     | \$ 4.58     | \$ 4.58     | \$ 4.68     | \$ 4.77     | \$ 4.86     | \$ 4.96     | \$ 5.06     | \$ 5.16     |
| O & M                  | \$ 2.74     | \$ 2.77     | \$ 2.54     | \$ 2.58     | \$ 2.61     | \$ 2.65     | \$ 2.70     | \$ 2.74     | \$ 2.78     | \$ 2.83     |
| R&R (DEBT COVERAGE)    | \$ .10      | \$ .10      | \$ .10      | \$ .10      | \$ .10      | \$ .10      | \$ .10      | \$ .10      | \$ .10      | \$ .10      |
| TOTAL PER UNIT COST    | \$12.18     | \$12.22     | \$11.98     | \$12.02     | \$12.15     | \$12.28     | \$12.42     | \$12.56     | \$12.71     | \$12.85     |
| COOLING PORTION        | \$15.43     | \$15.47     | \$15.21     | \$15.25     | \$15.40     | \$15.55     | \$15.70     | \$15.85     | \$16.01     | \$16.18     |
| HEATING PORTION        | \$10.01     | \$10.05     | \$ 9.83     | \$ 9.87     | \$ 9.99     | \$10.11     | \$10.24     | \$10.37     | \$10.50     | \$10.64     |

TABLE 10

1,875,000 SQ. FT.

LINCOLN DISTRICT HEATING SYSTEM  
CAPITAL AND OPERATING COST  
PUBLIC CASE

\*\*\* ASSUMPTIONS \*\*\*

|                        |           |
|------------------------|-----------|
| TOTAL MMBTUS PRODUCED  | 93,750    |
| COOLING ENERGY OUTPUT  | 37,500    |
| HEATING ENERGY OUTPUT  | 56,250    |
| HEAT PUMP COST         | 1,100,000 |
| PROJECT LIFE           | 30        |
| FINANCED PORTION       | 5,276,514 |
| SALVAGE VALUE          | 50,000    |
| COOLING COP            | 4.800     |
| HEATING COP            | 2.400     |
| HEATING RATE           | .030      |
| COOLING RATE           | .060      |
| FINANCED INTEREST RATE | .075      |

DATE GENERATED: 10/01/86

ANNUAL COSTS

|                        | 1987        | 1988        | 1989        | 1990        | 1991        | 1992        | 1993        | 1994        | 1995        | 1996        |
|------------------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|
| PUMPING COST           | \$ 86,356   | \$ 86,356   | \$ 86,356   | \$ 86,356   | \$ 88,083   | \$ 89,845   | \$ 91,642   | \$ 93,475   | \$ 95,344   | \$ 97,251   |
| PLANT ENERGY COST      | \$ 343,357  | \$ 343,357  | \$ 343,357  | \$ 343,357  | \$ 350,224  | \$ 357,228  | \$ 364,373  | \$ 371,660  | \$ 379,094  | \$ 386,675  |
| CUSTOMER CHARGE        | \$ 3,240    | \$ 3,240    | \$ 3,240    | \$ 3,240    | \$ 3,240    | \$ 3,240    | \$ 3,240    | \$ 3,240    | \$ 3,240    | \$ 3,240    |
| MAINTENANCE COST       | \$ 93,470   | \$ 93,470   | \$ 93,470   | \$ 93,470   | \$ 93,470   | \$ 93,470   | \$ 93,470   | \$ 93,470   | \$ 93,470   | \$ 93,470   |
| OPERATOR COST          | \$ 79,875   | \$ 83,070   | \$ 86,393   | \$ 89,849   | \$ 93,442   | \$ 97,180   | \$ 101,067  | \$ 105,110  | \$ 109,314  | \$ 113,687  |
| INSURANCE              | \$ 30,000   | \$ 30,000   | \$ 30,000   | \$ 30,000   | \$ 30,000   | \$ 30,000   | \$ 30,000   | \$ 30,000   | \$ 30,000   | \$ 30,000   |
| SELLING ADMIN          | \$ 50,000   | \$ 50,000   | \$ 25,000   | \$ 25,000   | \$ 25,000   | \$ 25,000   | \$ 25,000   | \$ 25,000   | \$ 25,000   | \$ 25,000   |
| O & M                  | \$ 686,298  | \$ 689,493  | \$ 667,816  | \$ 671,272  | \$ 683,459  | \$ 695,963  | \$ 708,792  | \$ 721,955  | \$ 735,462  | \$ 749,323  |
| DEBT SERVICE (7.5%)    | \$ 446,769  | \$ 446,769  | \$ 446,769  | \$ 446,769  | \$ 446,769  | \$ 446,769  | \$ 446,769  | \$ 446,769  | \$ 446,769  | \$ 446,769  |
| OPERATION+DEBT SERVICE | \$1,133,067 | \$1,136,262 | \$1,114,585 | \$1,118,041 | \$1,130,228 | \$1,142,732 | \$1,155,561 | \$1,168,724 | \$1,182,231 | \$1,196,092 |
| R&R (DEBT COVERAGE)    | \$ 223,385  | \$ 223,385  | \$ 223,385  | \$ 223,385  | \$ 223,385  | \$ 223,385  | \$ 223,385  | \$ 223,385  | \$ 223,385  | \$ 223,385  |
| TOTAL ANNUAL COST      | \$1,356,452 | \$1,359,647 | \$1,337,970 | \$1,341,426 | \$1,353,613 | \$1,366,117 | \$1,378,946 | \$1,392,109 | \$1,405,616 | \$1,419,477 |
| COST PER MILLION BTUS  |             |             |             |             |             |             |             |             |             |             |
| DEBT SERVICE           | \$ 4.77     | \$ 4.77     | \$ 4.77     | \$ 4.77     | \$ 4.77     | \$ 4.77     | \$ 4.77     | \$ 4.77     | \$ 4.77     | \$ 4.77     |
| ENERGY COST            | \$ 4.58     | \$ 4.58     | \$ 4.58     | \$ 4.58     | \$ 4.68     | \$ 4.77     | \$ 4.86     | \$ 4.96     | \$ 5.06     | \$ 5.16     |
| O & M                  | \$ 2.74     | \$ 2.77     | \$ 2.54     | \$ 2.58     | \$ 2.61     | \$ 2.65     | \$ 2.70     | \$ 2.74     | \$ 2.78     | \$ 2.83     |
| R&R (DEBT COVERAGE)    | \$ 2.38     | \$ 2.38     | \$ 2.38     | \$ 2.38     | \$ 2.38     | \$ 2.38     | \$ 2.38     | \$ 2.38     | \$ 2.38     | \$ 2.38     |
| TOTAL PER UNIT COST    | \$14.47     | \$14.50     | \$14.27     | \$14.31     | \$14.44     | \$14.57     | \$14.71     | \$14.85     | \$14.99     | \$15.14     |
| COOLING PORTION        | \$18.86     | \$18.90     | \$18.64     | \$18.68     | \$18.83     | \$18.98     | \$19.13     | \$19.29     | \$19.45     | \$19.61     |
| HEATING PORTION        | \$11.54     | \$11.57     | \$11.36     | \$11.39     | \$11.51     | \$11.63     | \$11.76     | \$11.89     | \$12.02     | \$12.16     |

TABLE 11



CAPITAL COSTS SUMMARY  
 SIZE OPTION 2  
 -----

|                       |             |             |
|-----------------------|-------------|-------------|
| SOURCE PIPE           | \$ 440,000  |             |
| PIPE INSTALLATION     | \$ 220,000  |             |
| SOURCE PUMP STATION   | \$ 200,000  |             |
|                       | -----       |             |
| SOURCE SYSTEM COST    | \$ 860,000  |             |
| DISTRIBUTION PIPE     | \$1,031,000 |             |
| HEAT PUMP             | \$1,100,000 |             |
| CENTRAL PLANT BOILER  | \$ 250,000  |             |
| CENTRAL PLANT CHILLER | \$ 480,000  |             |
| LAND & BUILDING       | \$ 380,000  |             |
| PIPING & AUX.         | \$ 200,000  |             |
| STORAGE               | \$ 372,500  |             |
|                       | -----       |             |
| CENTRAL PLANT SYSTEM  | \$2,782,500 |             |
| TOTAL CAPITAL COST    |             | \$4,673,500 |
| TAXES                 | \$ 128,522  |             |
| A&G                   | \$ 0        |             |
| ENGINEERING           | \$ 240,102  |             |
| CONTINGENCY           | \$ 240,102  |             |
| SALVAGE VALUE         | \$ -5,712   |             |
|                       | -----       |             |
| MISC                  |             | \$ 603,014  |
|                       |             | -----       |
| TOTAL INITIAL COST    |             | \$5,276,514 |
|                       |             | =====       |

DATE GENERATED: 10/01/86

TABLE 12



SIZE OF PLANT  
1,875,000 SQ. FT.

LINCOLN DISTRICT HEATING SYSTEM  
CAPITAL AND OPERATING COST  
PRIVATE OWNERSHIP

DATE: 10/10/86

\*\*\* ASSUMPTIONS \*\*\*

TOTAL MMBTUS PRODUCED 93,750  
COOLING ENERGY OUTPUT 37,500  
HEATING ENERGY OUTPUT 56,250  
HEAT PUMP COST 1,100,000  
YEARS AMORTIZED OVER 30  
SALVAGE VALUE 50,000  
COOLING COP 4.800  
HEATING COP 2.400  
HEATING RATE .030  
COOLING RATE .060  
INTEREST RATE .115

ANNUAL COSTS

|                       | 1987        | 1988        | 1989        | 1990        | 1991        | 1992        | 1993        | 1994        | 1995        | 1996        |
|-----------------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|
| DEBT SERVICE          | \$ 520,222  | \$ 520,222  | \$ 520,222  | \$ 520,222  | \$ 520,222  | \$ 520,222  | \$ 520,222  | \$ 520,222  | \$ 520,222  | \$ 520,222  |
| PUMPING COST          | \$ 86,356   | \$ 86,356   | \$ 86,356   | \$ 86,356   | \$ 88,083   | \$ 89,845   | \$ 91,642   | \$ 93,475   | \$ 95,344   | \$ 97,251   |
| PLANT ENERGY COST     | \$ 343,357  | \$ 343,357  | \$ 343,357  | \$ 343,357  | \$ 350,224  | \$ 357,228  | \$ 364,373  | \$ 371,660  | \$ 379,094  | \$ 386,675  |
| CUSTOMER CHARGE       | \$ 3,240    | \$ 3,240    | \$ 3,240    | \$ 3,240    | \$ 3,240    | \$ 3,240    | \$ 3,240    | \$ 3,240    | \$ 3,240    | \$ 3,240    |
| MAINTENANCE COST      | \$ 93,470   | \$ 93,470   | \$ 93,470   | \$ 93,470   | \$ 93,470   | \$ 93,470   | \$ 93,470   | \$ 93,470   | \$ 93,470   | \$ 93,470   |
| OPERATOR COST         | \$ 79,875   | \$ 83,070   | \$ 86,393   | \$ 89,849   | \$ 93,443   | \$ 97,181   | \$ 101,068  | \$ 105,111  | \$ 109,315  | \$ 113,688  |
| SELLING ADMIN         | \$ 50,000   | \$ 50,000   | \$ 25,000   | \$ 25,000   | \$ 25,000   | \$ 25,000   | \$ 25,000   | \$ 25,000   | \$ 25,000   | \$ 25,000   |
| INSURANCE             | \$ 30,000   | \$ 30,000   | \$ 30,000   | \$ 30,000   | \$ 30,000   | \$ 30,000   | \$ 30,000   | \$ 30,000   | \$ 30,000   | \$ 30,000   |
| REPLACEMENT & RENEWAL | \$ 93,470   | \$ 93,470   | \$ 93,470   | \$ 93,470   | \$ 93,470   | \$ 93,470   | \$ 93,470   | \$ 93,470   | \$ 93,470   | \$ 93,470   |
| TOTAL ANNUAL COST     | \$1,299,990 | \$1,303,185 | \$1,281,508 | \$1,284,964 | \$1,297,152 | \$1,309,656 | \$1,322,485 | \$1,335,648 | \$1,349,155 | \$1,363,016 |

COST PER MILLION BTUS

|                      |         |         |         |         |         |         |         |         |         |         |
|----------------------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|
| DEBT SERVICE         | \$ 5.55 | \$ 5.55 | \$ 5.55 | \$ 5.55 | \$ 5.55 | \$ 5.55 | \$ 5.55 | \$ 5.55 | \$ 5.55 | \$ 5.55 |
| ENERGY COST          | \$ 4.58 | \$ 4.58 | \$ 4.58 | \$ 4.58 | \$ 4.68 | \$ 4.77 | \$ 4.86 | \$ 4.96 | \$ 5.06 | \$ 5.16 |
| FIXED OPERATING COST | \$ 3.73 | \$ 3.77 | \$ 3.54 | \$ 3.57 | \$ 3.61 | \$ 3.65 | \$ 3.69 | \$ 3.74 | \$ 3.78 | \$ 3.83 |
| TOTAL PER UNIT COST  | \$13.87 | \$13.90 | \$13.67 | \$13.71 | \$13.84 | \$13.97 | \$14.11 | \$14.25 | \$14.39 | \$14.54 |

TABLE 13

SIZE OF PLANT  
1,375,000 SQ. FT.

LINCOLN DISTRICT HEATING SYSTEM  
INCOME STATEMENT  
PRIVATE CASE

DATE: 10/10/86

|                            | 1987        | 1988        | 1989        | 1990        | 1991        | 1992        | 1993        | 1994        | 1995        | 1996        |
|----------------------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|
| SALES                      | \$1,550,889 | \$1,554,700 | \$1,518,587 | \$1,522,683 | \$1,537,126 | \$1,551,943 | \$1,534,083 | \$1,549,352 | \$1,565,020 | \$1,553,839 |
| VARIABLE COST:             |             |             |             |             |             |             |             |             |             |             |
| ENERGY COST                | \$ 429,713  | \$ 429,713  | \$ 429,713  | \$ 429,713  | \$ 438,307  | \$ 447,073  | \$ 456,015  | \$ 465,135  | \$ 474,438  | \$ 483,926  |
| CONTRIBUTION MARGIN        | \$1,121,176 | \$1,124,987 | \$1,088,874 | \$1,092,970 | \$1,098,819 | \$1,104,870 | \$1,078,068 | \$1,084,217 | \$1,090,582 | \$1,069,913 |
| FIXED COSTS:               |             |             |             |             |             |             |             |             |             |             |
| DEBT SERVICE               | \$ 520,222  | \$ 520,222  | \$ 520,222  | \$ 520,222  | \$ 520,222  | \$ 520,222  | \$ 520,222  | \$ 520,222  | \$ 520,222  | \$ 520,222  |
| MAINTENANCE COST           | \$ 93,470   | \$ 93,470   | \$ 93,470   | \$ 93,470   | \$ 93,470   | \$ 93,470   | \$ 93,470   | \$ 93,470   | \$ 93,470   | \$ 93,470   |
| OPERATOR COST              | \$ 79,875   | \$ 83,070   | \$ 86,393   | \$ 89,849   | \$ 93,443   | \$ 97,181   | \$ 101,068  | \$ 105,111  | \$ 109,315  | \$ 113,688  |
| REPLACEMENT RENEWAL        | \$ 93,470   | \$ 93,470   | \$ 93,470   | \$ 93,470   | \$ 93,470   | \$ 93,470   | \$ 93,470   | \$ 93,470   | \$ 93,470   | \$ 93,470   |
| SELLING & ADMIN.           | \$ 50,000   | \$ 50,000   | \$ 25,000   | \$ 25,000   | \$ 25,000   | \$ 25,000   | \$ 25,000   | \$ 25,000   | \$ 25,000   | \$ 25,000   |
| INSURANCE                  | \$ 30,000   | \$ 30,000   | \$ 30,000   | \$ 30,000   | \$ 30,000   | \$ 30,000   | \$ 30,000   | \$ 30,000   | \$ 30,000   | \$ 30,000   |
| CUSTOMER CHARGE            | \$ 3,240    | \$ 3,240    | \$ 3,240    | \$ 3,240    | \$ 3,240    | \$ 3,240    | \$ 3,240    | \$ 3,240    | \$ 3,240    | \$ 3,240    |
| TOTAL FIXED COSTS          | \$ 870,277  | \$ 873,472  | \$ 851,795  | \$ 855,251  | \$ 858,845  | \$ 862,583  | \$ 866,470  | \$ 870,513  | \$ 874,717  | \$ 879,090  |
| OPERATING INCOME           | \$ 250,899  | \$ 251,515  | \$ 237,079  | \$ 237,719  | \$ 239,974  | \$ 242,287  | \$ 211,598  | \$ 213,704  | \$ 215,865  | \$ 190,823  |
| LESS:                      |             |             |             |             |             |             |             |             |             |             |
| DEPRECIATION               | \$ 141,699  | \$ 141,699  | \$ 141,699  | \$ 141,699  | \$ 141,699  | \$ 141,699  | \$ 141,699  | \$ 141,699  | \$ 141,699  | \$ 141,699  |
| TAXABLE INCOME             | \$ 109,200  | \$ 109,816  | \$ 95,380   | \$ 96,020   | \$ 98,275   | \$ 100,588  | \$ 69,899   | \$ 72,005   | \$ 74,166   | \$ 49,124   |
| INCOME TAX                 | \$ 37,128   | \$ 37,337   | \$ 32,429   | \$ 32,647   | \$ 33,414   | \$ 34,200   | \$ 23,766   | \$ 24,482   | \$ 25,216   | \$ 16,702   |
| NET INCOME                 | \$ 72,072   | \$ 72,479   | \$ 62,951   | \$ 63,373   | \$ 64,862   | \$ 66,388   | \$ 46,133   | \$ 47,523   | \$ 48,950   | \$ 32,422   |
| POSITIVE NET INCOME        | \$ 72,072   | \$ 72,479   | \$ 62,951   | \$ 63,373   | \$ 64,862   | \$ 66,388   | \$ 46,133   | \$ 47,523   | \$ 48,950   | \$ 32,422   |
| INVESTMENT TAX CREDIT      | \$ 0        | \$ 0        | \$ 0        | \$ 0        | \$ 0        | \$ 0        | \$ 0        | \$ 0        | \$ 0        | \$ 0        |
| TAX VALUE DEPR             | \$ 48,178   | \$ 48,178   | \$ 48,178   | \$ 48,178   | \$ 48,178   | \$ 48,178   | \$ 48,178   | \$ 48,178   | \$ 48,178   | \$ 48,178   |
| EQUITY                     | \$ 19,858   | \$ 22,142   | \$ 24,688   | \$ 27,527   | \$ 30,693   | \$ 34,223   | \$ 38,158   | \$ 42,547   | \$ 47,440   | \$ 52,895   |
| EFFECTIVE NET INCOME       | \$ 140,108  | \$ 142,799  | \$ 135,817  | \$ 139,079  | \$ 143,733  | \$ 148,789  | \$ 132,470  | \$ 138,248  | \$ 144,567  | \$ 133,495  |
| RATE OF RETURN             | .133        | .135        | .129        | .132        | .136        | .141        | .125        | .131        | .137        | .126        |
| SELLING PRICE              | \$16.54     |             |             |             |             |             |             |             |             |             |
| TOTAL INVESTMENT           | \$5,280,317 |             |             |             |             |             |             |             |             |             |
| CAPITAL PORTION            | \$1,056,064 |             |             |             |             |             |             |             |             |             |
| FINANCED PORTION           | \$4,224,253 |             |             |             |             |             |             |             |             |             |
| POINTS COST                | \$ 126,728  |             |             |             |             |             |             |             |             |             |
| FIRST YEAR DEPR.           | \$ 141,699  |             |             |             |             |             |             |             |             |             |
| TOTAL MMBTU'S SOLD         | 93,750      |             |             |             |             |             |             |             |             |             |
| PERCENTAGE MARKUP          | .19         |             |             |             |             |             |             |             |             |             |
| INVESTMENT TAX CREDIT      | .00         |             |             |             |             |             |             |             |             |             |
| INCOME TAX RATE            | .34         |             |             |             |             |             |             |             |             |             |
| STRAIGHT LINE DEPRECIATION |             |             |             |             |             |             |             |             |             |             |

TABLE 14

SIZE OPTION 2  
1,875,000 SQ. FT.

LINCOLN DISTRICT HEATING SYSTEM  
CAPITAL AND OPERATING COST  
LEVERAGED LEASE CASE

DATE: 10/10/86

\*\*\* ASSUMPTIONS \*\*\*

|                       |           |
|-----------------------|-----------|
| TOTAL MMBTUS PRODUCED | 93,750    |
| COOLING ENERGY OUTPUT | 37,500    |
| HEATING ENERGY OUTPUT | 56,250    |
| HEAT PUMP COST        | 1,100,000 |
| YEARS AMORTIZED OVER  | 30        |
| COOLING COP           | 4.800     |
| HEATING COP           | 2.400     |
| HEATING RATE          | .030      |
| COOLING RATE          | .060      |
| DEBT INTEREST RATE    | .115      |
| RETURN ON EQUITY      | .100      |

ANNUAL COSTS

|                   | 1987        | 1988        | 1989        | 1990        | 1991        | 1992        | 1993        | 1994        | 1995        | 1996        |
|-------------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|
| DEBT SERVICE      | \$ 632,248  | \$ 632,248  | \$ 632,248  | \$ 632,248  | \$ 632,248  | \$ 632,248  | \$ 632,248  | \$ 632,248  | \$ 632,248  | \$ 632,248  |
| PUMPING COST      | \$ 86,356   | \$ 86,356   | \$ 86,356   | \$ 86,356   | \$ 88,083   | \$ 89,845   | \$ 91,642   | \$ 93,475   | \$ 95,344   | \$ 97,251   |
| PLANT ENERGY COST | \$ 343,357  | \$ 343,357  | \$ 343,357  | \$ 343,357  | \$ 350,224  | \$ 357,228  | \$ 364,373  | \$ 371,660  | \$ 379,094  | \$ 386,675  |
| CUSTOMER CHARGE   | \$ 3,240    | \$ 3,240    | \$ 3,240    | \$ 3,240    | \$ 3,240    | \$ 3,240    | \$ 3,240    | \$ 3,240    | \$ 3,240    | \$ 3,240    |
| MAINTENANCE COST  | \$ 93,470   | \$ 93,470   | \$ 93,470   | \$ 93,470   | \$ 93,470   | \$ 93,470   | \$ 93,470   | \$ 93,470   | \$ 93,470   | \$ 93,470   |
| OPERATOR COST     | \$ 79,875   | \$ 83,070   | \$ 86,393   | \$ 89,849   | \$ 93,443   | \$ 97,181   | \$ 101,068  | \$ 105,111  | \$ 109,315  | \$ 113,688  |
| SELLING ADMIN     | \$ 50,000   | \$ 50,000   | \$ 25,000   | \$ 25,000   | \$ 25,000   | \$ 25,000   | \$ 25,000   | \$ 25,000   | \$ 25,000   | \$ 25,000   |
| INSURANCE         | \$ 30,000   | \$ 30,000   | \$ 30,000   | \$ 30,000   | \$ 30,000   | \$ 30,000   | \$ 30,000   | \$ 30,000   | \$ 30,000   | \$ 30,000   |
| TOTAL ANNUAL COST | \$1,318,546 | \$1,321,741 | \$1,300,064 | \$1,303,520 | \$1,315,708 | \$1,328,212 | \$1,341,041 | \$1,354,204 | \$1,367,711 | \$1,381,572 |

COST PER MILLION BTUS

|                      |         |         |         |         |         |         |         |         |         |         |
|----------------------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|
| DEBT SERVICE         | \$ 6.74 | \$ 6.74 | \$ 6.74 | \$ 6.74 | \$ 6.74 | \$ 6.74 | \$ 6.74 | \$ 6.74 | \$ 6.74 | \$ 6.74 |
| ENERGY COST          | \$ 4.58 | \$ 4.58 | \$ 4.58 | \$ 4.58 | \$ 4.68 | \$ 4.77 | \$ 4.86 | \$ 4.96 | \$ 5.06 | \$ 5.16 |
| FIXED OPERATING COST | \$ 2.74 | \$ 2.77 | \$ 2.54 | \$ 2.58 | \$ 2.61 | \$ 2.65 | \$ 2.70 | \$ 2.74 | \$ 2.78 | \$ 2.83 |
| TOTAL PER UNIT COST  | \$14.06 | \$14.10 | \$13.87 | \$13.90 | \$14.03 | \$14.17 | \$14.30 | \$14.44 | \$14.59 | \$14.74 |

TABLE 15



1,875,000 SQ. FT.

LINCOLN DISTRICT HEATING SYSTEM  
INCOME STATEMENT  
LEVERAGED LEASE CASE

DATE: 10/10/86

LESSEE OPERATING STATEMENT:

|                     | 1987        | 1988        | 1989        | 1990        | 1991        | 1992        | 1993        | 1994        | 1995        | 1996        |
|---------------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|
| SALES               | \$1,318,546 | \$1,321,741 | \$1,300,064 | \$1,303,520 | \$1,315,708 | \$1,328,212 | \$1,341,041 | \$1,354,204 | \$1,367,711 | \$1,381,572 |
| VARIABLE COST:      |             |             |             |             |             |             |             |             |             |             |
| ENERGY COST         | \$ 429,713  | \$ 429,713  | \$ 429,713  | \$ 429,713  | \$ 438,307  | \$ 447,073  | \$ 456,015  | \$ 465,135  | \$ 474,438  | \$ 483,926  |
| CONTRIBUTION MARGIN | \$ 888,833  | \$ 892,028  | \$ 870,351  | \$ 873,807  | \$ 877,401  | \$ 881,139  | \$ 885,026  | \$ 889,069  | \$ 893,273  | \$ 897,646  |
| FIXED COSTS:        |             |             |             |             |             |             |             |             |             |             |
| LEASE PAYMENT       | \$ 632,248  | \$ 632,248  | \$ 632,248  | \$ 632,248  | \$ 632,248  | \$ 632,248  | \$ 632,248  | \$ 632,248  | \$ 632,248  | \$ 632,248  |
| MAINTENANCE COST    | \$ 93,470   | \$ 93,470   | \$ 93,470   | \$ 93,470   | \$ 93,470   | \$ 93,470   | \$ 93,470   | \$ 93,470   | \$ 93,470   | \$ 93,470   |
| OPERATOR COST       | \$ 79,875   | \$ 83,070   | \$ 86,393   | \$ 89,849   | \$ 93,443   | \$ 97,181   | \$ 101,068  | \$ 105,111  | \$ 109,315  | \$ 113,688  |
| SELLING & ADMIN.    | \$ 50,000   | \$ 50,000   | \$ 25,000   | \$ 25,000   | \$ 25,000   | \$ 25,000   | \$ 25,000   | \$ 25,000   | \$ 25,000   | \$ 25,000   |
| INSURANCE           | \$ 30,000   | \$ 30,000   | \$ 30,000   | \$ 30,000   | \$ 30,000   | \$ 30,000   | \$ 30,000   | \$ 30,000   | \$ 30,000   | \$ 30,000   |
| CUSTOMER CHARGE     | \$ 3,240    | \$ 3,240    | \$ 3,240    | \$ 3,240    | \$ 3,240    | \$ 3,240    | \$ 3,240    | \$ 3,240    | \$ 3,240    | \$ 3,240    |
| TOTAL FIXED COSTS   | \$ 888,833  | \$ 892,028  | \$ 870,351  | \$ 873,807  | \$ 877,401  | \$ 881,139  | \$ 885,026  | \$ 889,069  | \$ 893,273  | \$ 897,646  |
| OPERATING INCOME    | \$ 0        | \$ 0        | \$ 0        | \$ 0        | \$ 0        | \$ 0        | \$ 0        | \$ 0        | \$ 0        | \$ 0        |

LESSOR STATEMENT:

|                        |            |            |            |            |            |            |            |            |            |            |
|------------------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|
| DEBT PAYMENT           | \$ 520,221 | \$ 520,221 | \$ 520,221 | \$ 520,221 | \$ 520,221 | \$ 520,221 | \$ 520,221 | \$ 520,221 | \$ 520,221 | \$ 520,221 |
| EQUITY PAYMENT         | \$ 112,026 | \$ 112,026 | \$ 112,026 | \$ 112,026 | \$ 112,026 | \$ 112,026 | \$ 112,026 | \$ 112,026 | \$ 112,026 | \$ 112,026 |
| TOTAL DEBT SERVICE     | \$ 632,248 | \$ 632,248 | \$ 632,248 | \$ 632,248 | \$ 632,248 | \$ 632,248 | \$ 632,248 | \$ 632,248 | \$ 632,248 | \$ 632,248 |
| NET BENEFIT TO LESSOR: |            |            |            |            |            |            |            |            |            |            |
| INVESTMENT TAX CREDIT  | \$ 0       | \$ 0       | \$ 0       | \$ 0       | \$ 0       | \$ 0       | \$ 0       | \$ 0       | \$ 0       | \$ 0       |
| TAX VALUE DEPRECIATION | \$ 48,178  | \$ 48,178  | \$ 48,178  | \$ 48,178  | \$ 48,178  | \$ 48,178  | \$ 48,178  | \$ 48,178  | \$ 48,178  | \$ 48,178  |
| GAIN IN EQUITY         | \$ 26,279  | \$ 29,205  | \$ 32,457  | \$ 36,073  | \$ 40,093  | \$ 44,563  | \$ 49,533  | \$ 55,058  | \$ 61,202  | \$ 68,034  |
| EFFECTIVE NET INCOME   | \$ 74,457  | \$ 77,383  | \$ 80,635  | \$ 84,251  | \$ 88,271  | \$ 92,741  | \$ 97,711  | \$ 103,236 | \$ 109,380 | \$ 116,212 |

|                            |             |
|----------------------------|-------------|
| TOTAL INVESTMENT           | \$5,280,317 |
| EQUITY PORTION             | \$1,056,064 |
| DEBT PORTION               | \$4,224,253 |
| POINTS COST                | \$ 126,728  |
| FIRST YEAR DEPR.           | \$ 141,699  |
| TOTAL MMBTU'S SOLD         | 93,750      |
| INTEREST ON DEBT           | .12         |
| RETURN ON EQUITY           | .10         |
| INVESTMENT TAX CREDIT      | .00         |
| INCOME TAX RATE            | .34         |
| STRAIGHT LINE DEPRECIATION |             |

TABLE 16



# Sensitivity of Energy Cost to Equipment Cost Option 2 - 1,875,000 Sq. Ft.

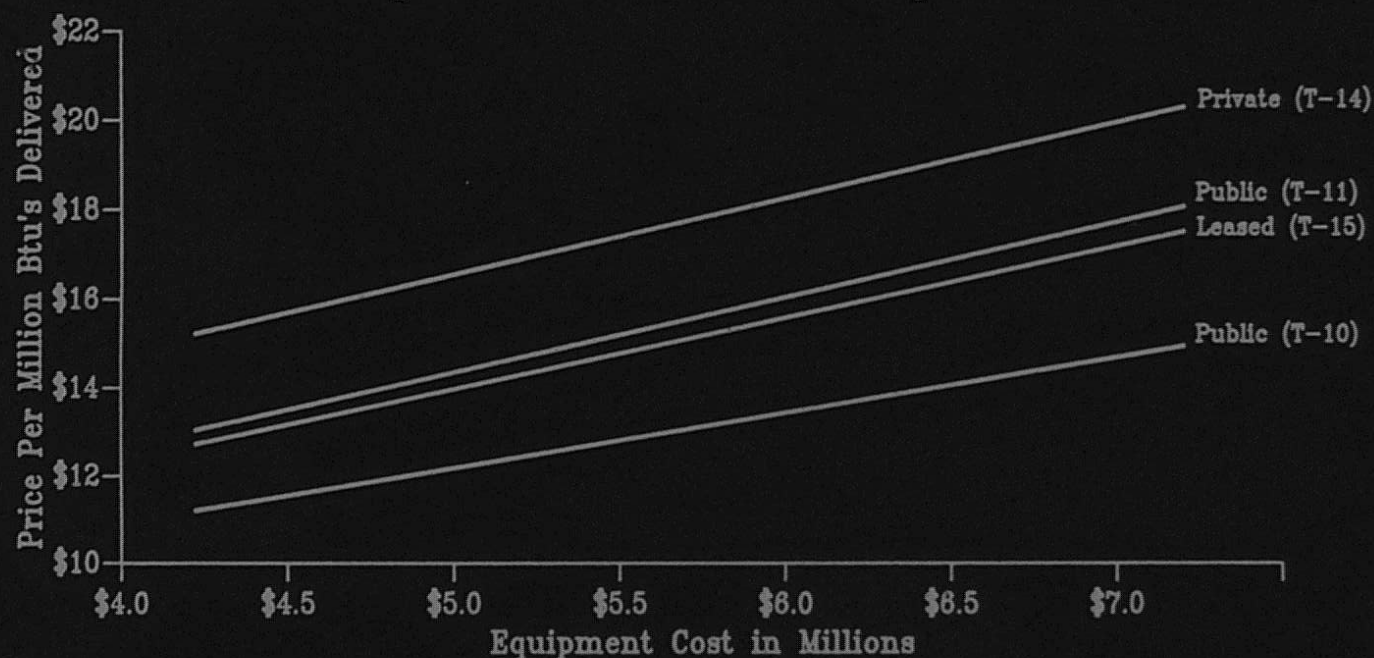


TABLE 17

# Sensitivity of Energy Cost to Thermal Energy Delivered Option 2 - 1,875,000 Sq. Ft.

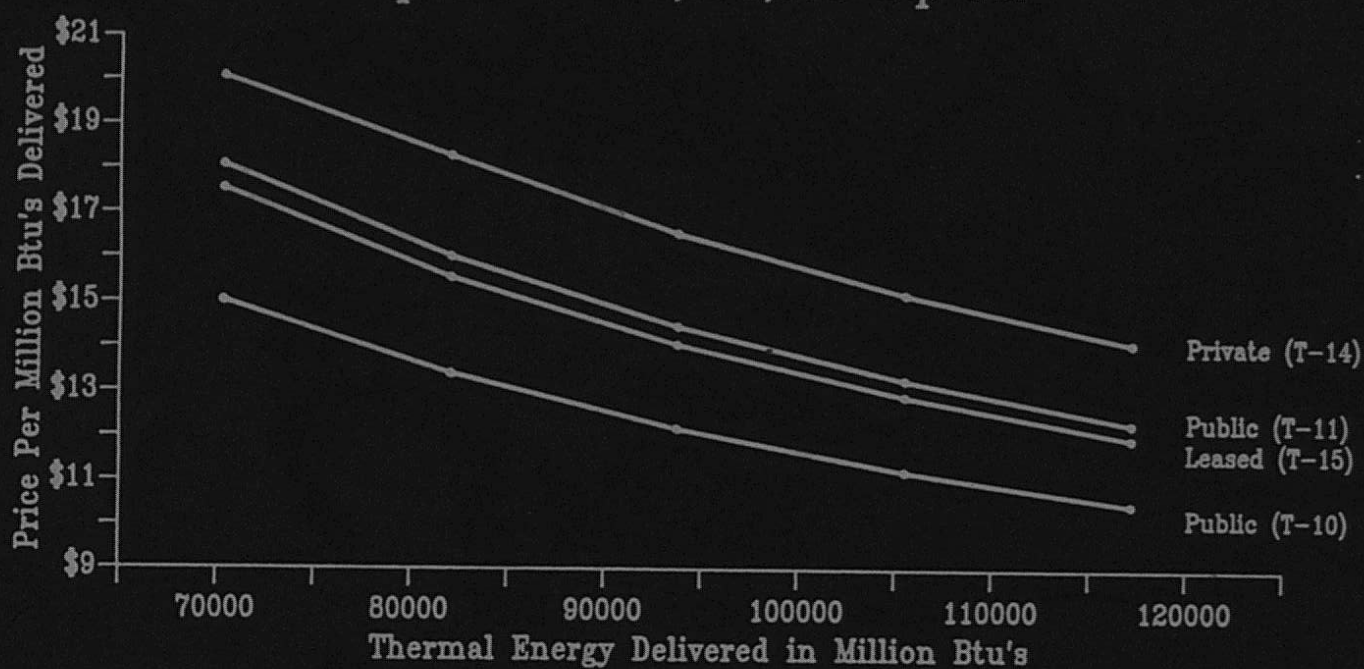


TABLE 18

SIZE OF PLANT  
2,500,000 SQ. FT.

LINCOLN DISTRICT HEATING SYSTEM  
CAPITAL AND OPERATING COST  
PUBLIC CASE

\*\*\* ASSUMPTIONS \*\*\*

TOTAL MMBTUS PRODUCED 125,000  
COOLING ENERGY OUTPUT 50,000  
HEATING ENERGY OUTPUT 75,000  
HEAT PUMP COST 1,500,000  
PROJECT LIFE 30  
FINANCED PORTION 6,645,810  
SALVAGE VALUE 50,000  
COOLING COP 5.000  
HEATING COP 2.500  
HEATING RATE .030  
COOLING RATE .060  
FINANCED INTEREST RATE .075

DATE GENERATED: 10/01/86

ANNUAL COSTS

|                        | 1987        | 1988        | 1989        | 1990        | 1991        | 1992        | 1993        | 1994        | 1995        | 1996        |
|------------------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|
| PUMPING COST           | \$ 149,019  | \$ 149,019  | \$ 149,019  | \$ 149,019  | \$ 151,999  | \$ 155,039  | \$ 158,140  | \$ 161,303  | \$ 164,529  | \$ 167,819  |
| PLANT ENERGY COST      | \$ 439,497  | \$ 439,497  | \$ 439,497  | \$ 439,497  | \$ 448,286  | \$ 457,252  | \$ 466,397  | \$ 475,725  | \$ 485,240  | \$ 494,944  |
| CUSTOMER CHARGE        | \$ 3,240    | \$ 3,240    | \$ 3,240    | \$ 3,240    | \$ 3,240    | \$ 3,240    | \$ 3,240    | \$ 3,240    | \$ 3,240    | \$ 3,240    |
| MAINTENANCE COST       | \$ 117,700  | \$ 117,700  | \$ 117,700  | \$ 117,700  | \$ 117,700  | \$ 117,700  | \$ 117,700  | \$ 117,700  | \$ 117,700  | \$ 117,700  |
| OPERATOR COST          | \$ 79,875   | \$ 83,070   | \$ 86,393   | \$ 89,849   | \$ 93,442   | \$ 97,180   | \$ 101,067  | \$ 105,110  | \$ 109,314  | \$ 113,687  |
| INSURANCE              | \$ 30,000   | \$ 30,000   | \$ 30,000   | \$ 30,000   | \$ 30,000   | \$ 30,000   | \$ 30,000   | \$ 30,000   | \$ 30,000   | \$ 30,000   |
| SELLING ADMIN          | \$ 50,000   | \$ 50,000   | \$ 25,000   | \$ 25,000   | \$ 25,000   | \$ 25,000   | \$ 25,000   | \$ 25,000   | \$ 25,000   | \$ 25,000   |
| O & M                  | \$ 869,331  | \$ 872,526  | \$ 850,849  | \$ 854,305  | \$ 869,667  | \$ 885,411  | \$ 901,544  | \$ 918,078  | \$ 935,023  | \$ 952,390  |
| DEBT SERVICE (7.5%)    | \$ 562,709  | \$ 562,709  | \$ 562,709  | \$ 562,709  | \$ 562,709  | \$ 562,709  | \$ 562,709  | \$ 562,709  | \$ 562,709  | \$ 562,709  |
| OPERATION+DEBT SERVICE | \$1,432,040 | \$1,435,235 | \$1,413,558 | \$1,417,014 | \$1,432,376 | \$1,448,120 | \$1,464,253 | \$1,480,787 | \$1,497,732 | \$1,515,099 |
| R&R (DEBT COVERAGE)    | \$ 11,255   | \$ 11,255   | \$ 11,255   | \$ 11,255   | \$ 11,255   | \$ 11,255   | \$ 11,255   | \$ 11,255   | \$ 11,255   | \$ 11,255   |
| TOTAL ANNUAL COST      | \$1,443,295 | \$1,446,490 | \$1,424,813 | \$1,428,269 | \$1,443,631 | \$1,459,375 | \$1,475,508 | \$1,492,042 | \$1,508,987 | \$1,526,354 |
| COST PER MILLION BTUS  |             |             |             |             |             |             |             |             |             |             |
| DEBT SERVICE           | \$ 4.50     | \$ 4.50     | \$ 4.50     | \$ 4.50     | \$ 4.50     | \$ 4.50     | \$ 4.50     | \$ 4.50     | \$ 4.50     | \$ 4.50     |
| ENERGY COST            | \$ 4.71     | \$ 4.71     | \$ 4.71     | \$ 4.71     | \$ 4.80     | \$ 4.90     | \$ 5.00     | \$ 5.10     | \$ 5.20     | \$ 5.30     |
| O & M                  | \$ 2.25     | \$ 2.27     | \$ 2.10     | \$ 2.13     | \$ 2.16     | \$ 2.18     | \$ 2.22     | \$ 2.25     | \$ 2.28     | \$ 2.32     |
| R&R (DEBT COVERAGE)    | \$ .09      | \$ .09      | \$ .09      | \$ .09      | \$ .09      | \$ .09      | \$ .09      | \$ .09      | \$ .09      | \$ .09      |
| TOTAL PER UNIT COST    | \$11.55     | \$11.57     | \$11.40     | \$11.43     | \$11.55     | \$11.68     | \$11.80     | \$11.94     | \$12.07     | \$12.21     |
| COOLING PORTION        | \$14.75     | \$14.78     | \$14.59     | \$14.62     | \$14.76     | \$14.90     | \$15.05     | \$15.20     | \$15.35     | \$15.51     |
| HEATING PORTION        | \$ 9.41     | \$ 9.43     | \$ 9.27     | \$ 9.30     | \$ 9.41     | \$ 9.52     | \$ 9.64     | \$ 9.76     | \$ 9.89     | \$10.01     |

TABLE 19

2,500,000 SQ. FT.

LINCOLN DISTRICT HEATING SYSTEM  
CAPITAL AND OPERATING COST  
PUBLIC CASE

\*\*\* ASSUMPTIONS \*\*\*

|                        |           |
|------------------------|-----------|
| TOTAL MMBTUS PRODUCED  | 125,000   |
| COOLING ENERGY OUTPUT  | 50,000    |
| HEATING ENERGY OUTPUT  | 75,000    |
| HEAT PUMP COST         | 1,500,000 |
| PROJECT LIFE           | 30        |
| FINANCED PORTION       | 6,645,810 |
| SALVAGE VALUE          | 50,000    |
| COOLING COP            | 5.000     |
| HEATING COP            | 2.500     |
| HEATING RATE           | .030      |
| COOLING RATE           | .060      |
| FINANCED INTEREST RATE | .075      |

DATE GENERATED: 10/01/86

ANNUAL COSTS

|                        | 1987        | 1988        | 1989        | 1990        | 1991        | 1992        | 1993        | 1994        | 1995        | 1996        |
|------------------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|
| PUMPING COST           | \$ 149,019  | \$ 149,019  | \$ 149,019  | \$ 149,019  | \$ 151,999  | \$ 155,039  | \$ 158,140  | \$ 161,303  | \$ 164,529  | \$ 167,819  |
| PLANT ENERGY COST      | \$ 439,497  | \$ 439,497  | \$ 439,497  | \$ 439,497  | \$ 448,286  | \$ 457,252  | \$ 466,397  | \$ 475,725  | \$ 485,240  | \$ 494,944  |
| CUSTOMER CHARGE        | \$ 3,240    | \$ 3,240    | \$ 3,240    | \$ 3,240    | \$ 3,240    | \$ 3,240    | \$ 3,240    | \$ 3,240    | \$ 3,240    | \$ 3,240    |
| MAINTENANCE COST       | \$ 117,700  | \$ 117,700  | \$ 117,700  | \$ 117,700  | \$ 117,700  | \$ 117,700  | \$ 117,700  | \$ 117,700  | \$ 117,700  | \$ 117,700  |
| OPERATOR COST          | \$ 79,875   | \$ 83,070   | \$ 86,393   | \$ 89,849   | \$ 93,442   | \$ 97,180   | \$ 101,067  | \$ 105,110  | \$ 109,314  | \$ 113,687  |
| INSURANCE              | \$ 30,000   | \$ 30,000   | \$ 30,000   | \$ 30,000   | \$ 30,000   | \$ 30,000   | \$ 30,000   | \$ 30,000   | \$ 30,000   | \$ 30,000   |
| SELLING ADMIN          | \$ 50,000   | \$ 50,000   | \$ 25,000   | \$ 25,000   | \$ 25,000   | \$ 25,000   | \$ 25,000   | \$ 25,000   | \$ 25,000   | \$ 25,000   |
| O & M                  | \$ 869,331  | \$ 872,526  | \$ 850,849  | \$ 854,305  | \$ 869,667  | \$ 885,411  | \$ 901,544  | \$ 918,078  | \$ 935,023  | \$ 952,390  |
| DEBT SERVICE (7.5%)    | \$ 562,709  | \$ 562,709  | \$ 562,709  | \$ 562,709  | \$ 562,709  | \$ 562,709  | \$ 562,709  | \$ 562,709  | \$ 562,709  | \$ 562,709  |
| OPERATION+DEBT SERVICE | \$1,432,040 | \$1,435,235 | \$1,413,558 | \$1,417,014 | \$1,432,376 | \$1,448,120 | \$1,464,253 | \$1,480,787 | \$1,497,732 | \$1,515,099 |
| R&R (DEBT COVERAGE)    | \$ 281,355  | \$ 281,355  | \$ 281,355  | \$ 281,355  | \$ 281,355  | \$ 281,355  | \$ 281,355  | \$ 281,355  | \$ 281,355  | \$ 281,355  |
| TOTAL ANNUAL COST      | \$1,713,395 | \$1,716,590 | \$1,694,913 | \$1,698,369 | \$1,713,731 | \$1,729,475 | \$1,745,608 | \$1,762,142 | \$1,779,087 | \$1,796,454 |
| COST PER MILLION BTUS  |             |             |             |             |             |             |             |             |             |             |
| DEBT SERVICE           | \$ 4.50     | \$ 4.50     | \$ 4.50     | \$ 4.50     | \$ 4.50     | \$ 4.50     | \$ 4.50     | \$ 4.50     | \$ 4.50     | \$ 4.50     |
| ENERGY COST            | \$ 4.71     | \$ 4.71     | \$ 4.71     | \$ 4.71     | \$ 4.80     | \$ 4.90     | \$ 5.00     | \$ 5.10     | \$ 5.20     | \$ 5.30     |
| O & M                  | \$ 2.25     | \$ 2.27     | \$ 2.10     | \$ 2.13     | \$ 2.16     | \$ 2.18     | \$ 2.22     | \$ 2.25     | \$ 2.28     | \$ 2.32     |
| R&R (DEBT COVERAGE)    | \$ 2.25     | \$ 2.25     | \$ 2.25     | \$ 2.25     | \$ 2.25     | \$ 2.25     | \$ 2.25     | \$ 2.25     | \$ 2.25     | \$ 2.25     |
| TOTAL PER UNIT COST    | \$13.71     | \$13.73     | \$13.56     | \$13.59     | \$13.71     | \$13.84     | \$13.96     | \$14.10     | \$14.23     | \$14.37     |
| COOLING PORTION        | \$17.99     | \$18.02     | \$17.83     | \$17.86     | \$18.00     | \$18.14     | \$18.29     | \$18.44     | \$18.59     | \$18.75     |
| HEATING PORTION        | \$10.85     | \$10.87     | \$10.71     | \$10.74     | \$10.85     | \$10.96     | \$11.08     | \$11.20     | \$11.33     | \$11.45     |

TABLE 20



CAPITAL COSTS SUMMARY  
 SIZE OPTION 3  
 -----

|                          |             |             |
|--------------------------|-------------|-------------|
| SOURCE PIPE              | \$ 440,000  |             |
| PIPE INSTALLATION        | \$ 220,000  |             |
| SOURCE PUMP STATION      | \$ 200,000  |             |
|                          | -----       |             |
| SOURCE SYSTEM COST       | \$ 860,000  |             |
| DISTRIBUTION PIPE        | \$1,430,000 |             |
| HEAT PUMP                | \$1,500,000 |             |
| CENTRAL PLANT BOILER     | \$ 340,000  |             |
| CENTRAL PLANT CHILLER    | \$ 640,000  |             |
| LAND & BUILDING          | \$ 400,000  |             |
| PIPING & AUX.            | \$ 250,000  |             |
| STORAGE                  | \$ 465,000  |             |
|                          | -----       |             |
| CENTRAL PLANT SYSTEM     | \$3,595,000 |             |
| TOTAL CAPITAL COST       |             | \$5,885,000 |
| TAXES                    | \$ 161,838  |             |
| A&G                      | \$ 0        |             |
| ENGINEERING              | \$ 302,342  |             |
| CONTINGENCY              | \$ 302,342  |             |
| SALVAGE VALUE            | \$ -5,712   |             |
|                          | -----       |             |
| MISC                     |             | \$ 760,810  |
|                          |             | -----       |
| TOTAL INITIAL COST       |             | \$6,645,810 |
|                          |             | =====       |
| DATE GENERATED: 10/01/86 |             |             |

TABLE 21



2,500,000 SQ. FT.

LINCOLN DISTRICT HEATING SYSTEM  
CAPITAL AND OPERATING COST  
PRIVATE OWNERSHIP

DATE: 10/10/86

\*\*\* ASSUMPTIONS \*\*\*

TOTAL MMBTUS PRODUCED 125,000  
COOLING ENERGY OUTPUT 50,000  
HEATING ENERGY OUTPUT 75,000  
HEAT PUMP COST 1,500,000  
YEARS AMORTIZED OVER 30  
SALVAGE VALUE 50,000  
COOLING COP 5.000  
HEATING COP 2.500  
HEATING RATE .030  
COOLING RATE .060  
INTEREST RATE .115

ANNUAL COSTS

|                       | 1987        | 1988        | 1989        | 1990        | 1991        | 1992        | 1993        | 1994        | 1995        | 1996        |
|-----------------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|
| DEBT SERVICE          | \$ 655,126  | \$ 655,126  | \$ 655,126  | \$ 655,126  | \$ 655,126  | \$ 655,126  | \$ 655,126  | \$ 655,126  | \$ 655,126  | \$ 655,126  |
| PUMPING COST          | \$ 149,019  | \$ 149,019  | \$ 149,019  | \$ 149,019  | \$ 151,999  | \$ 155,039  | \$ 158,140  | \$ 161,303  | \$ 164,529  | \$ 167,819  |
| PLANT ENERGY COST     | \$ 439,497  | \$ 439,497  | \$ 439,497  | \$ 439,497  | \$ 448,286  | \$ 457,252  | \$ 466,397  | \$ 475,725  | \$ 485,240  | \$ 494,944  |
| CUSTOMER CHARGE       | \$ 3,240    | \$ 3,240    | \$ 3,240    | \$ 3,240    | \$ 3,240    | \$ 3,240    | \$ 3,240    | \$ 3,240    | \$ 3,240    | \$ 3,240    |
| MAINTENANCE COST      | \$ 117,700  | \$ 117,700  | \$ 117,700  | \$ 117,700  | \$ 117,700  | \$ 117,700  | \$ 117,700  | \$ 117,700  | \$ 117,700  | \$ 117,700  |
| OPERATOR COST         | \$ 79,875   | \$ 83,070   | \$ 86,393   | \$ 89,849   | \$ 93,443   | \$ 97,181   | \$ 101,068  | \$ 105,111  | \$ 109,315  | \$ 113,688  |
| SELLING ADMIN         | \$ 50,000   | \$ 50,000   | \$ 25,000   | \$ 25,000   | \$ 25,000   | \$ 25,000   | \$ 25,000   | \$ 25,000   | \$ 25,000   | \$ 25,000   |
| INSURANCE             | \$ 30,000   | \$ 30,000   | \$ 30,000   | \$ 30,000   | \$ 30,000   | \$ 30,000   | \$ 30,000   | \$ 30,000   | \$ 30,000   | \$ 30,000   |
| REPLACEMENT & RENEWAL | \$ 117,700  | \$ 117,700  | \$ 117,700  | \$ 117,700  | \$ 117,700  | \$ 117,700  | \$ 117,700  | \$ 117,700  | \$ 117,700  | \$ 117,700  |
| TOTAL ANNUAL COST     | \$1,642,157 | \$1,645,352 | \$1,623,675 | \$1,627,131 | \$1,642,494 | \$1,658,238 | \$1,674,371 | \$1,690,905 | \$1,707,850 | \$1,725,217 |

COST PER MILLION BTUS

|                      |         |         |         |         |         |         |         |         |         |         |
|----------------------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|
| DEBT SERVICE         | \$ 5.24 | \$ 5.24 | \$ 5.24 | \$ 5.24 | \$ 5.24 | \$ 5.24 | \$ 5.24 | \$ 5.24 | \$ 5.24 | \$ 5.24 |
| ENERGY COST          | \$ 4.71 | \$ 4.71 | \$ 4.71 | \$ 4.71 | \$ 4.80 | \$ 4.90 | \$ 5.00 | \$ 5.10 | \$ 5.20 | \$ 5.30 |
| FIXED OPERATING COST | \$ 3.19 | \$ 3.21 | \$ 3.04 | \$ 3.07 | \$ 3.10 | \$ 3.13 | \$ 3.16 | \$ 3.19 | \$ 3.22 | \$ 3.26 |
| TOTAL PER UNIT COST  | \$13.14 | \$13.16 | \$12.99 | \$13.02 | \$13.14 | \$13.27 | \$13.39 | \$13.53 | \$13.66 | \$13.80 |

TABLE 22

LINCOLN DISTRICT HEATING SYSTEM  
INCOME STATEMENT  
PRIVATE CASE

DATE: 10/10/86

|                            | 1987        | 1988        | 1989        | 1990        | 1991        | 1992        | 1993        | 1994        | 1995        | 1996        |
|----------------------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|
| SALES                      | \$1,959,094 | \$1,962,905 | \$1,924,055 | \$1,928,151 | \$1,946,356 | \$1,965,013 | \$1,942,271 | \$1,961,450 | \$1,981,106 | \$1,966,748 |
| VARIABLE COST:             |             |             |             |             |             |             |             |             |             |             |
| ENERGY COST                | \$ 588,516  | \$ 588,516  | \$ 588,516  | \$ 588,516  | \$ 600,285  | \$ 612,291  | \$ 624,537  | \$ 637,028  | \$ 649,769  | \$ 662,763  |
| CONTRIBUTION MARGIN        | \$1,370,578 | \$1,374,389 | \$1,335,539 | \$1,339,635 | \$1,346,071 | \$1,352,722 | \$1,317,734 | \$1,324,422 | \$1,331,337 | \$1,303,985 |
| FIXED COSTS:               |             |             |             |             |             |             |             |             |             |             |
| DEBT SERVICE               | \$ 655,126  | \$ 655,126  | \$ 655,126  | \$ 655,126  | \$ 655,126  | \$ 655,126  | \$ 655,126  | \$ 655,126  | \$ 655,126  | \$ 655,126  |
| MAINTENANCE COST           | \$ 117,700  | \$ 117,700  | \$ 117,700  | \$ 117,700  | \$ 117,700  | \$ 117,700  | \$ 117,700  | \$ 117,700  | \$ 117,700  | \$ 117,700  |
| OPERATOR COST              | \$ 79,875   | \$ 83,070   | \$ 86,393   | \$ 89,849   | \$ 93,443   | \$ 97,181   | \$ 101,068  | \$ 105,111  | \$ 109,315  | \$ 113,688  |
| REPLACEMENT RENEWAL        | \$ 117,700  | \$ 117,700  | \$ 117,700  | \$ 117,700  | \$ 117,700  | \$ 117,700  | \$ 117,700  | \$ 117,700  | \$ 117,700  | \$ 117,700  |
| SELLING & ADMIN.           | \$ 50,000   | \$ 50,000   | \$ 25,000   | \$ 25,000   | \$ 25,000   | \$ 25,000   | \$ 25,000   | \$ 25,000   | \$ 25,000   | \$ 25,000   |
| INSURANCE                  | \$ 30,000   | \$ 30,000   | \$ 30,000   | \$ 30,000   | \$ 30,000   | \$ 30,000   | \$ 30,000   | \$ 30,000   | \$ 30,000   | \$ 30,000   |
| CUSTOMER CHARGE            | \$ 3,240    | \$ 3,240    | \$ 3,240    | \$ 3,240    | \$ 3,240    | \$ 3,240    | \$ 3,240    | \$ 3,240    | \$ 3,240    | \$ 3,240    |
| TOTAL FIXED COSTS          | \$1,053,641 | \$1,056,836 | \$1,035,159 | \$1,038,615 | \$1,042,209 | \$1,045,947 | \$1,049,834 | \$1,053,877 | \$1,058,081 | \$1,062,454 |
| OPERATING INCOME           | \$ 316,937  | \$ 317,553  | \$ 300,380  | \$ 301,020  | \$ 303,862  | \$ 306,775  | \$ 267,900  | \$ 270,545  | \$ 273,256  | \$ 241,531  |
| LESS:                      |             |             |             |             |             |             |             |             |             |             |
| DEPRECIATION               | \$ 179,309  | \$ 179,309  | \$ 179,309  | \$ 179,309  | \$ 179,309  | \$ 179,309  | \$ 179,309  | \$ 179,309  | \$ 179,309  | \$ 179,309  |
| TAXABLE INCOME             | \$ 137,628  | \$ 138,244  | \$ 121,071  | \$ 121,711  | \$ 124,553  | \$ 127,466  | \$ 88,591   | \$ 91,236   | \$ 93,947   | \$ 62,222   |
| INCOME TAX                 | \$ 46,794   | \$ 47,003   | \$ 41,164   | \$ 41,382   | \$ 42,348   | \$ 43,338   | \$ 30,121   | \$ 31,020   | \$ 31,942   | \$ 21,155   |
| NET INCOME                 | \$ 90,834   | \$ 91,241   | \$ 79,907   | \$ 80,329   | \$ 82,205   | \$ 84,128   | \$ 58,470   | \$ 60,216   | \$ 62,005   | \$ 41,067   |
| POSITIVE NET INCOME        | \$ 90,834   | \$ 91,241   | \$ 79,907   | \$ 80,329   | \$ 82,205   | \$ 84,128   | \$ 58,470   | \$ 60,216   | \$ 62,005   | \$ 41,067   |
| INVESTMENT TAX CREDIT      | \$ 0        | \$ 0        | \$ 0        | \$ 0        | \$ 0        | \$ 0        | \$ 0        | \$ 0        | \$ 0        | \$ 0        |
| TAX VALUE DEPR             | \$ 60,966   | \$ 60,966   | \$ 60,966   | \$ 60,966   | \$ 60,966   | \$ 60,966   | \$ 60,966   | \$ 60,966   | \$ 60,966   | \$ 60,966   |
| EQUITY                     | \$ 25,008   | \$ 27,884   | \$ 31,091   | \$ 34,666   | \$ 38,653   | \$ 43,098   | \$ 48,054   | \$ 53,580   | \$ 59,742   | \$ 66,612   |
| EFFECTIVE NET INCOME       | \$ 176,808  | \$ 180,091  | \$ 171,963  | \$ 175,961  | \$ 181,823  | \$ 188,191  | \$ 167,490  | \$ 174,762  | \$ 182,713  | \$ 168,644  |
| RATE OF RETURN             | .133        | .135        | .129        | .132        | .137        | .142        | .126        | .131        | .137        | .127        |
| SELLING PRICE              | \$15.67     |             |             |             |             |             |             |             |             |             |
| TOTAL INVESTMENT           | \$6,649,613 |             |             |             |             |             |             |             |             |             |
| CAPITAL PORTION            | \$1,329,923 |             |             |             |             |             |             |             |             |             |
| FINANCED PORTION           | \$5,319,690 |             |             |             |             |             |             |             |             |             |
| POINTS COST                | \$ 159,591  |             |             |             |             |             |             |             |             |             |
| FIRST YEAR DEPR.           | \$ 179,309  |             |             |             |             |             |             |             |             |             |
| TOTAL MMBTU'S SOLD         | 125,000     |             |             |             |             |             |             |             |             |             |
| PERCENTAGE MARKUP          | .19         |             |             |             |             |             |             |             |             |             |
| INVESTMENT TAX CREDIT      | .00         |             |             |             |             |             |             |             |             |             |
| INCOME TAX RATE            | .34         |             |             |             |             |             |             |             |             |             |
| STRAIGHT LINE DEPRECIATION |             |             |             |             |             |             |             |             |             |             |

TABLE 23

2,500,000 SQ. FT.

LINCOLN DISTRICT HEATING SYSTEM  
CAPITAL AND OPERATING COST  
LEVERAGED LEASE CASE

DATE:10/10/86

\*\*\* ASSUMPTIONS \*\*\*

TOTAL MMBTUS PRODUCED 125,000  
COOLING ENERGY OUTPUT 50,000  
HEATING ENERGY OUTPUT 75,000  
HEAT PUMP COST 1,500,000  
YEARS AMORTIZED OVER 30  
COOLING COP 5.000  
HEATING COP 2.500  
HEATING RATE .030  
COOLING RATE .060  
DEBT INTEREST RATE .115  
RETURN ON EQUITY .100

ANNUAL COSTS

|                   | 1987        | 1988        | 1989        | 1990        | 1991        | 1992        | 1993        | 1994        | 1995        | 1996        |
|-------------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|
| DEBT SERVICE      | \$ 796,202  | \$ 796,202  | \$ 796,202  | \$ 796,202  | \$ 796,202  | \$ 796,202  | \$ 796,202  | \$ 796,202  | \$ 796,202  | \$ 796,202  |
| PUMPING COST      | \$ 149,019  | \$ 149,019  | \$ 149,019  | \$ 149,019  | \$ 151,999  | \$ 155,039  | \$ 158,140  | \$ 161,303  | \$ 164,529  | \$ 167,819  |
| PLANT ENERGY COST | \$ 439,497  | \$ 439,497  | \$ 439,497  | \$ 439,497  | \$ 448,266  | \$ 457,252  | \$ 466,397  | \$ 475,725  | \$ 485,240  | \$ 494,944  |
| CUSTOMER CHARGE   | \$ 3,240    | \$ 3,240    | \$ 3,240    | \$ 3,240    | \$ 3,240    | \$ 3,240    | \$ 3,240    | \$ 3,240    | \$ 3,240    | \$ 3,240    |
| MAINTENANCE COST  | \$ 117,700  | \$ 117,700  | \$ 117,700  | \$ 117,700  | \$ 117,700  | \$ 117,700  | \$ 117,700  | \$ 117,700  | \$ 117,700  | \$ 117,700  |
| OPERATOR COST     | \$ 79,875   | \$ 83,070   | \$ 86,393   | \$ 89,849   | \$ 93,443   | \$ 97,181   | \$ 101,068  | \$ 105,111  | \$ 109,315  | \$ 113,688  |
| SELLING ADMIN     | \$ 50,000   | \$ 50,000   | \$ 25,000   | \$ 25,000   | \$ 25,000   | \$ 25,000   | \$ 25,000   | \$ 25,000   | \$ 25,000   | \$ 25,000   |
| INSURANCE         | \$ 30,000   | \$ 30,000   | \$ 30,000   | \$ 30,000   | \$ 30,000   | \$ 30,000   | \$ 30,000   | \$ 30,000   | \$ 30,000   | \$ 30,000   |
| TOTAL ANNUAL COST | \$1,665,533 | \$1,668,728 | \$1,647,051 | \$1,650,507 | \$1,665,870 | \$1,681,614 | \$1,697,747 | \$1,714,281 | \$1,731,226 | \$1,748,593 |

COST PER MILLION BTUS

|                      |         |         |         |         |         |         |         |         |         |         |
|----------------------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|
| DEBT SERVICE         | \$ 6.37 | \$ 6.37 | \$ 6.37 | \$ 6.37 | \$ 6.37 | \$ 6.37 | \$ 6.37 | \$ 6.37 | \$ 6.37 | \$ 6.37 |
| ENERGY COST          | \$ 4.71 | \$ 4.71 | \$ 4.71 | \$ 4.71 | \$ 4.80 | \$ 4.90 | \$ 5.00 | \$ 5.10 | \$ 5.20 | \$ 5.30 |
| FIXED OPERATING COST | \$ 2.25 | \$ 2.27 | \$ 2.10 | \$ 2.13 | \$ 2.16 | \$ 2.18 | \$ 2.22 | \$ 2.25 | \$ 2.28 | \$ 2.32 |
| TOTAL PER UNIT COST  | \$13.32 | \$13.35 | \$13.18 | \$13.20 | \$13.33 | \$13.45 | \$13.58 | \$13.71 | \$13.85 | \$13.99 |

TABLE 24



2,500,000 SQ. FT.

LINCOLN DISTRICT HEATING SYSTEM  
INCOME STATEMENT  
LEVERAGED LEASE CASE

DATE: 10/10/86

## LESSEE OPERATING STATEMENT:

|                     | 1987        | 1988        | 1989        | 1990        | 1991        | 1992        | 1993        | 1994        | 1995        | 1996        |
|---------------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|
| SALES               | \$1,665,533 | \$1,668,728 | \$1,647,051 | \$1,650,507 | \$1,665,870 | \$1,681,614 | \$1,697,747 | \$1,714,281 | \$1,731,226 | \$1,748,593 |
| VARIABLE COST:      |             |             |             |             |             |             |             |             |             |             |
| ENERGY COST         | \$ 588,516  | \$ 588,516  | \$ 588,516  | \$ 588,516  | \$ 600,285  | \$ 612,291  | \$ 624,537  | \$ 637,028  | \$ 649,769  | \$ 662,763  |
| CONTRIBUTION MARGIN | \$1,077,017 | \$1,080,212 | \$1,058,535 | \$1,061,991 | \$1,065,585 | \$1,069,323 | \$1,073,210 | \$1,077,253 | \$1,081,457 | \$1,085,830 |
| FIXED COSTS:        |             |             |             |             |             |             |             |             |             |             |
| LEASE PAYMENT       | \$ 796,202  | \$ 796,202  | \$ 796,202  | \$ 796,202  | \$ 796,202  | \$ 796,202  | \$ 796,202  | \$ 796,202  | \$ 796,202  | \$ 796,202  |
| MAINTENANCE COST    | \$ 117,700  | \$ 117,700  | \$ 117,700  | \$ 117,700  | \$ 117,700  | \$ 117,700  | \$ 117,700  | \$ 117,700  | \$ 117,700  | \$ 117,700  |
| OPERATOR COST       | \$ 79,875   | \$ 83,070   | \$ 86,393   | \$ 89,849   | \$ 93,443   | \$ 97,181   | \$ 101,068  | \$ 105,111  | \$ 109,315  | \$ 113,688  |
| SELLING & ADMIN.    | \$ 50,000   | \$ 50,000   | \$ 25,000   | \$ 25,000   | \$ 25,000   | \$ 25,000   | \$ 25,000   | \$ 25,000   | \$ 25,000   | \$ 25,000   |
| INSURANCE           | \$ 30,000   | \$ 30,000   | \$ 30,000   | \$ 30,000   | \$ 30,000   | \$ 30,000   | \$ 30,000   | \$ 30,000   | \$ 30,000   | \$ 30,000   |
| CUSTOMER CHARGE     | \$ 3,240    | \$ 3,240    | \$ 3,240    | \$ 3,240    | \$ 3,240    | \$ 3,240    | \$ 3,240    | \$ 3,240    | \$ 3,240    | \$ 3,240    |
| TOTAL FIXED COSTS   | \$1,077,017 | \$1,080,212 | \$1,058,535 | \$1,061,991 | \$1,065,585 | \$1,069,323 | \$1,073,210 | \$1,077,253 | \$1,081,457 | \$1,085,830 |
| OPERATING INCOME    | \$ 0        | \$ 0        | \$ 0        | \$ 0        | \$ 0        | \$ 0        | \$ 0        | \$ 0        | \$ 0        | \$ 0        |

## LESSOR STATEMENT:

|                        |            |            |            |            |            |            |            |            |            |            |
|------------------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|
| DEBT PAYMENT           | \$ 655,125 | \$ 655,125 | \$ 655,125 | \$ 655,125 | \$ 655,125 | \$ 655,125 | \$ 655,125 | \$ 655,125 | \$ 655,125 | \$ 655,125 |
| EQUITY PAYMENT         | \$ 141,077 | \$ 141,077 | \$ 141,077 | \$ 141,077 | \$ 141,077 | \$ 141,077 | \$ 141,077 | \$ 141,077 | \$ 141,077 | \$ 141,077 |
| TOTAL DEBT SERVICE     | \$ 796,202 | \$ 796,202 | \$ 796,202 | \$ 796,202 | \$ 796,202 | \$ 796,202 | \$ 796,202 | \$ 796,202 | \$ 796,202 | \$ 796,202 |
| NET BENEFIT TO LESSOR: |            |            |            |            |            |            |            |            |            |            |
| INVESTMENT TAX CREDIT  | \$ 0       | \$ 0       | \$ 0       | \$ 0       | \$ 0       | \$ 0       | \$ 0       | \$ 0       | \$ 0       | \$ 0       |
| TAX VALUE DEPRECIATION | \$ 60,965  | \$ 60,965  | \$ 60,965  | \$ 60,965  | \$ 60,965  | \$ 60,965  | \$ 60,965  | \$ 60,965  | \$ 60,965  | \$ 60,965  |
| GAIN IN EQUITY         | \$ 33,093  | \$ 36,778  | \$ 40,874  | \$ 45,427  | \$ 50,490  | \$ 56,119  | \$ 62,377  | \$ 69,336  | \$ 77,073  | \$ 85,676  |
| EFFECTIVE NET INCOME   | \$ 94,058  | \$ 97,743  | \$ 101,839 | \$ 106,392 | \$ 111,455 | \$ 117,084 | \$ 123,342 | \$ 130,301 | \$ 138,038 | \$ 146,641 |

|                            |             |
|----------------------------|-------------|
| TOTAL INVESTMENT           | \$6,649,613 |
| EQUITY PORTION             | \$1,329,923 |
| DEBT PORTION               | \$5,319,690 |
| POINTS COST                | \$ 159,591  |
| FIRST YEAR DEPR.           | \$ 179,309  |
| TOTAL MMBTU'S SOLD         | 125,000     |
| INTEREST ON DEBT           | .12         |
| RETURN ON EQUITY           | .10         |
| INVESTMENT TAX CREDIT      | .00         |
| INCOME TAX RATE            | .34         |
| STRAIGHT LINE DEPRECIATION |             |



# Sensitivity of Energy Cost to Equipment Cost Option 3 - 2,500,000 Sq. Ft.

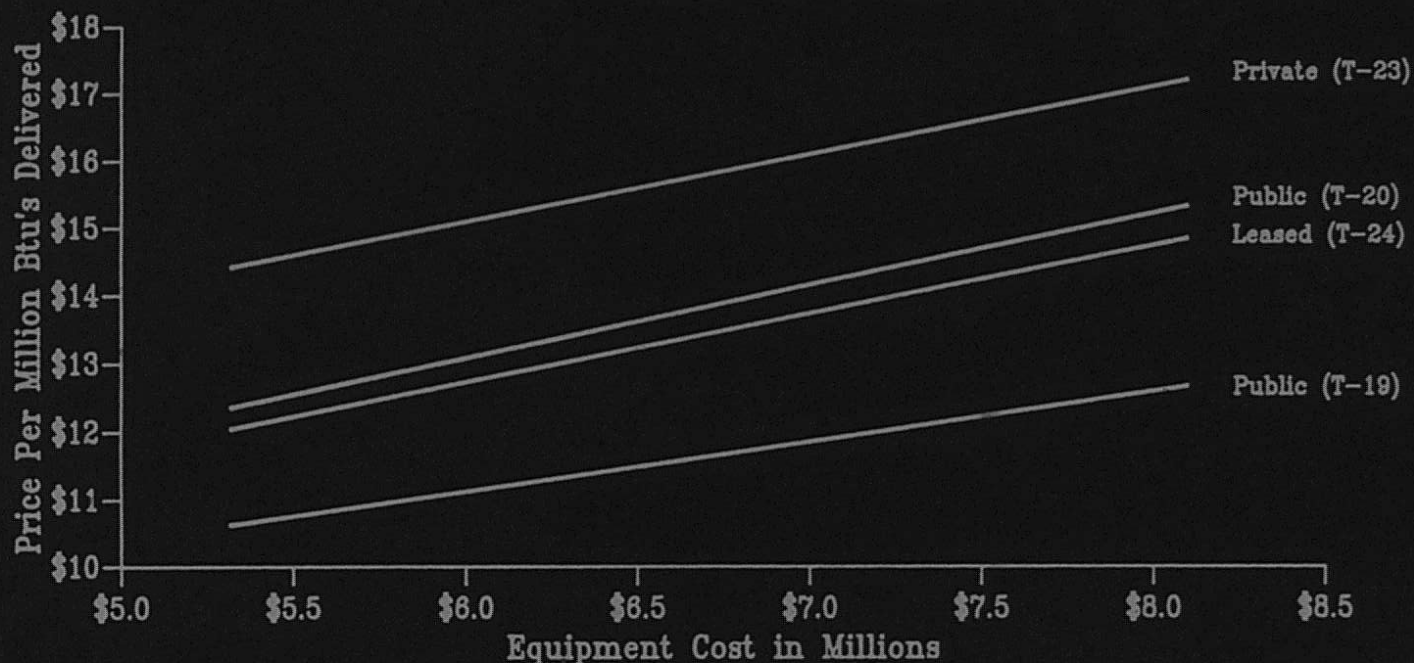


TABLE 26

# Sensitivity of Energy Cost to Thermal Energy Delivered Option 3 - 2,500,000 Sq. Ft.

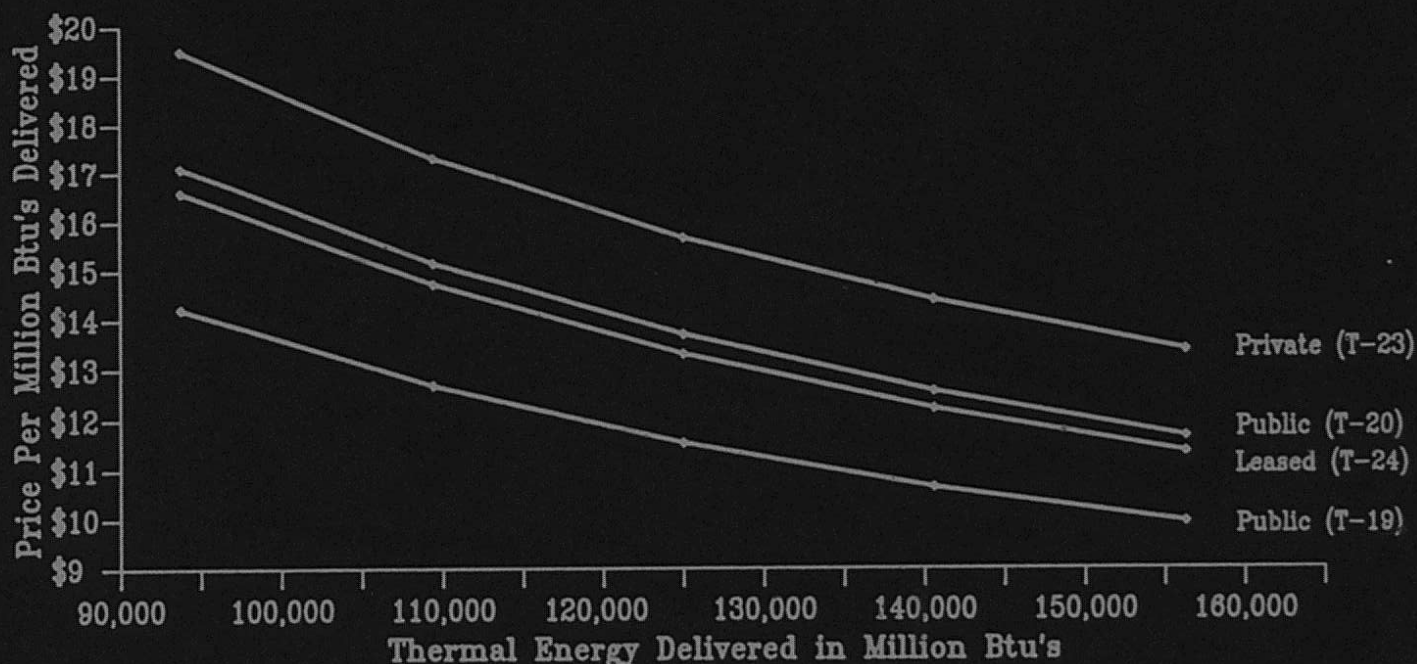


TABLE 27

## VARIABLES COMMON TO ALL OPTIONS AND CASES:

SOURCE PIPE COST = \$440,000  
 SOURCE PIPE INSTALLATION = \$220,000  
 SOURCE PUMP STATION = \$200,000  
 SALVAGE VALUE = \$50,000  
 COOLING ENERGY PERCENTAGE = .4  
 HEATING ENERGY PERCENTAGE = .6  
 COOLING OPERATING HOURS = 4300  
 HEATING OPERATING HOURS = 5325  
 COOLING LOAD FACTOR = .25  
 HEATING LOAD FACTOR = .30  
 INITIAL HEATING ENERGY RATE = \$.03  
 INITIAL COOLING ENERGY RATE = \$.06  
 HEATING RATE ESCALLATION = 0 FOR 4, .02  
 COOLING RATE ESCALLATION = 0 FOR 4, .02  
 INITIAL DEMAND RATE = \$0  
 INITIAL OPERATOR RATE = \$15  
 SALARY ESCALLATION = .04  
 OPERATOR HOURS = 5325  
 YEARS = 30  
 SALES TAX = .055  
 INVESTMENT TAX CREDIT = 0  
 MATERIALS PERCENTAGE = .5  
 ENGINEERING FACTOR = .05  
 MAINTENANCE FACTOR = .02  
 CONTINGENCY = .05  
 OPERATING AG = 0  
 ANNUAL CUSTOMER CHARGE = 3240  
 SELLING ADMIN = \$50,000 FOR 2, \$25,000  
 INSURANCE = \$30,000  
 PERCENTAGE MARKUP = 0

## VARIABLES WHICH DIFFER BETWEEN SIZE OPTIONS:

|                          | OPTION 1  | OPTION 2    | OPTION 3    |
|--------------------------|-----------|-------------|-------------|
| SQUARE FOOTAGE SERVED =  | 1,250,000 | 1,875,000   | 2,500,000   |
| TOTAL ENERGY =           | 62,500E6  | 93,750E6    | 125,000E6   |
| HEAT PUMP COST =         | \$850,000 | \$1,100,000 | \$1,500,000 |
| CENTRAL PLANT BOILER =   | \$170,000 | \$250,000   | \$340,000   |
| DISTRIBUTION PIPE COST = | \$921,000 | \$1,031,000 | \$1,430,000 |
| DISTRIBUTION PUMP SIZE = | 100 HP    | 150         | 200         |
| SOURCE PUMP SIZE =       | 29 HP     | 127         | 278         |
| PIPING & AUX. =          | \$150,000 | \$200,000   | \$250,000   |
| CHILLER =                | \$320,000 | \$480,000   | \$640,000   |
| COOLING STORAGE COST =   | \$210,000 | \$280,000   | \$350,000   |
| HEATING STORAGE COST =   | \$ 70,000 | \$ 92,500   | \$115,000   |
| LAND BUILDING COST =     | \$250,000 | \$380,000   | \$400,000   |
| COOLING COP =            | 4.8       | 4.8         | 5.0         |
| HEATING COP =            | 2.4       | 2.4         | 2.5         |

## VARIABLES WHICH DIFFER BETWEEN OWNERSHIP CASES:

|                              | PUBLIC | PRIVATE | LEASED |
|------------------------------|--------|---------|--------|
| TAX RATE =                   | 0      | .34     | .34    |
| RESERVE RENEWAL FACTOR =     | .5     | N/A     | N/A    |
| REPLACEMENT RENEWAL FACTOR = | N/A    | .02     | .02    |
| INTEREST =                   | .075   | .115    | N/A    |
| DEBT INTEREST =              | N/A    | N/A     | .115   |
| EQUITY INTEREST =            | N/A    | N/A     | .1     |
| EQUITY FACTOR =              | 0      | .2      | .2     |
| POINTS =                     | 0      | .03     | .03    |

FILE MODEL DHC 08/14/8613 35 33  
10 \* LINCOLN DISTRICT HEATING SYSTEM COSTS PROGRAM  
20 \* CREATED 12/20/85 BY THE GENERATION ENGINEERING AND SPECIAL PROJECTS DEPT.  
30 \* OF THE LINCOLN ELECTRIC SYSTEM  
40 \* PUBLIC OWNERSHIP CASE  
50 COLUMNS 1-30  
60 \*  
70 \* INPUT DATA ENTERED IN SEPERATE DATA FILE LABELED 'DHC DATA IFPS'  
80 \*  
90 SOURCE PIPE COST = DATA  
100 SOURCE PIPE INSTALLATION = DATA  
110 SOURCE PUMP STATION = DATA  
120 DISTRIBUTION PIPE COST = DATA  
130 DISTRIBUTION PIPE INSTALLATION = DATA  
140 \*  
150 \* PUMPED SIZED IN BREAKING HORSE-POWER  
160 SOURCE PUMP SIZE = DATA  
170 DISTRIBUTION PUMP SIZE = DATA  
180 COOLING STORAGE COST = DATA  
185 HEATING STORAGE COST = DATA  
190 CENTRAL PLANT BOILER = DATA  
200 LAND BUILDING COST = DATA  
210 PIPING AUX = DATA  
220 CHILLER = DATA  
230 \*  
240 \* HEAT PUMP SIZED IN TONS  
250 HEAT PUMP SIZE = DATA  
260 \* HEAT PUMP COST IN \$/TON  
270 HEAT PUMP COST = DATA  
280 \*  
290 \* ENERGY IN BTUS  
320 TOTAL ENERGY = DATA  
330 COOLING ENERGY PERCENTAGE = DATA  
340 HEATING ENERGY PERCENTAGE = DATA  
350 PEAK COOLING = DATA  
360 PEAK HEATING = DATA  
370 INITIAL OPERATOR RATE = DATA  
380 COOLING COP = DATA  
390 HEATING COP = DATA  
400 INITIAL HEATING ENERGY RATE = DATA  
410 INITIAL DEMAND RATE = DATA  
420 HEATING RATE ESCALLATION = DATA  
430 HEATING LOAD FACTOR = DATA  
440 INITIAL COOLING ENERGY RATE = DATA  
450 INITIAL DEMAND RATE = DATA  
460 COOLING RATE ESCALLATION = DATA  
470 COOLING LOAD FACTOR = DATA  
480 ANNUAL CUSTOMER CHARGE = DATA  
490 HEATING OPERATING HOURS = DATA  
500 COOLING OPERATING HOURS = DATA  
510 PERCENTAGE MARKUP = DATA  
520 OPERATOR HOURS = DATA  
530 MAINTENANCE FACTOR = DATA  
540 SALVAGE VALUE = DATA  
550 \*



```

560 * NUMBER OF YEARS DEBT IS TO BE AMORTIZED OVER
570 YEARS = DATA
580 INSTALLATION COST = DATA
590 TREATMENT COST = DATA
600 ENGINEERING FACTOR = DATA
610 OPERATING AG = 0
620 SALES TAX = DATA
625 MATERIALS PERCENTAGE = DATA
630 TAX RATE = DATA
640 CONTINGENCY = DATA
650 SALARY ESCALLATION = DATA
660 RESERVE RENEWAL FACTOR = DATA
670 SELLING ADMIN = DATA
680 INSURANCE = DATA
690 POINTS = DATA
700 DOWNPAYMENT FACTOR = DATA
710 INVESTMENT TAX FACTOR = DATA
720 SQUARE FOOTAGE SERVED = DATA
730 * INVESTMENT FACTORS
740 FINANCED PORTION INTEREST = DATA
750 EXXON PORTION INTEREST = DATA
760 EXXON CONTRIBUTION = DATA
770 EXXON PAYMENTS START = DATA
780 EXXON YEARS = DATA
790 INITIAL EST TOTAL PU = DATA
800 EST ESC = DATA
810 *
820 * ENERGY AND DEMAND RATE ESCALLATION
830 *
840 HEATING ENERGY RATE = INITIAL HEATING ENERGY RATE, PREVIOUS HEATING ENERGY RATE *
850 (1 + HEATING RATE ESCALLATION)
860 COOLING ENERGY RATE = INITIAL COOLING ENERGY RATE, PREVIOUS COOLING ENERGY RATE *
870 (1 + COOLING RATE ESCALLATION)
880 DEMAND RATE = INITIAL DEMAND RATE, PREVIOUS DEMAND RATE *
890 (1 + COOLING RATE ESCALLATION)
900 DEMAND RATE = INITIAL DEMAND RATE, PREVIOUS DEMAND RATE *
910 (1 + HEATING RATE ESCALLATION)
920 *
930 * CALCULATION OF BLENDED RATES
940 *
950 ELECT HEATING RATE = HEATING ENERGY RATE + (DEMAND RATE / (730 * HEATING LOAD FACTOR))
960 ELECT COOLING RATE = COOLING ENERGY RATE + (DEMAND RATE / (730 * COOLING LOAD FACTOR))
970 *
980 * ENERGY COST CALCULATIONS
990 *
1000 COOLING OUTPUT ENERGY = TOTAL ENERGY * COOLING ENERGY PERCENTAGE
1010 HEATING OUTPUT ENERGY = TOTAL ENERGY * HEATING ENERGY PERCENTAGE
1020 COOLING ENERGY OUTPUT = COOLING OUTPUT ENERGY / 1000000
1030 HEATING ENERGY OUTPUT = HEATING OUTPUT ENERGY / 1000000
1040 ENERGY COST = ROUNDUP (PUMPING COST + PLANT ENERGY COST)
1050 PUMPING COST = ROUNDUP (COOLING PUMPING COST + HEATING PUMPING COST)
1060 HEATING INPUT ENERGY = HEATING OUTPUT ENERGY / (HEATING COP * 3413)
1070 COOLING INPUT ENERGY = COOLING OUTPUT ENERGY / (COOLING COP * 3413)
1080 PLANT ENERGY COST = ROUNDUP ((HEATING INPUT ENERGY * ELECT HEATING RATE) +
1090 (COOLING INPUT ENERGY * ELECT COOLING RATE))

```



```

1100 HEATING ENERGY COST=HEATING INPUT ENERGY*ELECT HEATING RATE
1110 COOLING ENERGY COST=COOLING INPUT ENERGY*ELECT COOLING RATE
1120 OPERATING COST = PUMPING COST + PLANT ENERGY COST + OPERATOR COST
1130 COOLING PUMPING COST = ELECT COOLING RATE * PUMP SIZE * COOLING OPERATING HOURS
1140 HEATING PUMPING COST = ELECT HEATING RATE * PUMP SIZE * HEATING OPERATING HOURS
1150 PUMP SIZE = (DISTRIBUTION PUMP SIZE + SOURCE PUMP SIZE) / 1.34
1160 *
1170 * PIPING AND PLANT COST
1180 *
1185 STORAGE COST = HEATING STORAGE COST + COOLING STORAGE COST
1190 SOURCE SYSTEM COST = SOURCE PIPE COST + SOURCE PIPE INSTALLATION + SOURCE PUMP STATION
1200 DISTRIBUTION SYSTEM COST = DISTRIBUTION PIPE COST + DISTRIBUTION PIPE INSTALLATION
1210 CENTRAL PLANT COST=HEAT PUMP COST + CENTRAL PLANT BOILER+CHILLER
1220 + LAND BUILDING COST + PIPING AUX + STORAGE COST
1230 HEAT PUMP = HEAT PUMP COST
1240 EQUIP COST = SOURCE SYSTEM COST + DISTRIBUTION SYSTEM COST + CENTRAL PLANT COST
1250 *
1260 * OPERATOR RATE ESCALLATION AND ANNUAL OPERATOR COST
1270 *
1280 OPERATOR RATE = INITIAL OPERATOR RATE,PREVIOUS OPERATOR RATE * (1+SALARY ESCALLATION)
1290 OPERATOR COST = OPERATOR RATE * OPERATOR HOURS
1300 OPERATING HOURS = HEATING OPERATING HOURS + COOLING OPERATING HOURS
1310 *
1320 * TAXES, A&G, SALVAGE, O&M
1330 *
1340 TAX = ROUNDUP(EQUIP COST * SALES TAX) * MATERIALS PERCENTAGE
1350 RESERVE RENEWAL =ROUNDUP( RESERVE RENEWAL FACTOR * LOAN PAYMENT)
1360 AG = ROUNDUP(OPERATING AG * (EQUIP COST + INSTALLATION COST + TAX + CONT))
1370 ANNUAL AG = OPERATING AG * (RESERVE RENEWAL + OPERATOR COST)
1380 CONT = ROUNDUP(CONTINGENCY * (EQUIP COST + INSTALLATION COST + TAX))
1390 SALVA =ROUNDUP((SALVAGE VALUE * (1 / Z))*(-1))
1400 OM = OPERATOR COST+MAINTENANCE COST+INSURANCE+SELLING ADMIN+ENERGY COST+
1401 ANNUAL CUSTOMER CHARGE
1410 ENGINEERING = ROUNDUP(ENGINEERING FACTOR*(EQUIP COST+INSTALLATION COST+TAX))
1420 MAINTENANCE COST = ROUNDUP(MAINTENANCE FACTOR * EQUIP COST)
1430 MISC = ROUNDUP(TAX+AG+CONT+ENGINEERING+SALVA)
1440 *
1450 * AMORTIZATION CALCULATION UTILIZING CONTINUOUS COMPOUNDING CAPITAL RECOVERY FACTOR
1460 *
1470 TOTAL EQUIP COST = ROUNDUP(EQUIP COST + TAX + CONT + AG+SALVA+ENGINEERING)
1480 INITIAL CAPITAL INVESTMENT = ROUNDUP(DOWN PAYMENT FACTOR * TOTAL EQUIP COST)
1490 FINANCED BASE = ROUNDUP(TOTAL EQUIP COST - EXXON CONTRIBUTION)
1500 COST OF FINANCING = ROUNDUP(POINTS * FINANCED BASE)
1510 BASE COST = FINANCED BASE + COST OF FINANCING
1520 AMORT(BASE COST,0,FINANCED PORTION INTEREST,YEARS,1,1,LOAN PAYMENT,
1530 INTEREST PORTION,PRINCIPAL PORTION,OUTSTANDING PRINCIPAL)
1540 YR = EXXON YEARS
1550 AMORT(EXXON CONTRIBUTION,0,EXXON PORTION INTEREST,YR,EXXON PAYMENTS START,
1560 1,EXXON PAYMENT,EXXON INTEREST,EXXON PRINCIPAL,EXXON OUTSTANDING)
1570 EXXON PERCENTAGE = EXXON CONTRIBUTION/TOTAL EQUIP COST
1580 FINANCED PERCENTAGE = 1 - EXXON PERCENTAGE
1590 DEBT SERVICE = ROUNDUP(LOAN PAYMENT+EXXON PAYMENT)
1600 *ANNUAL CAPITAL COST = BASE COST * INTEREST * Z / (Z-1)
1610 A = 1 + FINANCED PORTION INTEREST
1620 B = YEARS

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1630 Z = XPOWERY(A,B)
1640 *
1650 * ANNUAL COST
1660 *
1670 OPERATING COST=PUMPING COST+PLANT ENERGY COST+OPERATOR COST+INSURANCE+
1680     MAINTENANCE COST+SELLING ADMIN+ANNUAL CUSTOMER CHARGE
1690 OPERATION DEBT = OPERATING COST + DEBT SERVICE
1700 TOTAL ANNUAL COST = OPERATION DEBT + RESERVE RENEWAL
1710 *
1720 * TOTAL BTU OUTPUT IN MILLION BTUS
1730 TOTAL BTU =(HEATING OUTPUT ENERGY + COOLING OUTPUT ENERGY) / 1000000
1740 *
1750 * PER UNIT BTU COST CALCULATIONS
1760 *
1770 DEBT SERVICE PU = DEBT SERVICE / TOTAL BTU
1780 ENERGY PU = ENERGY COST / TOTAL BTU
1790 PUMPING COST PU = PUMPING COST / TOTAL BTU
1800 PLANT ENERGY PU = PLANT ENERGY COST / TOTAL BTU
1810 MAINTENANCE PU = MAINTENANCE COST / TOTAL BTU
1820 *VARIABLE OM PU = VARIABLE OM / TOTAL BTU
1830 CUSTOMER PU =ANNUAL CUSTOMER CHARGE / TOTAL BTU
1840 OPERATOR COST PU = OPERATOR COST / TOTAL BTU
1850 AG PU = ANNUAL AG / TOTAL BTU
1860 RESERVE RENEWAL PU = RESERVE RENEWAL / TOTAL BTU
1870 CONT PU = CONT / TOTAL BTU
1880 SELLING ADMIN PU = SELLING ADMIN / TOTAL BTU
1890 INSURANCE PU = INSURANCE/TOTAL BTU
1900 FIXED OPERATING COST = CUSTOMER PU+OPERATOR COST PU
1910     + MAINTENANCE PU+SELLING ADMIN PU+INSURANCE PU
1920 OPERATING COST = FIXED OPERATING COST * TOTAL BTU
1930 TOTAL PU =TOTAL ANNUAL COST / TOTAL BTU
1940 PW FACTOR = 1,PREVIOUS * 1.115
1950 PW TOTAL PU = TOTAL PU / PW FACTOR
1960 EXISTING PU = TOTAL PU - DEBT SERVICE
1970 PW EXISTING PU = EXISTING PU/PW FACTOR
1980 CUMM PW TOTAL PU = PREVIOUS CUMM PW TOTAL PU + PW TOTAL PU
1990 CUMM EXISTING PU = PREVIOUS CUMM EXISTING PU + PW EXISTING PU
2000 EST TOTAL PU = INITIAL EST TOTAL PU,PREVIOUS * (1 + EST ESC)
2010 PW EST TOTAL PU = EST TOTAL PU / PW FACTOR
2020 CUMM EST TOTAL PU = PREVIOUS CUMM EST TOTAL PU + PW EST TOTAL PU
2030 X = FIXED OPERATING COST + RESERVE RENEWAL PU
2040 Y = X + DEBT SERVICE PU
2045 *
2046 * ALLOCATION OF HEATING AND COOLING COST
2047 *
2050 COOLING COST PU= COOLING CAPITAL+COOLING ENERGY COST PU+COOLING OM+
2060     COOLING RR
2070 COOLING CAPITAL = DEBT SERVICE*(HEATING ENERGY OUTPUT/TOTAL BTU)/
2071     COOLING ENERGY OUTPUT
2080 COOLING ENERGY COST PU=(COOLING ENERGY COST+COOLING PUMPING COST)/
2090     COOLING ENERGY OUTPUT
2100 COOLING OM = (OPERATING COST*(COOLING OPERATING HOURS/
2110     OPERATING HOURS))/COOLING ENERGY OUTPUT
2120 COOLING RR = RESERVE RENEWAL*(HEATING ENERGY OUTPUT/TOTAL BTU)/
2121     COOLING ENERGY OUTPUT

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2130 HEATING COST PU= HEATING CAPITAL+HEATING ENERGY COST PU+HEATING OM+
2140     HEATING RR
2150 HEATING CAPITAL = DEBT SERVICE*(COOLING ENERGY OUTPUT/TOTAL BTU)/
2151     HEATING ENERGY OUTPUT
2160 HEATING ENERGY COST PU=(HEATING ENERGY COST+HEATING PUMPING COST)/
2170     HEATING ENERGY OUTPUT
2180 HEATING OM = (OPERATING COST*(HEATING OPERATING HOURS/
2190     OPERATING HOURS))/HEATING ENERGY OUTPUT
2200 HEATING RR = RESERVE RENEWAL*(COOLING ENERGY OUTPUT/TOTAL BTU)/
2201     HEATING ENERGY OUTPUT

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FILE REPORT PUBCOST 03/20/8613 31 08
10 NOCOMMENTS
20 NOINDENT
30 NEWPAGE 1
40 FORMAT .....10 $9,999,999
50 COLUMNS 1-10
60 CASELIST
70 CENTER LINCOLN DISTRICT HEATING SYSTEM
80 CENTER CAPITAL AND OPERATING COST
90 CENTER PUBLIC CASE
100 COLUMNS 1
110 * *** ASSUMPTIONS ***
120 FORMAT .....999,999,999
130 /TOTAL HMBTUS PRODUCED /TOTAL BTU
140 COOLING ENERGY OUTPUT
150 HEATING ENERGY OUTPUT
160 HEAT PUMP COST
170 /PROJECT LIFE/YEARS
176 /FINANCED PORTION/BASE COST
180 SALVAGE VALUE
190 FORMAT .....9.999
200 COOLING COP
210 HEATING COP
220 /HEATING RATE/ELECT HEATING RATE
230 /COOLING RATE/ELECT COOLING RATE
240 /FINANCED INTEREST RATE/FINANCED PORTION INTEREST
250 * DATE GENERATED *DATE*
270 FORMAT .....10 $9,999,999
280 COLUMNS 1-10
290 CENTER ANNUAL COSTS
310 SPACE 1
320 COLUMN TITLES 1987,1988,1989,1990,1991,1992,1993,1994,1995,1996
330 UNDERLINE
340 PUMPING COST
350 /PLANT ENERGY COST/PLANT ENERGY COST
360 /CUSTOMER CHARGE/ANNUAL CUSTOMER CHARGE
370 MAINTENANCE COST
380 OPERATOR COST
385 INSURANCE
390 SELLING ADMIN
400 UNDERLINE
410 /O & M/ OM
420 /DEBT SERVICE (7.5)/DEBT SERVICE
430 UNDERLINE
440 /OPERATION+DEBT SERVICE/OPERATION DEBT
450 /R&R (DEBT COVERAGE)/RESERVE RENEWAL
460 UNDERLINE
470 TOTAL ANNUAL COST
480 UNDERLINE=
500 * COST PER MILLION BTUS
510 UNDERLINE
520 FORMAT .....10 $99,99

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FILE DHCALL IFPS A STATE OF NEBRASKA VM/CMS TIMESHARING

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540 /DEBT SERVICE/DEBT SERVICE PU
550 /ENERGY COST/ENERGY PU
560 /O & M/ FIXED OPERATING COST
570 /R&R (DEBT COVERAGE)/RESERVE RENEWAL PU
580 UNDERLINE
590 /TOTAL PER UNIT COST/TOTAL PU
600 UNDERLINE=
610 /COOLING PORTION/COOLING COST PU
620 /HEATING PORTION/HEATING COST PU

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# Conversion Factors

| Multiply                                 | By                     | To Obtain                                |
|------------------------------------------|------------------------|------------------------------------------|
| acres                                    | $4.047 \times 10^3$    | square meters                            |
| acre-foot                                | $1.233 \times 10^3$    | cubic meters                             |
| amperes/square inch                      | $1.550 \times 10^3$    | amperes/sq meter                         |
| amperes/square meter                     | $6.452 \times 10^{-4}$ | amperes/sq inch                          |
| ampere-turns/inch                        | $3.937 \times 10^3$    | amp-turns/meter                          |
| ampere-turns/meter                       | $2.540 \times 10^{-3}$ | amp-turns/inch                           |
| atmospheres                              | $2.992 \times 10^3$    | Inches mercury (32 deg. F)               |
| atmospheres                              | $1.033 \times 10^3$    | kilogram/sq meter                        |
| atmospheres (760 torr)                   | $1.013 \times 10^3$    | kilopascals                              |
| barrels (oil)                            | $4.200 \times 10^3$    | gallons                                  |
| bars                                     | $9.869 \times 10^3$    | atmospheres                              |
| bars                                     | $1.000 \times 10^3$    | kilopascals                              |
| British thermal units (Btu)              | $3.927 \times 10^{-3}$ | horsepower-hours                         |
| British thermal units (Btu)              | 1.056                  | kilojoules                               |
| British thermal units (Btu)              | $2.928 \times 10^{-3}$ | kilowatt-hours                           |
| British thermal units (Btu)              | $1.221 \times 10^{-3}$ | megawatt-days                            |
| Btu/hr-square foot                       | $3.153 \times 10^{-3}$ | Watts/sq centimeter                      |
| Btu/hr-sq ft-deg. F                      | $5.676 \times 10^{-3}$ | W/sq cm-degrees Celsius                  |
| Btu/minute                               | $2.356 \times 10^{-3}$ | horsepower                               |
| Btu/minute                               | $1.757 \times 10^3$    | Watts                                    |
| calories                                 | 4.190                  | Joules                                   |
| centipoises                              | $1.000 \times 10^{-3}$ | Pascal-seconds                           |
| centistokes                              | 1.000                  | sq millimeter/sec                        |
| cubic feet                               | $2.832 \times 10^{-3}$ | cubic meters                             |
| cubic feet                               | $2.832 \times 10^3$    | liters                                   |
| cubic feet/min                           | $4.720 \times 10^{-3}$ | cubic meters/sec                         |
| cubic meters                             | $8.107 \times 10^{-4}$ | acre-foot                                |
| cubic meters                             | $3.531 \times 10^3$    | cubic feet                               |
| cubic meters                             | $2.642 \times 10^3$    | gallons (US)                             |
| cubic meters/sec                         | $2.119 \times 10^3$    | cubic feet/min                           |
| cubic meters/sec                         | $1.585 \times 10^3$    | gallons/min                              |
| degrees Celsius                          | (9/5) C+32             | degrees Fahrenheit                       |
| degrees Fahrenheit                       | 5/9 (F-32)             | degrees Celsius                          |
| feet                                     | $3.048 \times 10^{-3}$ | meters                                   |
| feet of H <sub>2</sub> O (39.2 deg. F)   | $3.048 \times 10^3$    | kilogram/sq meter                        |
| feet of H <sub>2</sub> O (39.2 deg. F)   | $4.335 \times 10^3$    | pounds/sq inch                           |
| feet/sec                                 | $3.048 \times 10^{-3}$ | meters/sec                               |
| foot-candles                             | $1.076 \times 10^3$    | lux                                      |
| foot-pound (force)                       | 1.356                  | Joules                                   |
| foot-pounds (force)/min                  | $2.260 \times 10^{-3}$ | Watts                                    |
| gallons                                  | $3.785 \times 10^{-3}$ | cubic meters                             |
| gallons/min                              | $6.309 \times 10^{-3}$ | cubic meters/sec                         |
| grains/gallon (US)                       | $1.712 \times 10^3$    | parts/million                            |
| horsepower                               | $4.244 \times 10^3$    | British thermal units/min                |
| horsepower                               | $7.457 \times 10^{-3}$ | kilowatts                                |
| horsepower (boiler)                      | $3.352 \times 10^3$    | British thermal units/hr                 |
| horsepower (boiler)                      | 9.803                  | kilowatts                                |
| horsepower-hours                         | $2.547 \times 10^3$    | British thermal units                    |
| horsepower-hours                         | $7.457 \times 10^{-3}$ | kilowatt-hrs                             |
| inches of H <sub>2</sub> O (39.2 deg. F) | $2.491 \times 10^{-3}$ | kilopascals                              |
| inches mercury (32 deg. F)               | $3.342 \times 10^{-3}$ | atmospheres                              |
| inches mercury (32 deg. F)               | $3.453 \times 10^3$    | kilograms/sq meter                       |
| inches mercury (32 deg. F)               | 3.386                  | kilopascals                              |
| inches mercury (32 deg. F)               | $4.912 \times 10^{-3}$ | pounds/sq inch                           |
| Joules                                   | $7.376 \times 10^{-3}$ | foot-pounds (force)                      |
| Joules                                   | 1.000                  | Watt-seconds                             |
| Joules                                   | $2.387 \times 10^{-3}$ | calories                                 |
| kilograms                                | 2.205                  | pounds                                   |
| kilograms                                | $1.102 \times 10^{-3}$ | tons (short)                             |
| kilograms/cubic meter                    | $6.243 \times 10^{-3}$ | pounds/cubic foot                        |
| kilograms/square meter                   | $9.678 \times 10^{-3}$ | atmospheres                              |
| kilograms/square meter                   | $3.281 \times 10^{-3}$ | ft H <sub>2</sub> O (at 39.2 deg. F)     |
| kilograms/square meter                   | $2.896 \times 10^{-3}$ | inches mercury (32 deg. F)               |
| kilograms/square meter                   | $1.422 \times 10^{-3}$ | pounds/sq inch                           |
| kilojoules                               | $9.471 \times 10^{-3}$ | British thermal units                    |
| kilopascals                              | 4.015                  | inches H <sub>2</sub> O (at 39.2 deg. F) |
| kilopascals                              | $1.450 \times 10^{-3}$ | pounds (force)/sq inch                   |
| kilopascals                              | $2.953 \times 10^{-3}$ | inches mercury (32 deg. F)               |
| kilopascals                              | $1.000 \times 10^{-3}$ | bars                                     |
| kilopascals                              | $9.869 \times 10^{-3}$ | atmospheres (760 torr)                   |
| kilowatts                                | 1.341                  | horsepower                               |
| kilowatt-hours                           | $3.413 \times 10^3$    | British thermal units                    |
| kilowatt-hours                           | 1.341                  | horsepower-hours                         |
| kilowatt-hours                           | $4.167 \times 10^{-3}$ | megawatt-days                            |
| liters                                   | $3.531 \times 10^{-3}$ | cubic feet                               |
| lux                                      | $9.290 \times 10^{-3}$ | foot-candles                             |
| megawatt-days                            | $8.189 \times 10^3$    | British thermal units                    |
| megawatt-days                            | $2.400 \times 10^3$    | kilowatt-hours                           |
| meters                                   | 3.281                  | feet                                     |
| Newtons                                  | $2.248 \times 10^{-3}$ | pounds (force)                           |
| parts/million                            | $5.840 \times 10^{-3}$ | grains/gallon (US)                       |
| Pascal-seconds                           | $1.000 \times 10^{-3}$ | centipoises                              |
| pounds                                   | $4.536 \times 10^{-3}$ | kilograms                                |
| pounds (force)                           | 4.448                  | Newtons                                  |
| pounds/cubic feet                        | $1.602 \times 10^3$    | kilograms/cu meter                       |
| pounds/square inch                       | 2.307                  | ft H <sub>2</sub> O (at 39.2 deg. F)     |
| pounds/square inch                       | 2.036                  | inches mercury (32 deg. F)               |
| pounds/square inch                       | $7.031 \times 10^3$    | kilograms/sq meter                       |
| pounds/square inch                       | 6.895                  | kilopascals                              |
| square feet                              | $9.290 \times 10^{-3}$ | square meters                            |
| square meters                            | $2.471 \times 10^{-3}$ | acres                                    |
| square meters                            | $1.076 \times 10^3$    | square feet                              |
| square millimeters/sec                   | 1.000                  | centistokes                              |
| tonnes                                   | $2.205 \times 10^3$    | pounds                                   |
| tons (short)                             | $9.072 \times 10^3$    | kilograms                                |
| Watts                                    | $5.688 \times 10^{-3}$ | Btu/minute                               |
| Watts                                    | $4.427 \times 10^3$    | foot-pounds (force)/minute               |
| Watt-seconds                             | 1.000                  | Joules                                   |
| Watts/sq centimeter                      | $3.171 \times 10^3$    | Btu/hr-sq ft                             |
| Watts/sq cm-deg. C                       | $1.762 \times 10^3$    | Btu/hr-sq ft-deg. F                      |