OPTUMR a digital computer program to cost optimize a district heat piping network to remove waste heat from nuclear power reactors

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OPTUMR

A DIGITAL COMPUTER PROGRAM TO COST OPTIMIZE A DISTRICT HEAT PIPING NETWORK TO REMOVE WASTE HEAT FROM NUCLEAR POWER REACTORS

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THESIS

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ABSTRACT

The thermal pollution problem of a nuclear reactor electrical generating facility can be eliminated if an economical, productive use for the waste heat can be found. The computer program presented here is designed to investigate the economic feasibility of utilizing this waste heat to heat buildings. The program optimizes a district heating network using the reactor's rejected heat and performs a comparative analysis with a selected conventional heat rejection system. The results indicate that the system is feasible only if the reactor can be sited relatively close (5 miles) to an urban center. Increasing national concern regarding thermal pollution and recently enacted legislation will tend to make this system more competitive so long as the current siting restrictions (about 10-12 miles) are not made more stringent.

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I. INTRODUCTION

The consumption of electrical power in the United States is doubling about every ten years [30][1]. To meet this increasing energy demand, the use of nuclear powered generating plants is currently considered by many to be the best solution. Among the many problems that have developed with the use of nuclear powered generating facilities is the increased thermal pollution from nuclear reactors as compared to fossil fueled plants. Although this problem exists in conventionally powered generating facilities, the nuclear powered plant rejects from ten to fifty per cent more waste heat than its conventionally powered counterpart.

The problem under consideration here is one possible solution to the thermal pollution problem by a nuclear powered generating plant. The heat rejected from a nuclear powered generating plant is low energy waste heat because the prime, high energy steam is used for electrical generation. If a practical use of this low energy waste heat cen be developed and exploited, then this major problem of nuclear powered generating plants can be solved.

A practical use of this low energy rejected heat is in a district heating network. This use has been investigated by A. J. Miller [22] and most dramatically by the Swedish experimental nuclear reactor Agesta[2]. In both of these investigations, it has been determined that, under proper conditions, the use of nuclear reactor waste heat to heat buildings can be profitable. To date, however, this scheme has not been utilized in the United States.

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1. Numbers in brackets indicate references in bibliography.
2. In some references the designation ADAM or R3 are used.

The most significant disadvantage of the nuclear district heating system is the requirement to provide continuous heat to the system. An unscheduled shutdown of the reactor could cause serious consumer relationships. However, because the current tendency in the nuclear industry is to construct multiple reactor sites, the solution to this problem is to design the nuclear plants such that either plant could provide the base heating requirements of district heating network. Further, the reliability problem can be alleviated using conventional heat sources for peaking service (with the additional capability of providing the base load requirements for short periods of time) as is done in the Agesta Plant. (See Page 5.)

To further develop this use of nuclear reactor waste heat, the digital computer program described herein has been developed to cost optimize and economically analyze a district heat distribution network. The program is designed for use by an electrical generating facility that is considering the use of nuclear reactor power generation. By supplying appropriate input data, the electrical utility can determine the feasibility of installing a district heat distribution system to remove the reactor's waste heat.

II. REVIEW OF LITERATURE

Probably the most frequently discussed topic in the United States today is pollution -- smog, industrial pollution, automobile pollution, radioactive pollution, and thermal pollution [21,24,30]. At the present time there are numerous legal struggles in progress attempting to stop the construction of industrial plants on pollution grounds or to cause the shutdown of existing plants because of excessive pollution. In addition to the legal struggles, there is a newly enacted law (The National Environmental Policy Act) which may bring about even more dramatic legal action [21]. Further, Jaske [19] reported that growing national interest in the thermal and radioactive pollution problems could ultimately prevent the construction of nuclear reactor generating facilities.

There are many proposed solutions to the thermal pollution problem. Among these are: 1. cooling towers [25], 2. natural convection cooling ponds [20], 3. spray cooling ponds [25], 4. concurrent electrical production and desalination [28], 5. use of waste heat for industrial processes [3], 6. melting of the Saint Lawrence Seaway in the winter [6], 7. more efficient methods of sewage treatment [4], 8. heated irrigation water [2], and 9. district heating systems [6,13, 22,31]. The first three methods can cause a severe mist or fog under certain weather conditions, particularly in the northern part of the United States, and, in general, require a relatively large makeup water supply. The next two require, in general, a higher energy source than the waste heat from a nuclear reactor. The remaining four have the disadvantage of being seasonal requirements. The district heating system, however, can be used to provide air conditioning [18] using an absorption air conditioning plant.

The preliminary investigation by the United States into the utilization of waste heat from nuclear generating plants for district heating was conducted by A. J. Miller under an Atomic Energy Commission contract [22]. The results of this investigation revealed that if the nuclear reactor could be sited a reasonable distance from an urban-industrial area (by a reasonable distance, five miles is considered a maximum), then the installation of a district heating network would be profitable.

In addition to Miller's investigation, the Swedish government has constructed and successfully operated the Agesta heavy water reactor in a district heating network [7,27,31]. The Agesta reactor is a 65 Megawatt Thermal (MwT), dual purpose (10 Mw Electrical, 55 MwT) reactor designed to produce electrical power and to heat the city of Farsta which is 10-15 miles from Stockholm. This reactor has been in operation since about 1964.

The Agesta reactor is located about three miles from Farsta. The justification for the proximity to the population center is that the reactor is built underground. (In fact, the reactor is built in a mountain under rock.) The district heating water from the reactor ties into an existing district heating distribution system. The nuclear reactor is designed to absorb the base heating load with conventional plants assuming the peaking loads. This load distribution is shown as Figure 1. The plant is shut down for maintenance in the summer months [27]. A summary of the parameters of the Agesta reactor are shown in Table I.

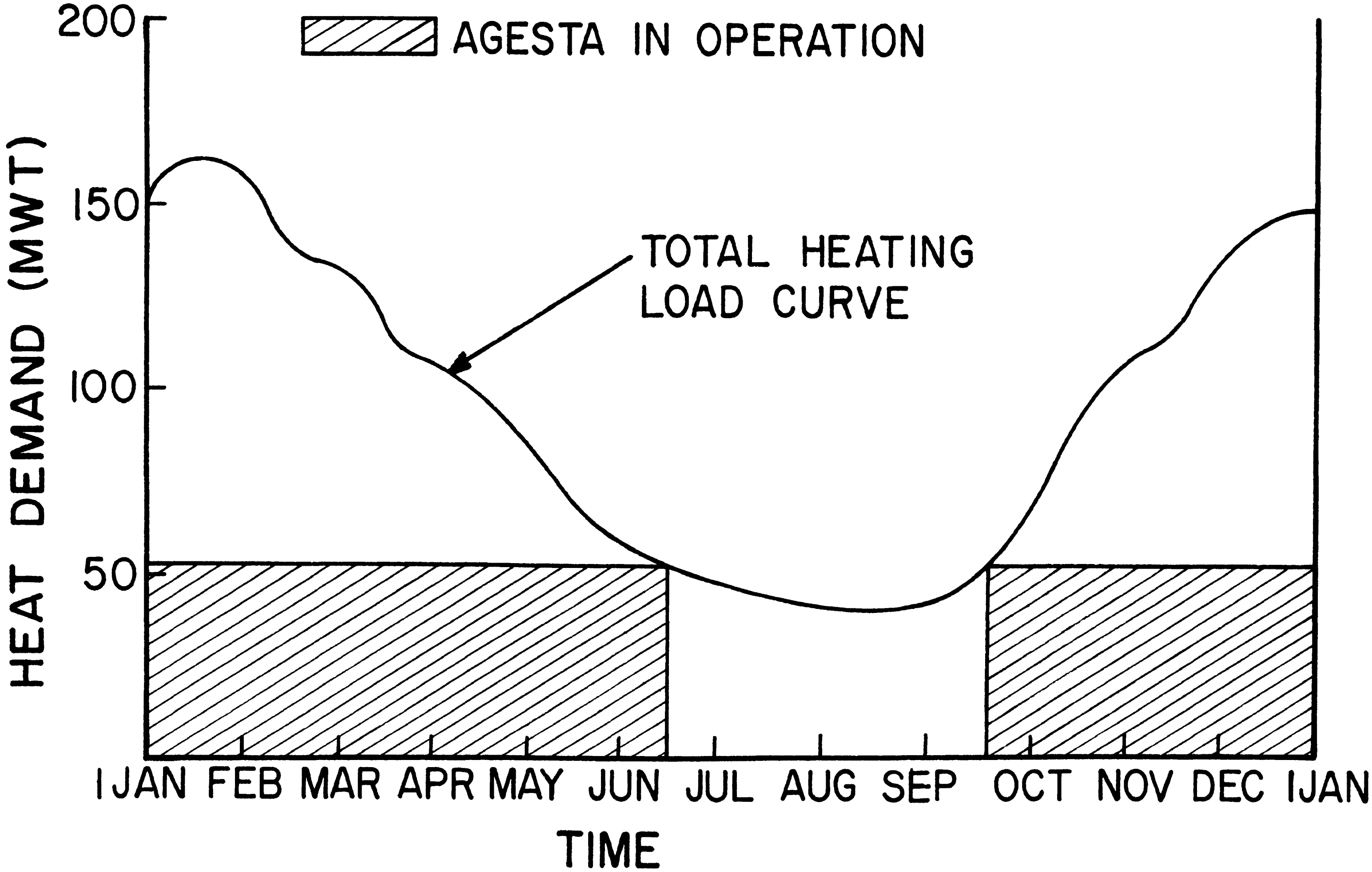

FIGURE 1. LOAD DISTRIBUTION OF FARSTA REACTOR

TABLE I

PARAMETERS OF AGESTA

Rating	55 Mw Thermal 10 Mw Electrical
Type	Pressurized, heavy water moderated and cooled, slightly enriched Uranium.
Flowrate	4,800,000 lbs./hour
Outlet Temperature	160 to 240 degrees F
Return Temperature	130 to 150 degrees F
Operating time	5000 to 6000 hours/year
Make up water when operating cooling towers	75 tons/hour

The economic performance of the Agesta reactor is not satisfactory [27]. This statement is made, even with consideration given to the reduction in size of conventional heat removal equipment, and the advantages gained from lesser maintenance expenses. (The Agesta has fully capable conventional heat removal system.) The problem with Agesta, however, is not in the district heating concept. The economic difficulties in Agesta are caused by severe losses of heavy water (D_2O) from the primary plant. The replacement cost of the D_2O has led to the development of a pressurized light water reactor for district heating [5].

The design, construction, operation and maintenance of district heating systems have been under development and used for many years [6]. Due to the volume of literature available dealing with these systems, a summary of the opinions of several authors [8,9,16,20,32] is presented:

1. The system should be installed underground.

2. A closed liquid system (e.g. water) should be used in preference to steam.

3. Due to the corrosiveness of the environment, the piping should be relatively corrosion resistant, insulated for protection, and encased in a conduit with provision for conduit drainage.

4. Adequate duplication of equipment, manholes, isolation capability, and instrumentation should be provided to increase the system's reliability.

These guidelines were used to prepare the computer program. In some cases, the user has the option of changing these guidelines. See Appendix D for input instructions.

III. DISCUSSION

The logical starting point of the district heating system analysis is at the heat source. A schematic diagram of a typical power reactor and the reactor's heat rejection system is shown in Figure 2. Figure 3 shows the heat rejection system for a typical reactor plant that has a district heating network capability. Since the systems are equivalent from the reactor to the condenser, for the rest of this discussion, the heat source is considered to be the condenser. Figure 3 shows that in addition to the district heating network, a small heat rejection system (cooling tower, cooling pond, etc.) would be installed. This would give the plant the capability of following minor transient heat demands on the district heating network while producing a constant amount of electrical power.

An automatic control system would sense the fluid temperature to the district heating network and the inlet to the condenser. The control system would then generate position commands for the automatically controlled throttle valves in the pump suction and condenser discharge lines. This would distribute the flow to the district heating network and to the tower to maintain the desired temperature. Figure 4 shows a block diagram of a simple analog circuit that will control the system as described above.

A. Simulation of Piping Network by an Electrical Circuit

The piping network that is proposed for installation as the district heat piping network is simulated using an electrical circuit to represent the network. The mass flowrate is treated as an electrical current; pressure drops are treated as voltage drops; and piping lengths, bends, traps, etc. are treated as resistors. Pumps

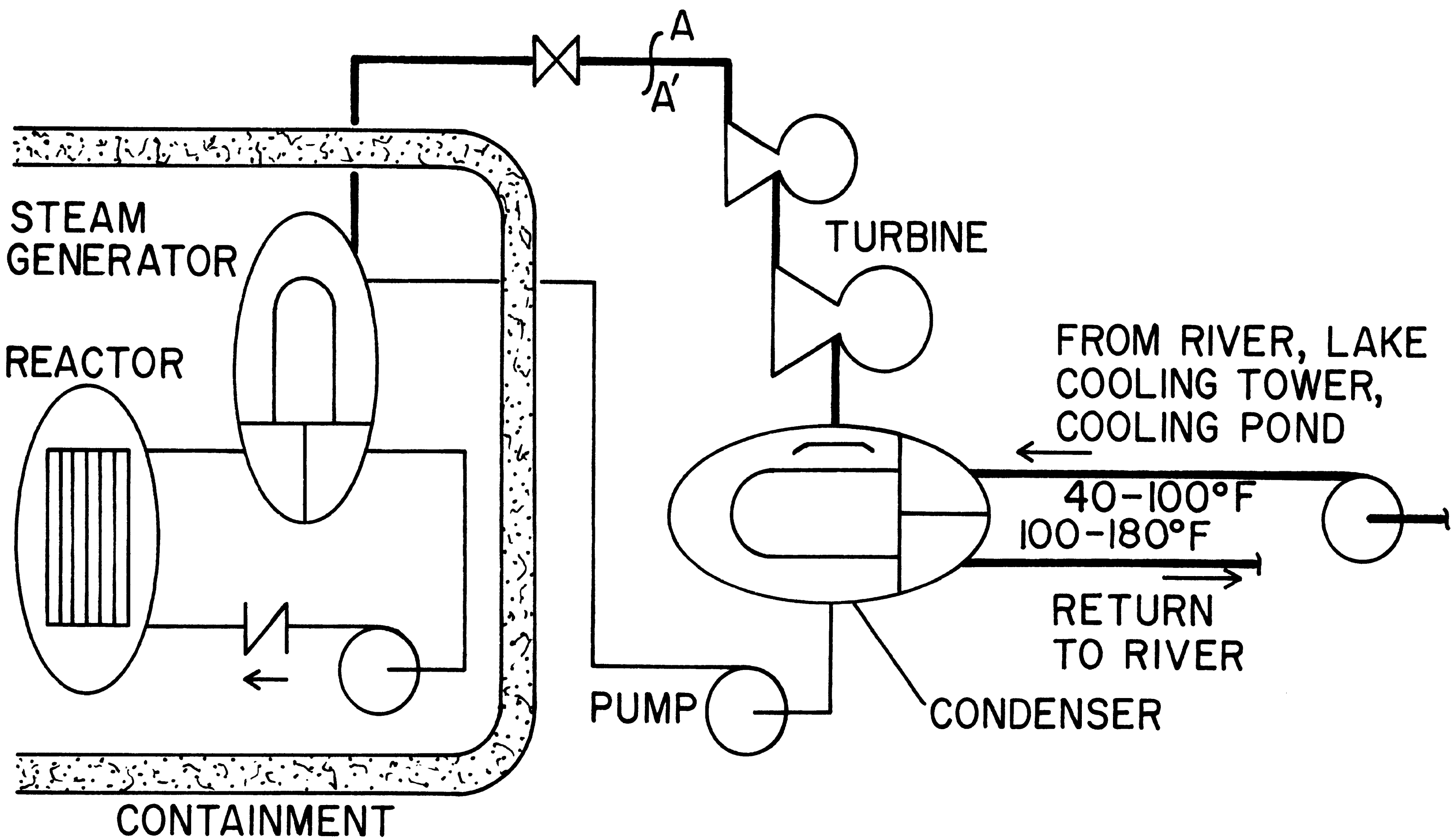

FIGURE 2. SCHEMATIC OF CONVENTIONAL REJECTION SYSTEM

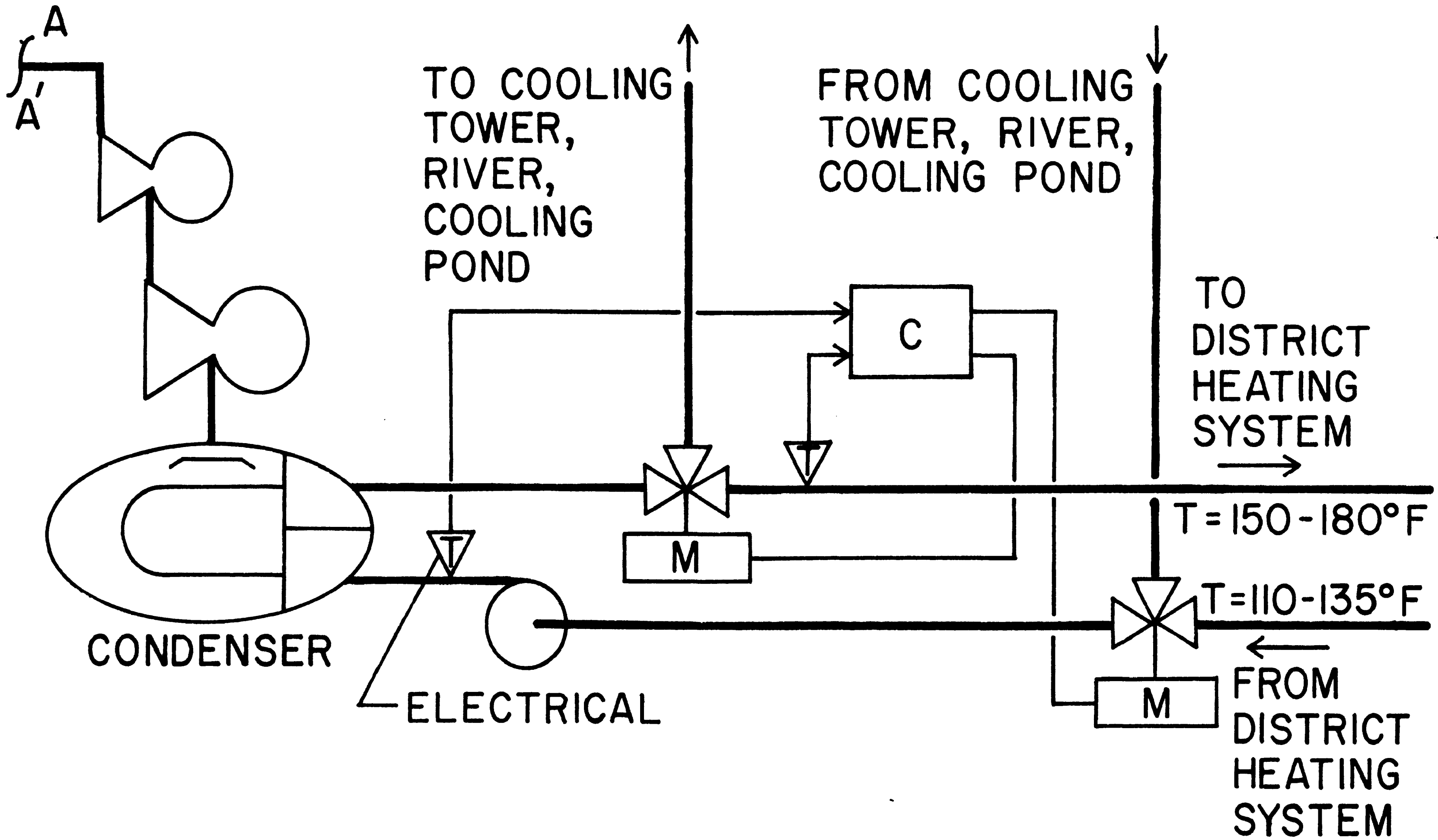

FIGURE 3. SCHEMATIC OF DISTRICT HEATING REJECTION SYSTEM

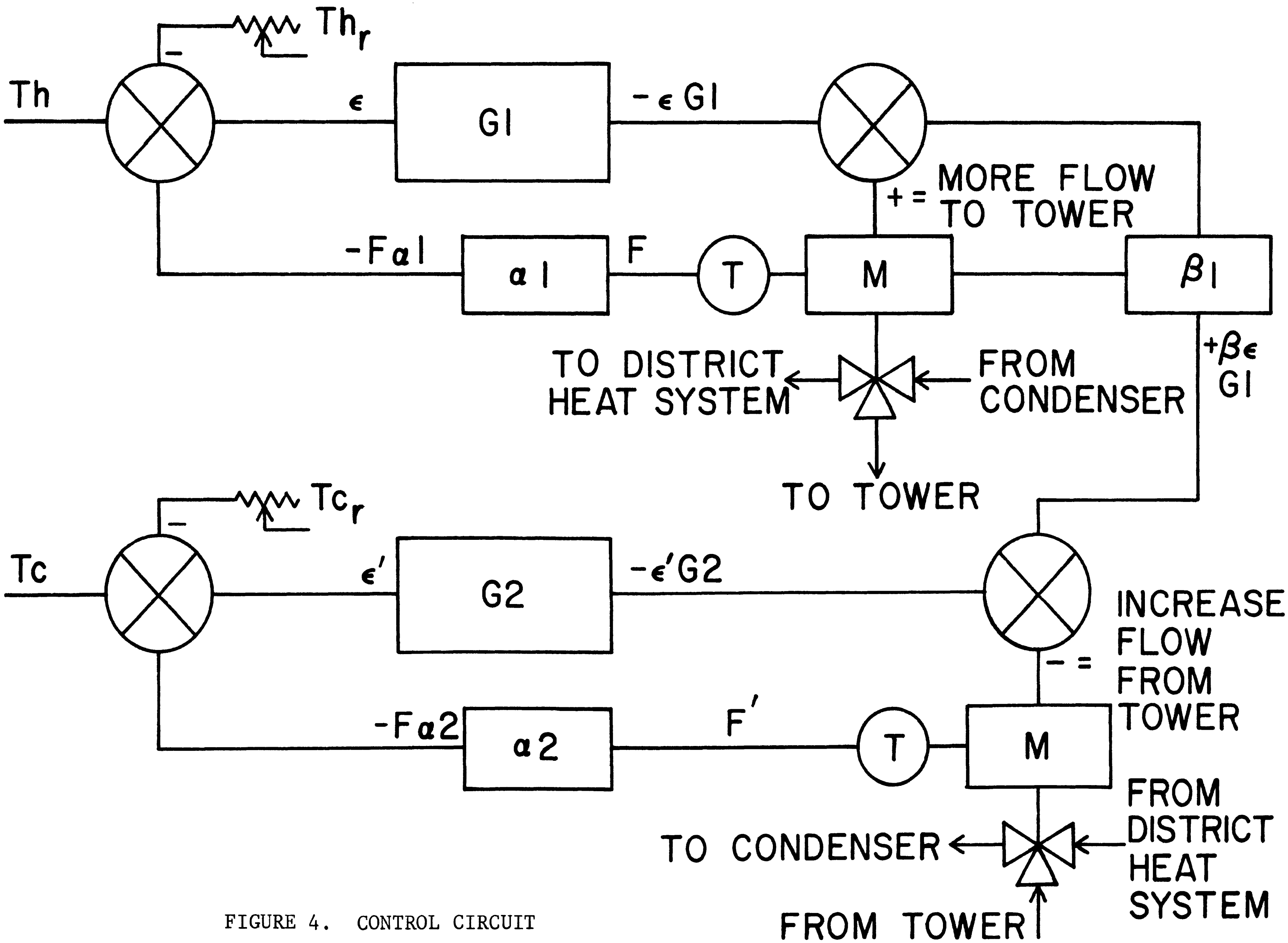

FIGURE 4. CONTROL CIRCUIT

are analyzed as voltage or current sources and the head losses, due to the fluid passing through the buildings, are treated as series resistors.

The principles used to accomplish this simulation are illustrated using Figures 5 and 6. Figure 5 shows a piping system that might be a typical, scale district heating system using a nuclear reactor's waste heat. The reduction of this network to an electrical circuit is shown in Figure 6. The current source is the representation of the pump; R1 is the line loss from the reactor to the city; R2,R3, R5,R7,R8, and R9 are the losses in the piping to and from buildings 2,3,5,7,8, and 9 of Figure 5; R4,R6,R10, and R11 are the losses in the lines between building groups; and R12 is the loss from the city back to the reactor.

Since the heating requirements for the buildings are known, one can readily compute the mass flowrates (currents) required for each building. A simple Kirchoff's node law application gives a mass balance at the nodes. In addition, one can readily calculate the pressure drops in each path of the network if one is given the size of piping required. The details of the above outlined technique are more fully explained in the next section and are illustrated by means of an example on page 40.

B. Reduction of the Circuit

Once the physical space heating network has been simulated by an electrical circuit, there is a reduction procedure that is employed to insure that:

1. All piping runs are optimized,

and

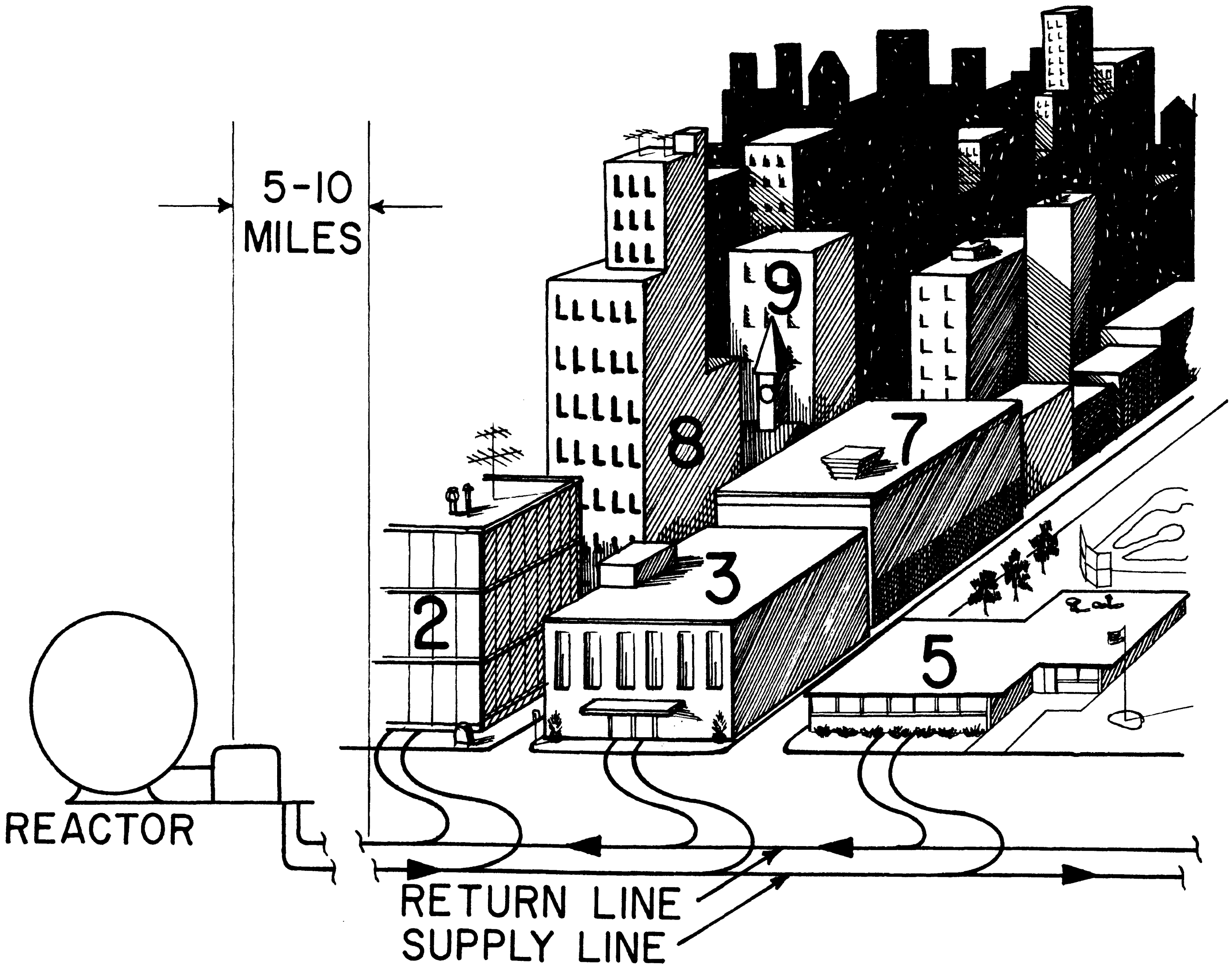

FIGURE 5. ARTIST'S SKETCH OF DISTRICT HEAT SYSTEM

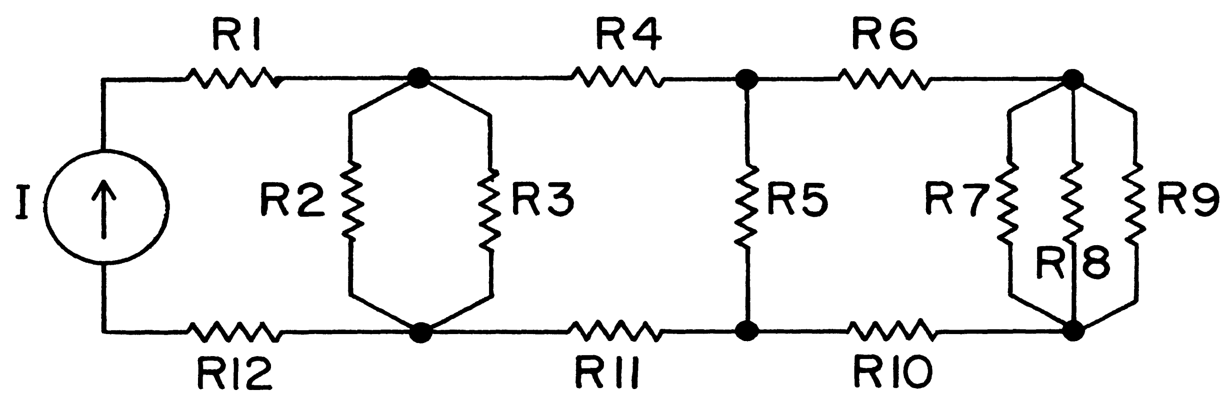

FIGURE 6. EQUIVALENT CIRCUIT DIAGRAM

2. No piping run has duplicate calculations performed.

To accomplish these objectives, the electrical network is step-by-step reduced in the manner discussed below.

The basic principle used is that any linear, purely resistive, two terminal electrical circuit can be simulated by an equivalent circuit composed of a voltage or current source and an equivalent resistance [10,17,23].

The reduction is accomplished by starting at the most distant flowpath from the reactor and by step-wise reducing the network until the entire system is optimized. This reduction is best illustrated by using the example problem shown in Figure 6. The step-by-step reduction is shown in Figure 7. This reduction technique is explained in more detail in Appendix D.

C. Theory of the Calculations

In this section, the basic equations and theory used in computing the cost and economic values are presented.

The calculations start with a given mass flow rate and an assumed diameter. From this data and the continuity equation

$$W = \rho \, A \, \overline{V} \, , \tag{1}$$

one can calculate the average velocity for a one pipe system. If more than one pipe of the same diameter is used, the flow is assumed to be equally distributed. Thus, by increasing the number of pipes, the average velocity can be reduced. This is done by the program to insure that $\overline{V}$ is less than the maximum desired by the programmer. For later use, it is also noted that the volumetric flowrate, Q, is given by

$$Q = A \, \overline{V} \tag{2}$$

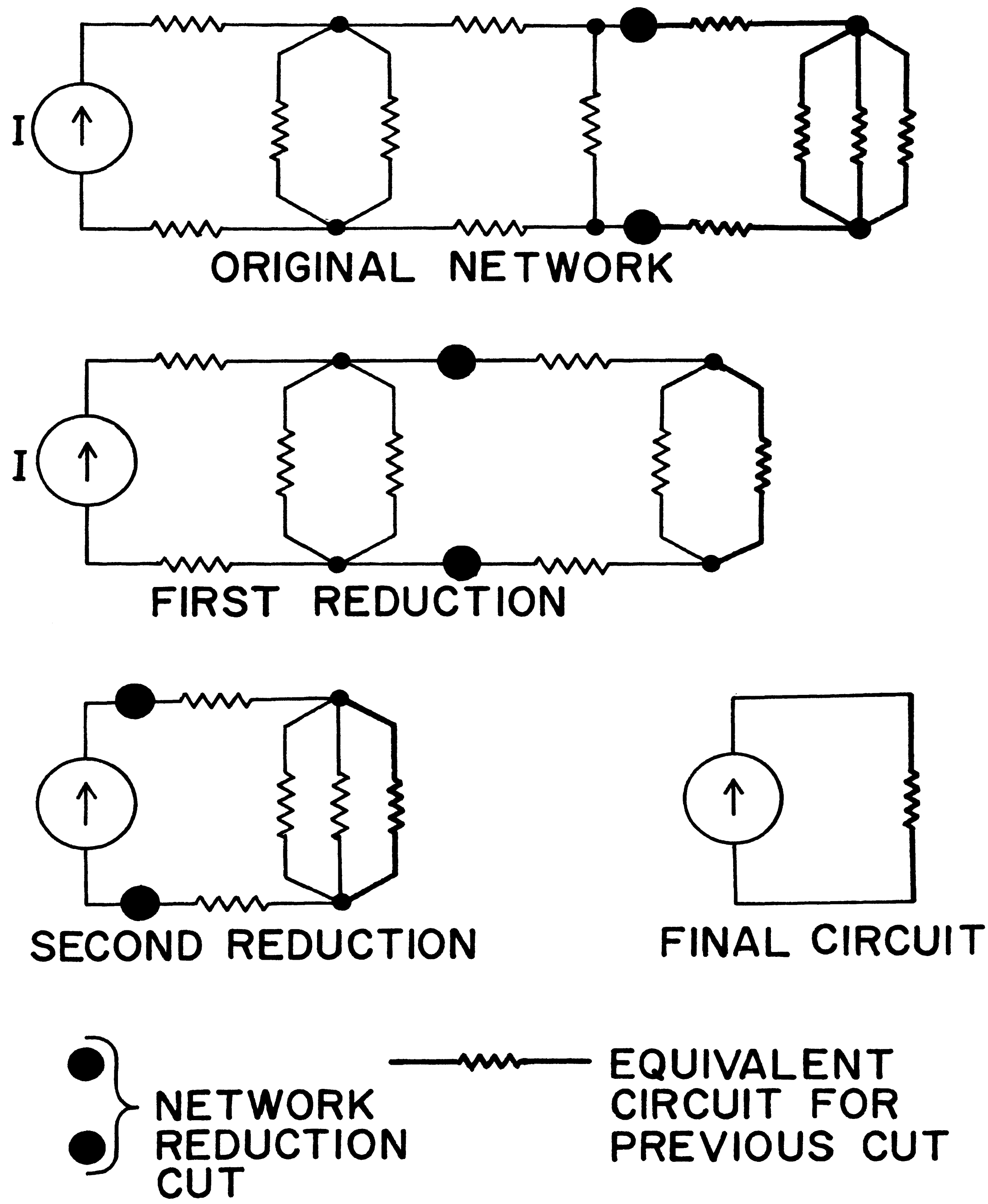

FIGURE 7. NETWORK REDUCTION

For incompressible, closed system fluid flow, the Bernoulli equation reduces to

$$H_{\ell} = \Delta p/\rho = \frac{4fL}{D} \frac{\overline{V}^2}{2gc} \qquad (3)$$

The unknown friction factor in equation 3 is computed using an emperical relationship [20] based on the Reynolds Number

$$RE = \frac{D\ V\ \rho}{\mu}\ , \qquad (4)$$

and the following relationships:

$$f = \frac{16}{RE} \qquad RE \leq 2200 \qquad (5)$$

$$f = 0.186 - .0026 \log RE \qquad 2100<RE<100000 \qquad (6)$$

$$f = 0.0025 \qquad RE \geq 100000 \qquad (7)$$

Summarizing the results, one has the head loss in the piping, volumetric flow rate, velocity and the number of pipes.

The installation costs that are computed are the pump cost, piping cost, excavation cost, insulation cost, conduit cost and manhole costs. In addition, a supplemental cost subroutine is provided to permit other cost inputs to be made. The cost estimation schemes for each of these items will be further described below.

Before describing the cost schemes in detail, however, some basic cost estimation techniques that are used frequently throughout the program will be described.

One of the most powerful tools of the cost estimator is the cost-price index [25,28,29]. For a variety of specific and general types of equipment, components, or operations, cost analysts compute a number called the cost-price index. A cost-price index is the ratio of the cost (price) of a specific item (e.g. a pump) at some specified time to the cost (price) of the same item at some other time. The advantageous feature of the cost-price index is the ability to accurately predict the cost of a specified item at some later time, using some previous time. If, for example, one had cost estimates for three different items: one based on 1965 dollars, one on 1967 dollars and one on 1969 dollars, the uncorrected addition of these costs to obtain a total cost would be in error. If, however, one uses the cost-price indices, one can adjust the costs to the same year. Further, using the same concept, one can estimate the cost at some future date.

Another tool for the estimator is the exponential estimation technique [25]. In this technique, one is given a base size of an item and a base price for that size. Then, to estimate the cost of the same item of a different size, one uses

$$\text{New Cost} = (\text{Base Cost}) \times \left(\frac{\text{New Size}}{\text{Base Size}}\right)^{a} \qquad (8)$$

Numerous references in the literature give values of the exponent, a, to use for various types of equipment. In general, this value lies from 0.4 to 1.5, average being about 0.6.

An extension of the exponent method is to have two values of item size and item cost. In equation 8, designate new cost, new size as cost 2, size 2; base values as cost 1, size 1. Thus,

$$\text{cost } 2 = (\text{cost } 1) \times \left(\frac{\text{size } 2}{\text{size } 1}\right)^{\text{expon}} \qquad (9)$$

Taking logarithms of (9),

$$\ln(\text{cost } 2) = \ln(\text{cost } 1) + (\text{expon}) \times \ln\left(\frac{\text{cost } 2}{\text{cost } 1}\right) \qquad (10)$$

Solving (10) for exponent

$$\text{expon} = \frac{\ln(\text{cost } 2) - \ln(\text{cost } 1)}{\ln(\text{cost } 2/\text{cost } 1)} \qquad (11)$$

Thus, one can calculate the exponent for use in equation 8.

Returning to the costs that are computed in the program, Table II indicates the options available for the cost calculations previously mentioned. In addition, the functional dependence of each cost is indicated. Notes are provided to explain the table.

D. Optimization Theory

There are an infinite number of combinations of pipe size and number of pipes that can transport fluid at a given rate. The principles of linear algebra can be used to describe the manner that the optimum size and number of pipes can be computed.

The first problem is to identify the independent variables that one can have. Certainly the mass flowrate, the number of pipes and the size of piping are independent variables. There are other independent variables (e.g. length), however, it is assumed that these variables are specified to fit the problem under consideration[3]. The result is that one has a three dimensional space in flowrate, number of pipes and size of pipes. This three dimensional space is not an infinite space. There are physical limitations imposed that reduce the space to a finite size. For example, the maximum pipe diameter commercially available is a finite number; the minimum

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3. For example, to get from the reactor to a building there are many conceivable paths of different lengths. However, one is going to select the one that is the most acceptable for the particular situation, and thus will specify the length and length will become a constant rather than a variable.

TABLE II

COST CALCULATIONS OPTIONS

	Cost Price Index	Table Cost vs. Size	Exponent Method	Extrapolated Exponent Method	Direct Input Method	Functional Relationship
Pump Cost	Yes	Yes	Yes	Yes	Yes	$N*Q^{.98}$ **
Pipe Cost	Yes	Yes	Yes	Yes	Yes	$N*L*D^{1.15}$
Excavation Cost	Yes	No	No	No	Yes	VOL*COST/VOL VOL=(2+N*D)(3+D) ***
Manhole Cost	Yes				Yes	L*DEPTH*HOLE COST/ # of ft. per hole
Insulation Cost	Yes				Yes	N*L*D*COST/ft.
Conduit Cost	Yes	Yes		Yes	Yes	$N*L*D^{.6}$
Pumping Cost	Yes				Yes	$N*H*\rho*Q/CONST$

** Exponents taken from reference

*** Assumes pipes side by side with 3 feet of earth on top number of pipes to be considered may be set by reliability criteria; the flowrate may be a specified flowrate.

In this problem, the constraints are chosen as follows:

1. Flowrate is fixed.
2. A maximum and minimum pipe diameter is specified.
3. A minimum number of pipes is specified.
4. A maximum velocity of fluid is specified. (This is not an independent variable. However, to define a finite region of interest in three dimensional space, a combination of three complete restraints is required. The flowrate is one restraint. The minimum and maximum diameter is a second restraint. The maximum fluid velocity and the minimum number of pipes combine to make the third restraint.)

Figure 8 shows a sketch of this three dimensional space and how these restraints define an operating line.

There are many dependent variables that could be chosen for an optimization scheme. Some of these could be:

1. minimize installation cost
2. minimize operating expense
3. minimize maintenance expense
4. minimize shut down time (maximize reliability)
5. minimize total costs
6. maximize profit

or

7. a combination of some or all of the above.

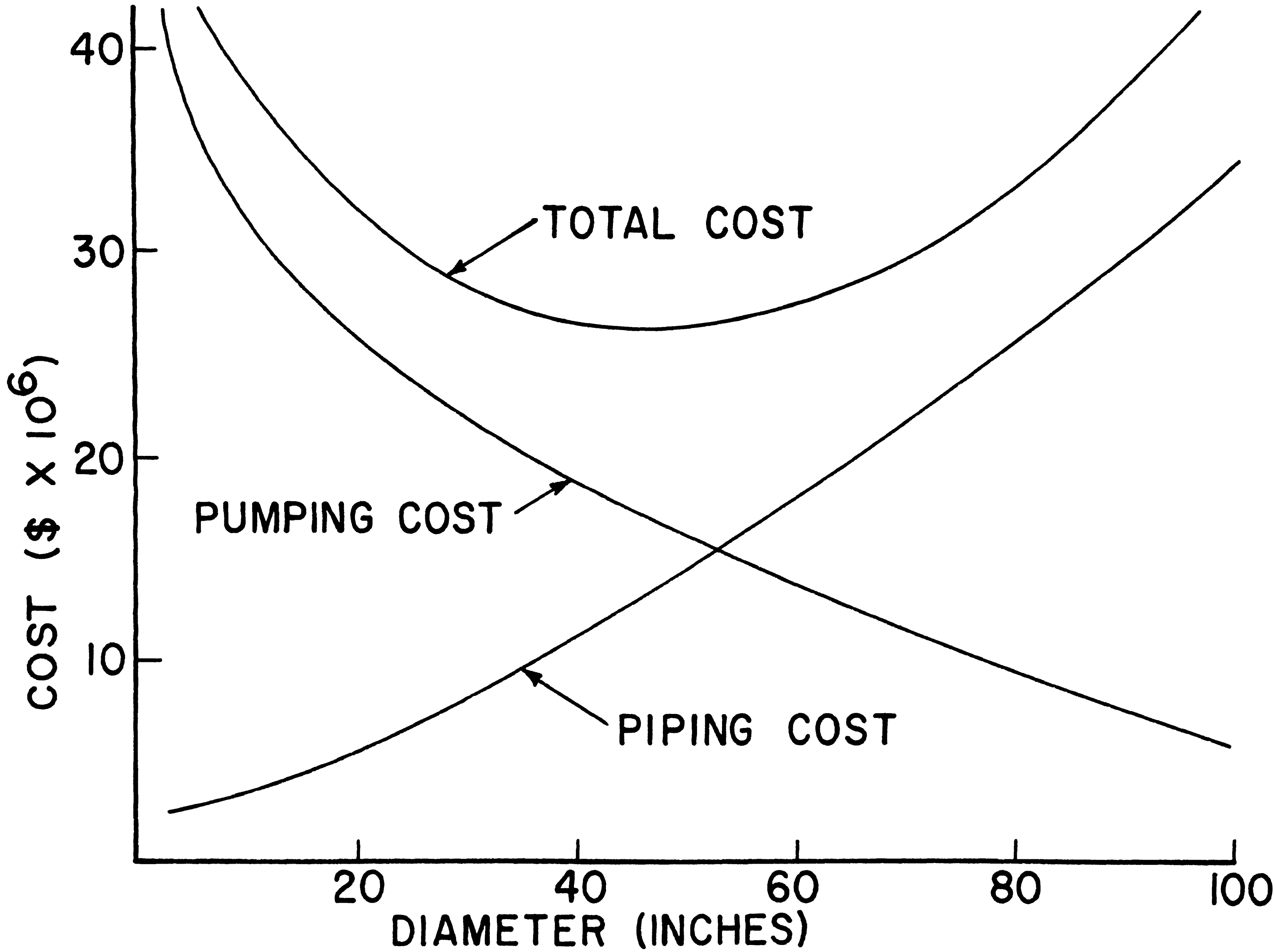

FIGURE 9. GENERAL COST CURVE

Two different schemes are available to be selected which will optimize the network as is described below[4].

The first of these schemes is an optimization based on the minimization of the cost of installing the network and the cost of operating the network for a specified period of time. The minimization of installation cost alone was not chosen as a basis for optimization due to the effect of operating expenses on the economic analysis[5]. Total cost was not chosen since the installation and operating expenses are the most important terms in the total cost analysis. The period of time for this optimization was chosen to be one year since the other economic considerations (depreciation, taxes, etc.) are annual charges. The user has the ability to change this time period if he desires. A description of the methods used to optimize the network using this technique follows.

Using the input data of flowrate (W), length of piping (L), and building loss (BLOSS), and the limits of pipe size to be considered, the program calculates the number of pumps and pipes required and the cost of the pumps, piping, excavation, insulation, manholes, conduits and any supplemental installation costs for a given piping diameter. It also calculates the pumping power cost for the specified period of time and pipe diameter as previously mentioned. The total of these cost items is then computed and stored in memory. In addition, the user can input right of way cost data and can input the

4. These schemes were selected by consideration of recommendations contained in reference [29].

5. Further details can be found in reference [26], pg 4-8 and pg 135-167.

economic advantage of installing the piping in rivers or lakes where no right of way expense is incurred.

The general form of the cost of installation and pumping cost is illustrated in Figure 9. As one can see, the total cost curve has a broad minimum that one should be able to find quite readily. However, the real world is not so simple. For the flow rates required by a heating system of the size under consideration, the economic feasibility and reality of the problem requires that a limit be placed on the velocity of fluid flowing in the pipes. This limiting velocity is input specified and determines the number of pipes and pumps required to move the quantity of fluid required. Thus, as the diameter varies, so does the number of pipes, pumps, etc. The result of this is the curve shown in Figure 10. As one can see, the curve is now discontinuous. (The discontinuities are caused by changing the number of pipes.)

One method of finding the minimum would be to take the range of pipe sizes under consideration, start at the smallest and proceed through to the largest in a step-by-step manner (hereafter referred to as a march-out technique). The optimum size would be the smallest total cost found while conducting the march-out technique. This method, however, can be very costly in computer time and a better technique has been found.

Referring to Figures 9 and 10, the cost is computed for the maximum size, the minimum size and the medium size (K1,K2, and K3 on Figure 10). A smooth curve is then fit to the points and the curve is analyzed for shape. Three possible shapes exist and are shown in Figure 11. If the curve orientation is as in Figure 11A, then

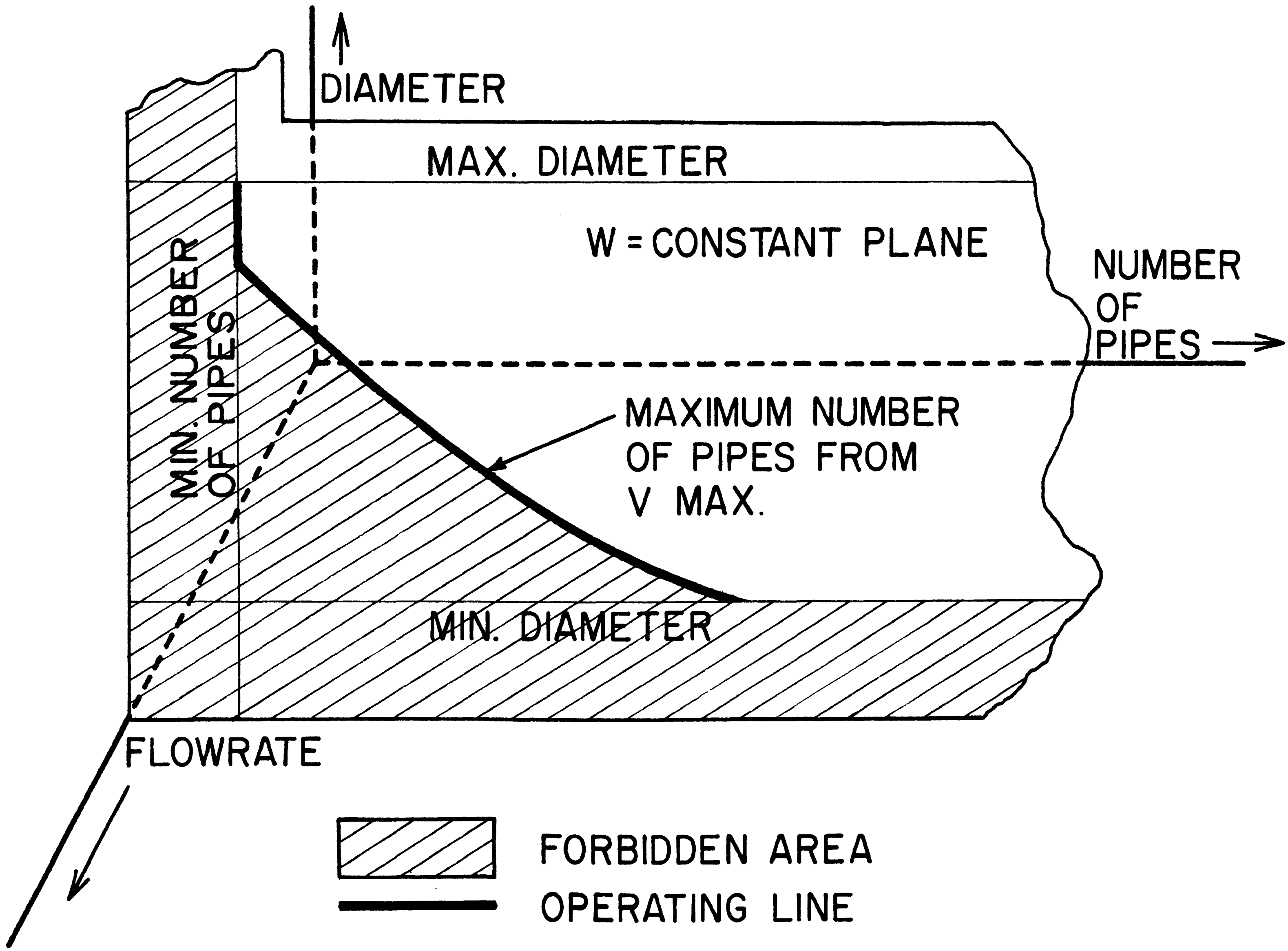

FIGURE 8. THREE DIMENSIONAL OPTIMIZATION SPACE

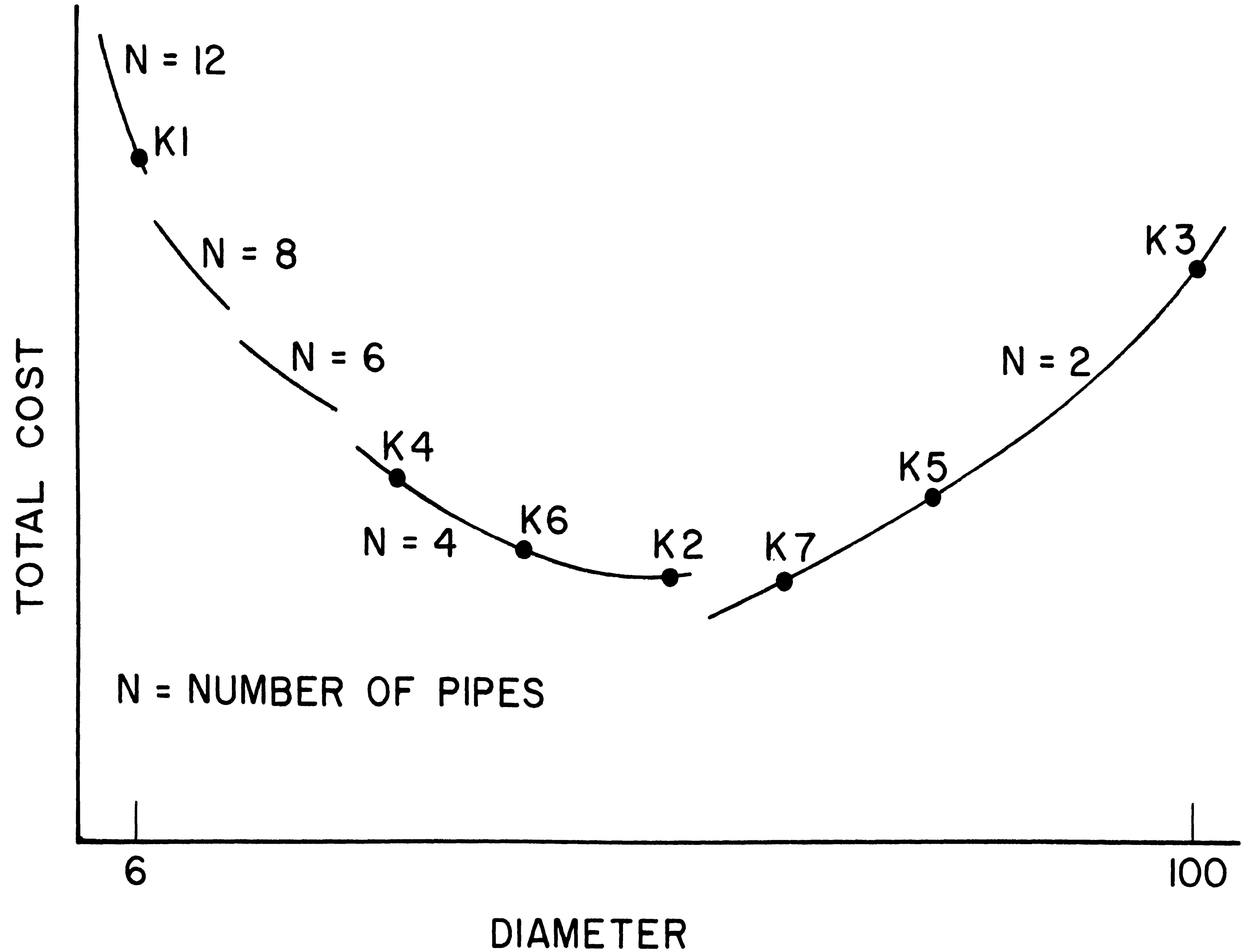

FIGURE 10. DISCONTINUOUS COST CURVE

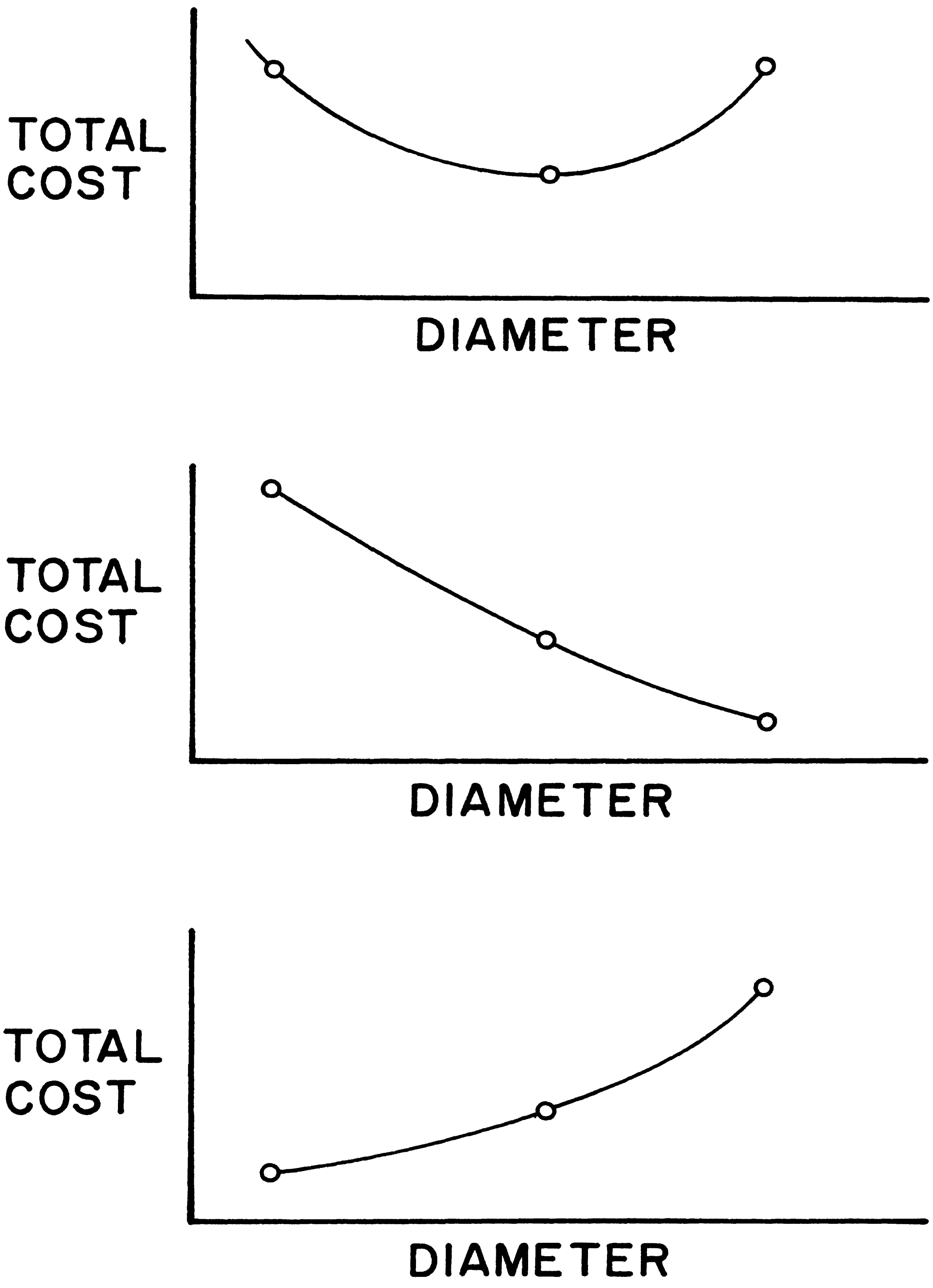

FIGURE 11. THREE POSSIBLE CURVE SHAPES

costs for sizes K4 and K5 are computed. The shape of the curve that fits through K4,K2 and K5 is then checked. If the shape is as in Figure 11A, the process is repeated (K6,K7 of Figure 10) until the orientation changes to 11B or 11C, or until K2 is found to be the minimum. When the orientation changes to either 11B or 11C (as it does in Figure 10 using points K6,K2, and K7), then the march-out procedure is used from a little before the smaller diameter to a little beyond the larger diameter. Thus, one finds the minimum using considerably less computer time than a straight march-out technique.

The second method of optimization is to maximize the profit that can be made. This is done by calculating the hourly financing cost, operating and maintenance costs, the pumping costs and then comparing these values with the hourly gross income from the sale of heat for a march-out of the pipe diameters. The maximum net income is found from this march-out technique. This is then taken to be the optimum size for maximum return or investment and a full set of cost calculations and cost analysis is performed.

E. Economic Analysis

The economic analysis is a basic discounted cash flow type of analysis. This type of analysis is a summary of all cash assets and liabilities as either cash inflows or as cash outflows on an annual basis. A net cash flow is the algebraic sum of the cash inflows and the cash outflows. The net cash flow for each year is then adjusted to the plant start-up time for the time value of money by applying an appropriate adjustment factor. This factor is obtained from a continuous interest table or from the equation

$$\text{factor} = e^{-rt} \left[\frac{e^{r} - 1}{r} \right] \tag{12}$$

In principle, this type of analysis is quite easy. The result of this analysis is the return on investment rate, r, which appears in the factor term in a rather complicated fashion requiring a trial and error type of solution.

The elements of the cash flow analysis are the fixed capital investment (assumed to be expended one year before start-up), operating and maintenance expenses, financing charges, insurance, taxes, overhead, taxes, miscellaneous annual expenses and the gross income from the sale of heat.

In the proposed system, there is a possibility that the system may not be a profitable investment. There are situations, however, which may justify the use of a non-profitable investment. Consider, for example, the situation that is developing in the field of electrical generation. At the projected rate of growth, the available cooling water supply that can be used without severely disturbing the ecological balance will soon be exhausted [24]. The use of rivers, lakes and streams for cooling of the generating facilities will therefore be precluded.

Continuing with the example, local legislation may forbid the use of cooling towers due to the severe fog and mist problems associated with cooling towers. Further, similar difficulties could be encountered in the other possible methods of heat rejection. The extreme case would be that the district heat rejection method would be the only acceptable method of heat rejection. Thus, as previously asserted, the use of a non-profitable system could be justified.

To make a meaningful analysis of the district heating system of heat rejection, an analysis of the cost of this system versus the cost of the alternative system must be made. The ultimate test of the district heating system can be stated as follows: Is the district heating system of heat rejection the least expensive method compared to the alternative methods (if any)? The method chosen to answer this question is described below.

Consider a district heating system that is not profitable. Adjustments to the cost of installation of the district heating system are made by computing the cost of construction and operation of a selected alternative system. This cost is then subtracted from the district heating systems cost. In addition, a factor can be specified to account for the intangible benefit of no thermal pollution. If, by repeating the cash flow analysis, the district heating system can then be shown to be profitable, the district heating system should be installed. Further, even if this adjusted system analysis does not show a true profit, but does yield an acceptable pay out time[6], the district heating system should be installed.

The adjusted economic analysis can reveal that the installation of a district heating system will not be profitable nor will yield an acceptable pay out time. However, the decision to install this system could still be made for better public relations or to gain technology in the field. To encourage this, the program calculates

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6. As used here, pay out time is the number of years to regain the capital investment.

the incremental increase in selling price of heat or selling price of electricity that would be required to pay off the plant in the specified lifetime.

F. Safety

A discussion of a project using nuclear reactors in any manner is not complete until a safety analysis of some sort is performed. It is assumed that the reactor plant and its' associated equipment meets the requirements set forth in Title 10 of the Code of Federal Regulations. With this assumption, the only safety analysis required is just the analysis of the district heating system.

The primary safety concern of a nuclear reactor is the release of radioactivity to the environment in such a manner that would be detrimental to the general population. The general criterion set forth in the federal regulations is that at least two barriers against release of radioactivity be provided.

Consider a boiling water reactor with a district heating system installed. (This reactor type is chosen because the possibility of radioactivity in the condenser is greatest for this type reactor.) The only source of radioactivity to the fluid in the system would be leakage from the condenser into the district heating system fluid. The tube walls of the condenser serve as the first barrier. The second barrier is a potential barrier. The condenser is operated in a slight vacuum while the district heating system is pressurized to about 200-300 pounds per square inch at the condenser. Thus, any leakage that would occur in the condenser tubes would be <u>from</u> the district heating system <u>into</u> the condenser. Further, the district heating system piping would serve as a third barrier. A periodic or continuous monitoring of the district heating system fluid for radioactivity would serve as an independent control.

The other serious problem (Maximum Credible Accident) is the effect of a major rupture in the district heating system. Since the reactor is protected against a loss of cooling system, all that need be considered is the effect on the district heating system. Since the major portion of the piping is underground, the effect of this accident would be slight if the rupture occured in a portion of the piping that is underground. However, one might consider the rupture of the pipe line inside a building. As one can readily see, this accident is the determining factor in the choice of fluid that is used. If steam were used, this accident would be very serious because of the high temperatures and high internal energy of the steam. Further, isolation of a steam system will not stop the steam flow from the rupture. However, since water is used, the rupture would cause an almost instantaneous depressurization of the system. This would then lead to hot (170-180 degree) water being pumped into the building at low pressure. With automatic isolation capabilities sensed by a severe pressure transient installed, the effect of this accident is only that a small quantity of fairly high temperature water is sprayed into a building. This hot water could cause some damage; however, the probability of this accident being serious is fairly low.

IV. COMPUTER PROGRAM FLOW DIAGRAM

Figure 12 shows a block diagram which indicates the flow control of the computer program. The figure consists of a flow diagram for the main program, a flow diagram for each of the three path types (series, parallel and series-parallel) and a flow diagram for the two optimization schemes (minimization of installation cost and pumping cost, and maximization of the rate of return on investment).

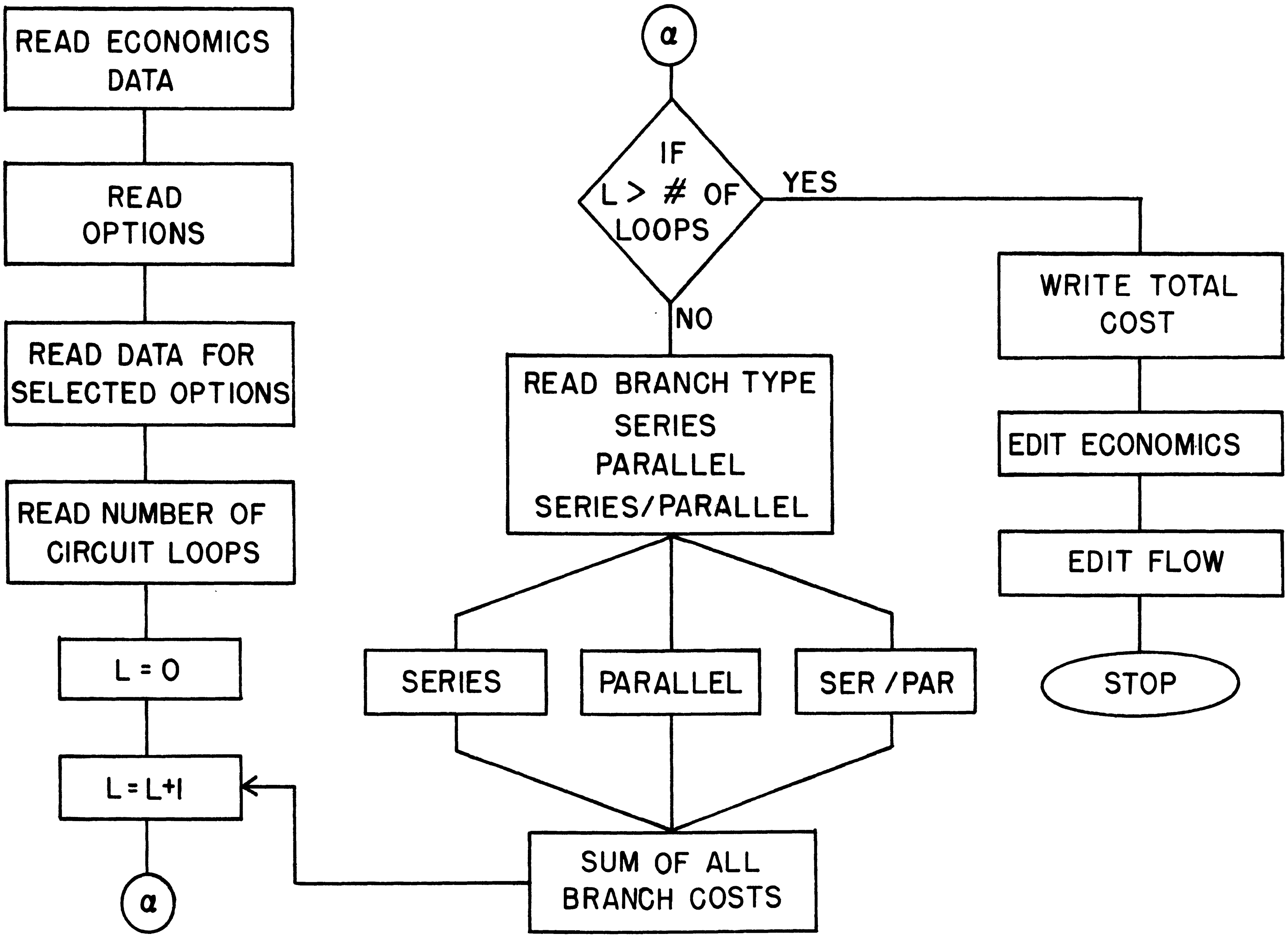


FIGURE 12. COMPUTER PROGRAM FLOW DIAGRAM

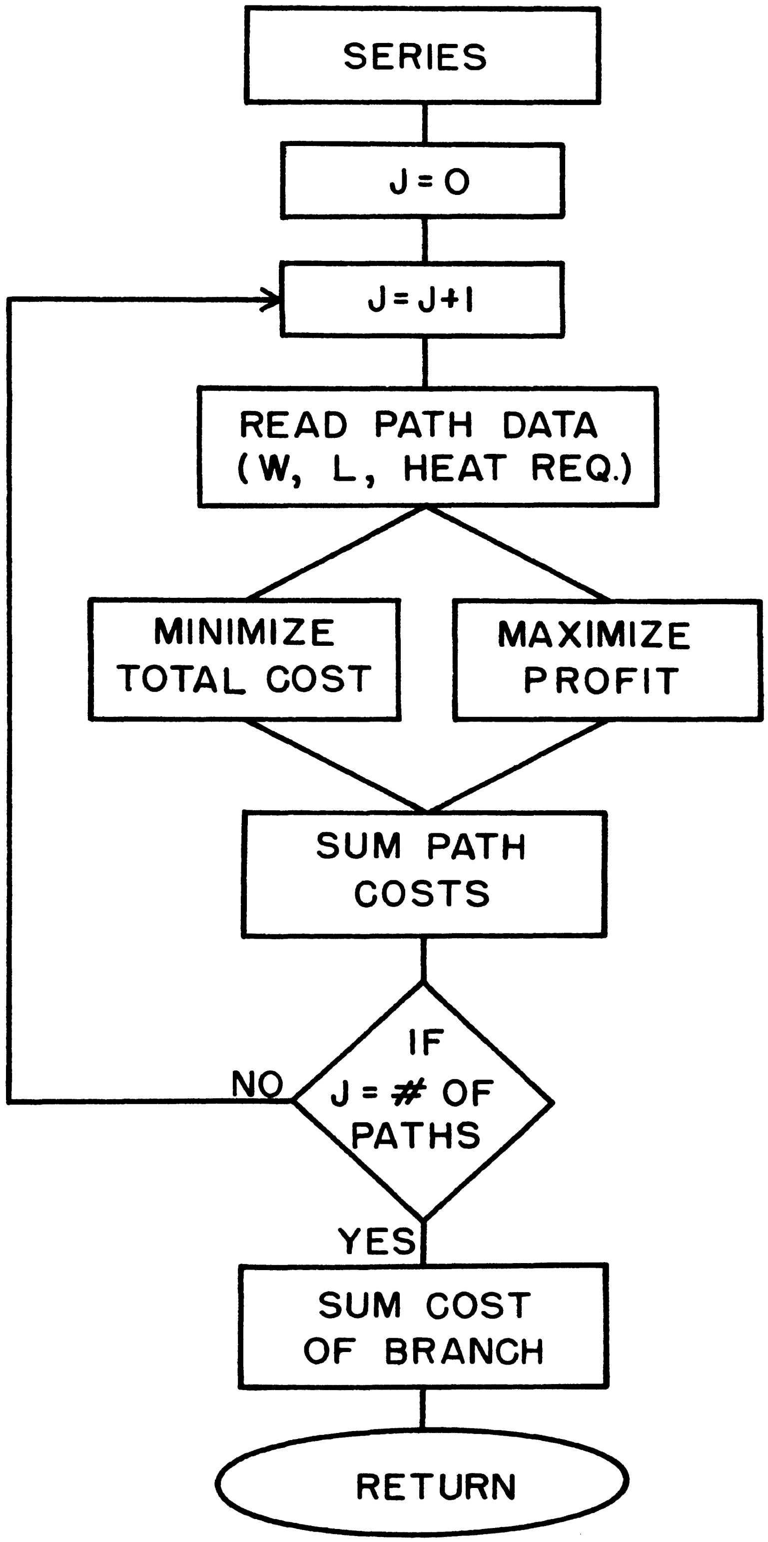


FIGURE 12. (CONT'D)

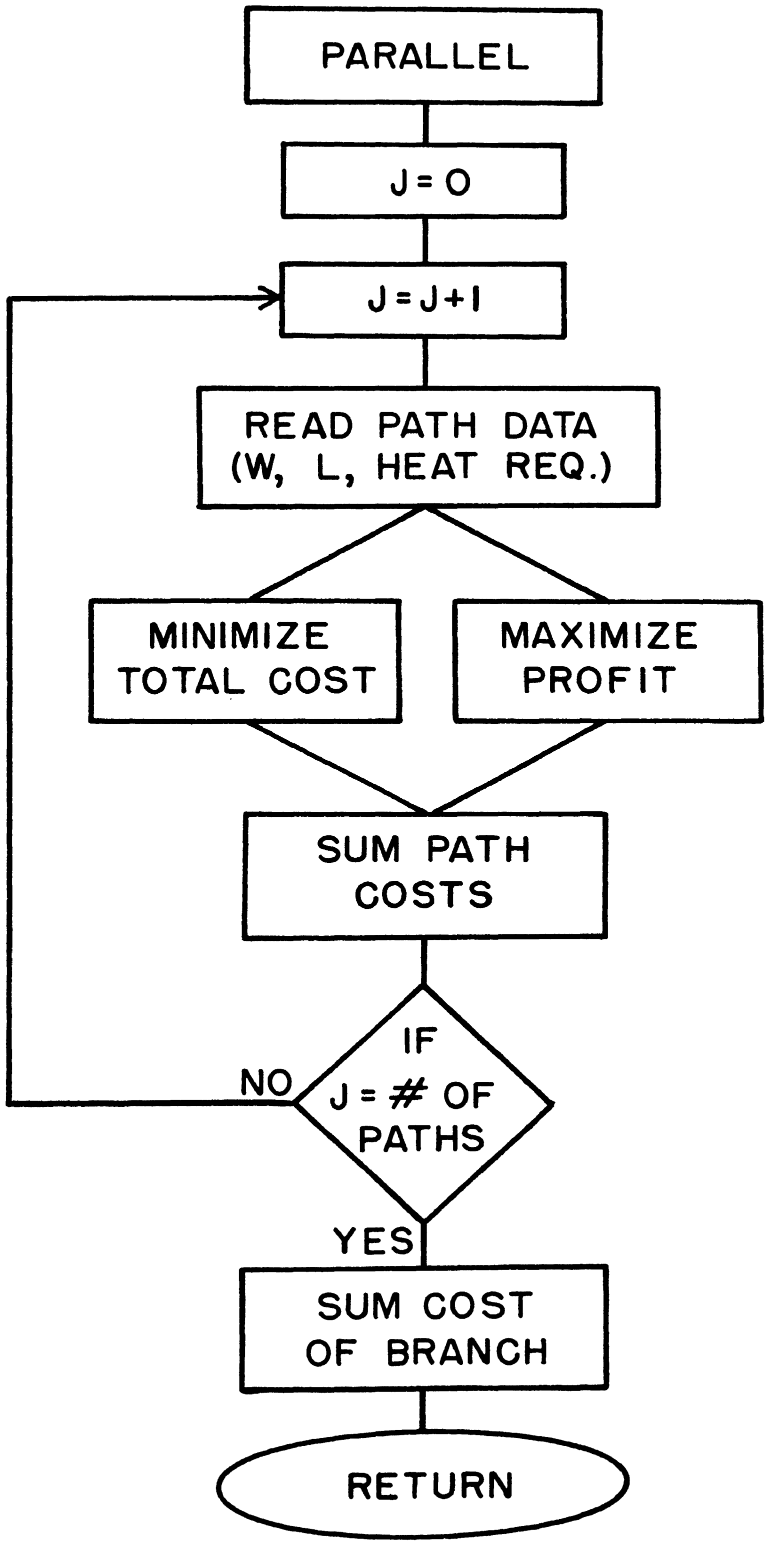


FIGURE 12. (CONT'D)

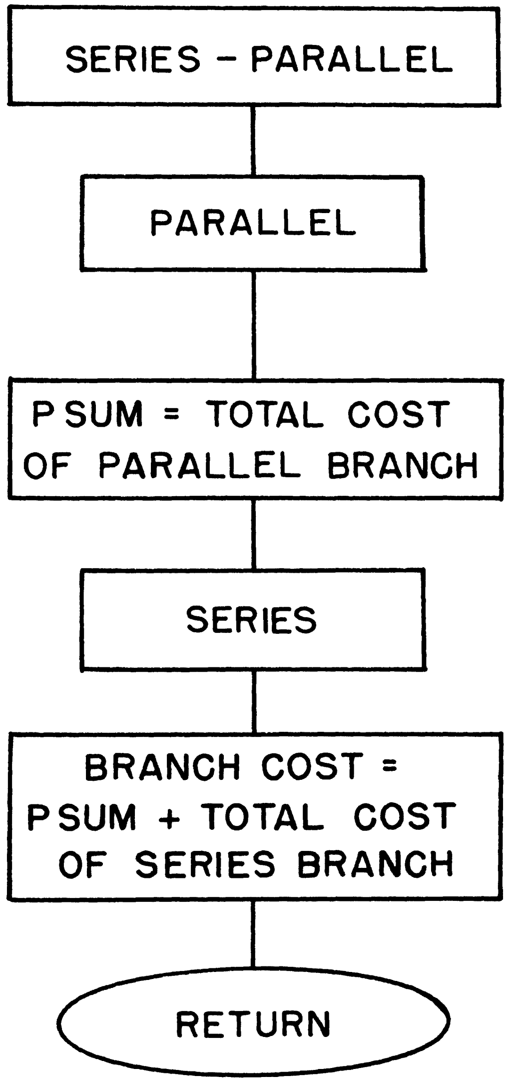


FIGURE 12. (CONT'D)

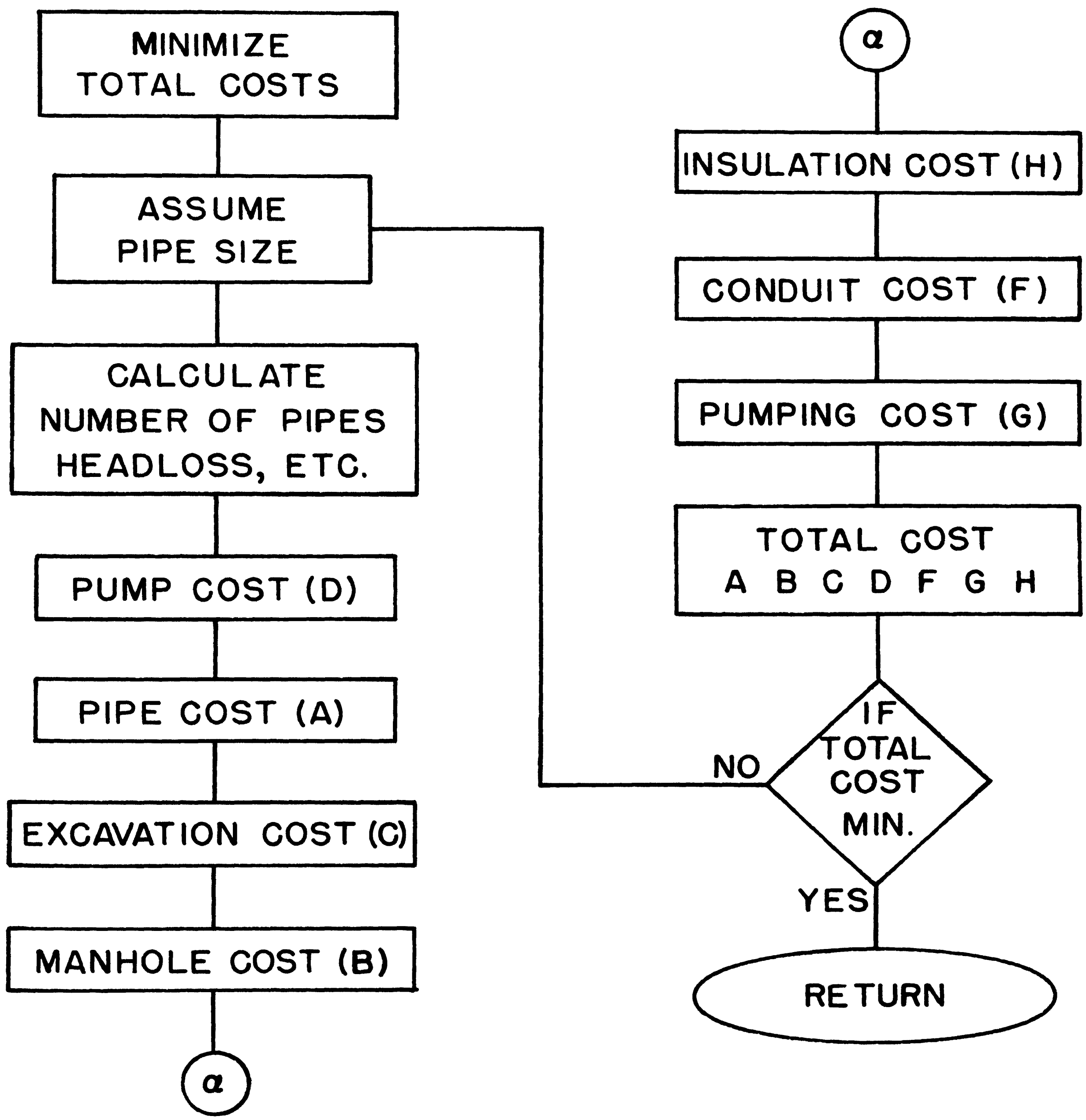


FIGURE 12. (CONT'D)

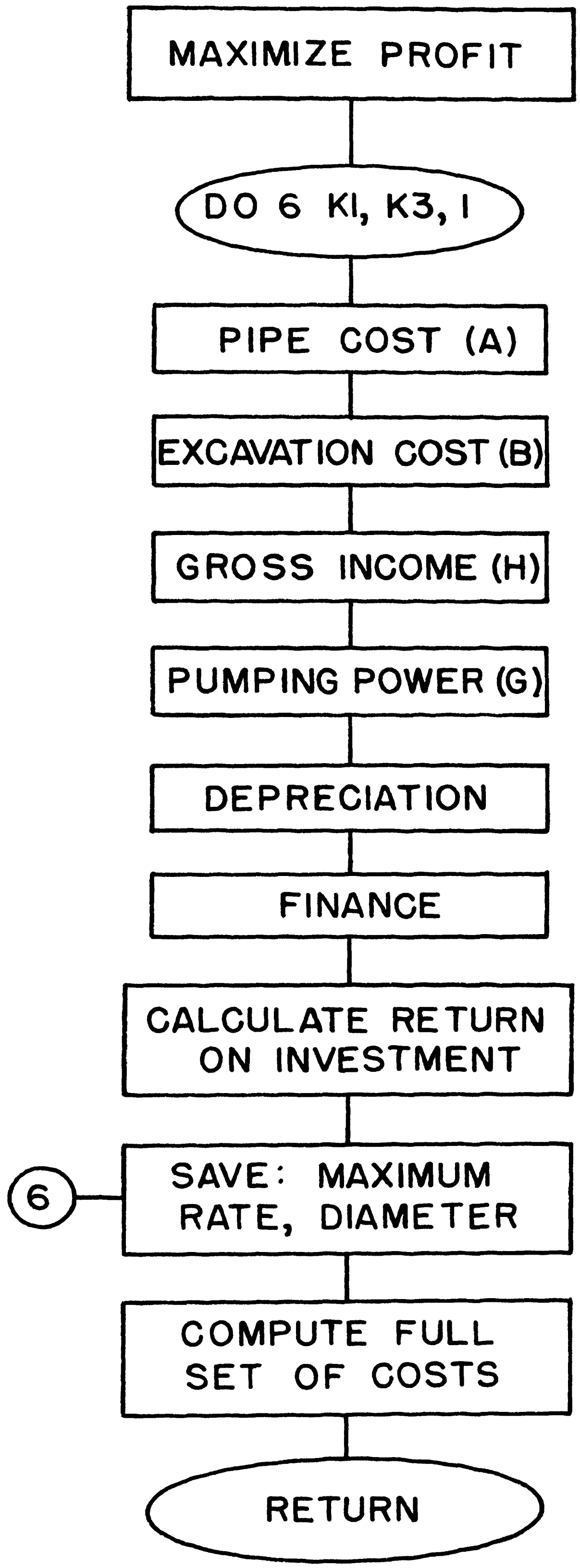


FIGURE 12. (CONT'D)

V. TYPICAL PROBLEM AND RESULTS

The following paragraphs will give the statement of a typical problem of the type that can be solved by OPTUMR.

Suppose it was desired to heat the buildings shown in Figure 5 and simulated by Figure 6 using the waste heat from a nuclear reactor. The objective is to find the installation cost, the operating cost, and the profit or loss potentials of such a system in sufficient detail to determine the feasibility of starting the preliminary design phases.

It is assumed that the following data is given:

1. The effective lifetime of the plant is 30 years.
2. The effect of pumping power cost determines the shape of the optimization curve (see Figures 9 and 10). For the optimization in the problem, a basis of 600 days is chosen at a cost of 1.1¢ per kilowatt-hour.
3. An overall plant load factor of 0.8 is specified.
4. The selling price of heat at 170 degrees F at the buildings is $1.37/million BTU.
5. Due to reliability requirements, no less than two pipes are permitted in any flowpath.
6. Due to reliability requirements, 150% of the number of pumps required will be purchased and installed.
7. The maximum velocity in any pipe is 12 ft/second.
8. The cooling medium is water (density is 62.4, viscosity is 0.000292.)
9. The plant's salvage value at the end of thirty years is 5%.
10. Depreciation is to be calculated by the sum of the years digits method.

11. The operating costs are 2% of the total installation charges.
12. Working capital is 10% of the annual pumping power cost.
13. The basic plant overhead is $1000.00 per month.
14. The cost of the conduit drainage system is 10% of the insulation cost.
15. The minimum and maximum diameters to be considered are 6 and 100 inches respectively.
16. It is desired to minimize the capital investment and operating expenses.
17. All costs are to be corrected to 1975 dollars. To accomplish this, use the following values for cost price indices:

Pumps	1.83	Pumping Power	1.28
Excavation	1.44	Insulation	1.39
Manhole	1.26	Piping	1.28
Conduit	1.33		

18. There is an engineering service charge of $200,000.
19. The company will borrow 50% of the investment cost at 7% interest.
20. The federal income tax rate is 50%.
21. The county tax rate is 1¢/$100 of capital investment.
22. Insurance costs are $7,623 dollars per year.
23. There is a paving cost of $2.00 per foot of piping that is installed.
24. The following cost data is supplied:

Pump Cost	Unknown
Pipe Cost	A 10" pipe costs $30.00 per foot

Conduit Cost	A 36" conduit costs $14.00 per foot; a 72" conduit costs $46.00 per foot
Insulation Cost	$1.50 per foot
Manhole Cost	$38.00 per foot of depth; one hole every 500 feet

25. The building requirements are as follows:

Building	Length To & From (ft)	Heat Requirement (BTU/hr)	Flow (lbs/hr)	Building Loss (ft)
2	300	10^7	$4. \times 10^5$	30
3	300	5×10^7	$2. \times 10^6$	40
5	400	2×10^8	$1. \times 10^7$	50
7	200	5×10^7	$2. \times 10^6$	40
8	200	10^7	$4. \times 10^5$	30
9	200	8×10^7	$4. \times 10^6$	45

26. The piping from the reactor site to buildings 2 & 3 is five miles.

27. The distance from building 2 & 3 to building 5 is 1/2 mile.

28. The distance from building 5 to buildings 7, 8, & 9 is 1000 feet.

29. The right of way costs are $1.00 per foot.

30. For comparative analysis, use:

Cost of physical plant	$5,000,000.00
Savings	50%
Flowrate of conventional plant	36,800 gal. per min.

Pumping cost	\$1,000,000.00
Piping cost	\$1,000,000.00

The input data describing this problem is given in Table III. (See also Appendix D.) Table IV shows the computer output for this problem. (The computer program computes an annual balance sheet for the life of the plant. Table IV contains only the balance sheet for the 1st year for the non-adjusted and the adjusted economic analyses; Appendix E contains the balance sheets for years 2-30.)

```
  .8          1.37          30.             .05
  12000.         .01                                       .035
               .50                         .0001
                              7623.        1.5
              .10                                          .10
                              2.
200000.
                 1.                1.
1000000.      1000000.      36800.          .5            5000000.
   1    1         1    1    1    3    2   1
   1    1    1    1                   1   1    1    2
   1    1         2    1         1    1
        6        53        100
     62.4              .000292
 1.83      1.28     1.44      1.39      1.26      1.33      1.28
      12.
   1
     38.               500.
    36.                14.                 72.              46.

    10.               30.
        2.25
        1.50
      600.           .011

        4
        2         6         3       12
   1    1 2000000.         200.        50000000.      40.
   2    1 400000.         200.         10000000.       30.
   3    1 4000000.       200.          80000000.       45.
   4    1 6400000.       1000.
   5    5    -1.            1.
   6       6400000.      1000.
        0         3                 12
   7    1 16400000.       2640.
   8    1 10000000.      400.         200000000.      50.
   9      16400000.       2640.
        1         2         2       12
  10    1   400000.      300.         10000000.        30.
  11    1 2000000.        300.         50000000.          40.
                  2                 12
  12    1 18400000.      52800.
  13    1 18400000.      52800.
```

TABLE III. INPUT DATA FOR TYPICAL PROBLEM

COST OPTIMIZATION OF A
DISTRICT HEATING PIPING
NETWORK

J1	J2	J3	J4	J5	J6	J7	J8	J9	J10	J11	J12	J13	J14	J15	J16	J17	J18	J19	J20
1	1	0	1	1	1	3	2	1	1	1	1	1	0	0	0	1	1	1	2
JJ1	JJ2	JJ3	JJ4	JJ5	JJ6	JJ7	JJ8	JJ9	I1	I2									
1	1	0	2	1	0	1	1	0	0	0									

THE INPUT DIAMETER LIMITS ARE 6 53 100

INPUT DENSITY AND VISCOSITY ARE: 62.3999939 0.0002920

COST PRICE INDICES ARE:
1.8299999 1.2799997 1.4399996 1.3899994 1.2599993 1.3299999 1.2799997

LIMITING VELOCITY IS : 12.0000000

THE MIN # OF PIPES IS : 2

MANHOLE COST IS : $ 38.0000000 A MANHOLE IS INSTALLED EVERY 500.0000000FEET

INPUT DATA BASE COSTS

BASE FLOW RATE	PUMP COST	BASE PIPE SIZE	PIPE COST	EXCAVATION	INSULATION	BASE DAYS	$$/KWH
0.0	0.0	10.000	30.000	2.250	1.500	600.000	0.011

TABLE IV. COMPUTER PROGRAM RESULTS FOR DATA IN TABLE III

PATH NO.	# OF PIPES	DIA.	PUMP COST	PIPE COST	EXCAVATION COST	INSULATION COST	MANHOLE COST	CONDUIT COST	PUMPING COST
1	2	9	0.0	13607.23	8505.00	625.50	172.37	3207.42	30362.38
2	2	6	0.0	8536.20	6804.00	417.00	172.37	2723.44	4296.41
3	2	12	0.0	18943.02	10367.99	834.00	172.37	3724.00	67299.25
4	2	15	0.0	122423.81	61964.97	5212.49	861.84	21361.80	36821.38
6	2	15	0.0	122423.81	61964.97	0.0	861.84	21361.80	36821.38
7	2	24	0.0	554890.88	256607.81	22017.59	2275.25	80538.50	155989.19
8	2	19	0.0	64266.86	30689.97	2641.00	344.74	10103.49	188932.06
9	2	24	0.0	554890.88	256607.81	0.0	2275.25	80538.50	155989.19
10	2	6	0.0	12804.30	10205.99	625.50	258.55	4085.16	4384.20
11	2	9	0.0	20410.84	12757.49	938.25	258.55	4811.13	31807.47
12	2	26	184606.25	6083923.00	2798923.00	238523.63	22752.56	863833.00	1476410.00
13	2	26	0.0	6083923.00	2798923.00	0.0	22752.56	863833.00	1476410.00

TOTAL COST IS: $$$ 30563344.0000000

TABLE IV. (CONT'D)

ECONOMIC INPUT DATA

LOAD FACTOR	SALE PRICE OF HEAT	EFFECTIVE LIFE	SALVAGE VALUE	SINKING FUND RATE
0.80000	1.37000	30.00000	0.05000	0.0

T1-T5 VALUES ARE :

0.0	0.0	0.0	0.0	0.0

T6-T10 VALUES ARE:

12000.00000	0.01000	0.0	0.0	0.03500

T11-T15 VALUES ARE:

0.0	0.50000	0.0	0.00010	0.0

T16-T18 VALUES ARE:

0.0	0.0	7623.00000

U1-U5 VALUES ARE:

1.50000	0.0	0.0	0.10000	0.0

U6-U10 VALUES ARE:

0.0	0.10000	0.0	0.0	2.00000

U11,U12,U13 VALUES ARE:

0.0	0.0	200000.00000

U14-U18 VALUES ARE:

0.0	1.00000	1.00000	0.0	0.0

U19-U23 VALUES ARE:

1000000.00000	1000000.00000	36800.00000	0.50000	5000000.00000

TABLE IV. (CONT'D)

COST DATA AND TOTALS

PATH #	PUMP COST	PIPE COST	EXCAVATION COST	INSULATION COST	MANHOLE COST	CONDUIT COST	PUMPING COST	GROSS INCOME/HOUR
1	0.0	13607.23	8505.00	625.50	172.37	3207.42	30362.38	54.80
2	0.0	8536.20	6804.00	417.00	172.37	2723.44	4296.41	10.96
3	0.0	18943.02	10367.99	834.00	172.37	3724.00	67299.25	87.68
4	0.0	122423.81	61964.97	5212.49	861.84	21361.80	36821.38	0.0
6	0.0	122423.81	61964.97	0.0	861.84	21361.80	36821.38	0.0
7	0.0	554890.88	256607.81	22017.59	2275.25	80538.50	155989.19	0.0
8	0.0	64266.86	30689.97	2641.00	344.74	10103.49	188932.06	219.20
9	0.0	554890.88	256607.81	0.0	2275.25	80538.50	155989.19	0.0
10	0.0	12804.30	10205.99	625.50	258.55	4085.16	4384.20	10.96
11	0.0	20410.84	12757.49	938.25	258.55	4811.13	31807.47	54.80
12	184606.25	6083923.00	2798923.00	238523.63	22752.56	863833.00	1476410.00	0.0
13	0.0	6083923.00	2798923.00	0.0	22752.56	863833.00	1476410.00	0.0
TOTALS	184606.25	13661042.00	6314321.00	271834.94	53158.24	1960121.00	3665522.00	438.40

TABLE IV. (CONT'D)

YEAR 1		OUTFLOWS	INFLOWS	
THE TOTAL INSTALLATION COST IS :	$$	26897824.00		
THE TOTAL SUPPLEMENTARY INSTALLATION COST IS:		4452744.00		
THE GROSS ANNUAL INCOME IS :				3787770.00
THE DEPRECIATION IS :		1648576.00		
THE ANNUAL OPERATING AND MAINTENANCE EXPENCE IS :		268978.13		
THE ANNUAL FINANCING AND SUPPLEMENTAL FINANCE COST IS:		941423.69		
THE ANNUAL PUMPING COST IS:		2199313.00		
THE ANNUAL SUPPLEMENTARY COSTS ARE:		12000.00		
THE PROPERTY TAXES ARE:		2689.78		
THE ANNUAL INSURANCE CHARGES ARE:		7623.00		
THE ANNUAL RIGHT-OF-WAY COST IS:		2056.00		
THE NET ANNUAL INCOME, BEFORE TAXES AND DEPRECIATION IS:			294061.19	

TABLE IV. (CONT'D)

A CASH FLOW SUMMARY FOLLOWS

YEAR	NET CASH FLOW	5%	10%	15%	20%	25%	30%	35%
-1	-27581776.00	-28288784.00	-29019856.00	-29776304.00	-30558624.00	-31368096.00	-32205712.00	
1		286830.44	279836.25	273069.13	266521.19	260184.38	254050.94	248113.56
2		279836.25	266521.19	254050.94	242365.13	231408.13	221128.31	211478.13
3		273069.13	254050.94	236798.88	221128.25	206875.31	193894.25	182055.31
4		266521.19	242365.19	221128.31	202413.69	185882.13	171243.06	158247.56
5		260184.38	231408.06	206875.31	185882.06	167849.00	152298.19	138834.88
6		254050.94	221128.31	193894.25	171243.06	152298.19	136362.88	122881.69
7		248113.56	211478.19	182055.31	158247.56	138834.88	122881.69	109667.56
8		242365.13	202413.69	171243.06	146682.00	127132.19	111410.19	98635.44
9		236798.88	193894.25	161354.56	136362.88	116918.81	101592.13	89352.38
10		231408.06	185892.13	152298.19	127132.19	107969.25	93140.25	81480.38
11		226186.56	178342.50	143991.94	118853.75	100095.44	85822.81	74754.19
12		221128.25	171243.06	136362.88	111410.19	93140.25	79451.75	68964.63
13		216227.31	164554.00	129345.63	104700.06	86972.06	73874.06	63945.89
14		211478.13	158247.63	122881.69	98635.44	81480.38	68964.63	59565.61
15		206875.31	152298.19	116918.81	93140.25	76572.13	64620.99	55717.73
16		202413.69	146682.00	111410.19	88148.31	72168.81	60758.56	52316.75
17		198088.25	141377.13	106313.88	83602.13	68203.88	57307.54	49293.27
18		193894.25	136362.88	101592.13	79451.75	64621.01	54209.83	46590.66
19		189827.00	131620.50	97211.00	75653.38	61372.02	51417.07	44162.50
20		185882.06	127132.19	93140.25	72168.81	58415.97	48888.72	41970.44
21		182055.31	122881.69	89352.38	68964.63	55717.75	46590.66	39982.62
22		178342.50	118853.75	85822.81	66011.56	53247.17	44494.11	38172.46
23		174739.63	115034.38	82529.25	63283.77	50978.32	42574.61	36517.68
24		171243.06	111410.25	79451.75	60758.56	48888.72	40811.33	34999.40
25		167849.00	107969.25	76572.13	58415.97	46958.97	39186.47	33601.66
26		159154.31	101264.44	71449.94	54392.86	43689.89	36448.12	31250.55
27		140983.38	38766.00	62335.61	47365.76	38019.96	31710.81	27186.81
28		123482.38	76966.44	53813.94	40823.37	32750.02	27310.44	23412.92
29		106623.31	65817.00	45833.61	34719.24	27839.96	23212.58	19899.04
30		90379.38	55272.90	38348.49	29012.38	23254.71	19387.25	16619.23
TOTALS		-21455536.00	-23527488.00	-25122192.00	-26468592.00	-27678704.00	-28812848.00	-29905776.00

TABLE IV. (CONT'D)

A LISTING OF THE NET CASH FLOW FOLLOWS:

YEAR AFTER START-UP	NET CASH FLOW
1	294061.19
2	294061.19
3	294061.19
4	294061.19
5	294061.19
6	294061.19
7	294061.19
8	294061.19
9	294061.19
10	294061.19
11	294061.19
12	294061.19
13	294061.19
14	294061.19
15	294061.19
16	294061.19
17	294061.19
18	294061.19
19	294061.19
20	294061.19
21	294061.19
22	294061.19
23	294061.19
24	294061.19
25	294061.19
26	284411.88
27	256935.63
28	229459.38
29	201983.13
30	174506.81

THE PAY OUT TIME AT CURRENT RATE IS: 9.1470154E 01

TABLE IV. (CONT'D)

YEAR 1		OUTFLOWS	INFLOWS	
THE TOTAL INSTALLATION COST IS :	$$	21345824.00		
THE TOTAL SUPPLEMENTARY INSTALLATION COST IS:		4452744.00		
THE GROSS ANNUAL INCOME IS :				3787770.00
THE DEPRECIATION IS :		1308292.00		
THE ANNUAL OPERATING AND MAINTENANCE EXPENCE IS :		213458.19		
THE ANNUAL FINANCING AND SUPPLEMENTAL FINANCE COST IS:		747103.75		
THE ANNUAL PUMPING COST IS:		1315456.00		
THE ANNUAL SUPPLEMENTARY COSTS ARE:		12000.00		
THE PROPERTY TAXES ARE:		2134.58		
THE ANNUAL INSURANCE CHARGES ARE:		7623.00		
THE ANNUAL RIGHT-OF-WAY COST IS:		2056.00		
THE NET ANNUAL INCOME, BEFORE TAXES AND DEPRECIATION IS:			1428313.00	
THE FEDERAL AND STATE INCOME TAXES ARE:		60010.50		

TABLE IV. (CONT'D)

A CASH FLOW SUMMARY FOLLOWS

YEAR	NET CASH FLOW	5%	10%	15%	20%	25%	30%	35%
-1	-21888592.00	-22449680.00	-23029840.00	-23630160.00	-24250992.00	-24893376.00	-25558096.00	
1		1334656.00	1302111.00	1270623.00	1240155.00	1210669.00	1182129.00	1154502.00
2		1281361.00	1220392.00	1163291.00	1109782.00	1059610.00	1012539.69	968351.81
3		1230126.00	1144453.00	1066735.00	996142.56	931935.75	873458.19	820126.13
4		1180866.00	1073839.00	979745.81	896827.69	823581.69	758720.88	701142.19
5		1133498.00	1008133.69	901256.25	809798.88	731237.50	663490.00	604836.75
6		1087939.00	946952.69	830326.38	733325.69	652196.94	583956.06	526224.50
7		1044115.69	889945.88	766128.25	665939.94	584247.19	517112.69	461505.00
8		1001953.31	836791.50	707929.88	606393.13	525572.69	460577.13	407765.44
9		961383.00	787194.00	655085.75	553621.63	474680.44	412455.19	362763.00
10		922337.69	740882.00	607024.50	506718.69	430339.94	371234.94	324761.44
11		884754.06	697606.50	563240.63	464909.63	391534.50	335705.44	292409.31
12		848571.69	657139.13	523287.69	427532.69	357422.31	304893.19	264649.38
13		813730.94	619268.06	486767.94	394019.06	327303.00	278011.19	240648.31
14		780176.88	583801.00	453330.31	363882.13	300594.19	254421.75	219747.13
15		747856.31	550559.50	422662.81	336702.94	276809.00	233605.50	201420.13
16		716718.56	519380.56	394488.00	312120.81	255539.63	215137.50	185246.25
17		686714.50	490113.44	368559.38	289824.44	236443.19	198668.56	170885.44
18		657797.56	462619.13	344657.19	269544.69	219230.50	183910.00	158061.50
19		629923.38	436770.44	322585.75	251048.69	203657.38	170622.75	146549.19
20		603049.19	412449.38	302170.88	234134.13	189516.38	158607.50	136162.81
21		577134.69	389548.00	283256.56	218625.25	176631.13	147697.31	126749.13
22		552140.44	367966.00	265703.56	204368.81	164850.88	137751.75	118180.19
23		528029.13	347611.38	249387.38	191231.13	154046.50	128652.13	110349.25
24		504765.13	328398.75	234196.19	179095.13	144106.94	120297.63	103166.06
25		482314.56	310250.00	220030.19	167858.38	134936.69	112602.38	96554.44
26		460644.50	293092.44	206799.50	157430.63	126452.75	105492.75	90449.25
27		439723.75	276858.94	194423.19	147732.63	118583.31	98905.19	84795.00
28		419522.06	261487.56	182828.69	138694.25	111265.69	92785.13	79543.56
29		400011.38	246921.19	171950.75	130253.75	104445.19	87085.00	74653.81
30		381164.13	233106.69	161730.06	122356.13	98073.88	81763.31	70089.56
TOTALS		1404426.00	-4014007.00	-7729589.00	-10510034.00	-12735397.00	-14610953.00	-16255642.00

TABLE IV. (CONT'D)

A LISTING OF THE NET CASH FLOW FOLLOWS:

YEAR AFTER START-UP	NET CASH FLOW
1	1368302.00
2	1346497.00
3	1324692.00
4	1302887.00
5	1281083.00
6	1259278.00
7	1237473.00
8	1215668.00
9	1193863.00
10	1172058.00
11	1150253.00
12	1128449.00
13	1106644.00
14	1084839.00
15	1063034.00
16	1041229.38
17	1019424.63
18	997619.75
19	975814.87
20	954009.88
21	932205.00
22	910400.31
23	888595.38
24	866790.38
25	844985.44
26	823180.69
27	801375.94
28	779570.69
29	757765.94
30	735961.19

THE RETURN ON INVESTMENT IS : 3 PER CENT

THE PAY OUT TIME AT CURRENT RATE IS: 1.4944779E 01

TABLE IV. (CONT'D)

FLOW EDIT

PATH #	# OF PIPES	FLOWRATE	LENGTH	BUILDING LOSS	DELTA T	Q	HEAD LOSS
1	2	0.2000000E 07	0.2000000E 03	0.4000000E 02	0.2500000E 02	0.4451570E 01	0.4420813E 02
2	2	0.4000000E 06	0.2000000E 03	0.3000000E 02	0.2500000E 02	0.8903134E 00	0.3127821E 02
3	2	0.4000000E 07	0.2000000E 03	0.4500000E 02	0.2000000E 02	0.8903137E 01	0.4899443E 02
4	2	0.6400000E 07	0.1000000E 04	0.0	0.0	0.1424502E 02	0.1675392E 02
6	2	0.6400000E 07	0.1000000E 04	0.0	0.0	0.1424502E 02	0.1675392E 02
7	2	0.1640000E 08	0.2640000E 04	0.0	0.0	0.3650284E 02	0.2769794E 02
8	2	0.1000000E 08	0.4000000E 03	0.5000000E 02	0.2000000E 02	0.2225783E 02	0.5501770E 02
9	2	0.1640000E 08	0.2640000E 04	0.0	0.0	0.3650284E 02	0.2769794E 02
10	2	0.4000000E 06	0.3000000E 03	0.3000000E 02	0.2500000E 02	0.8903134E 00	0.3191733E 02
11	2	0.2000000E 07	0.3000000E 03	0.4000000E 02	0.2500000E 02	0.4451570E 01	0.4631221E 02
12	2	0.1840000E 08	0.2640000E 05	0.0	0.0	0.4095441E 02	0.2336607E 03
13	2	0.1840000E 08	0.2640000E 05	0.0	0.0	0.4095442E 02	0.2179092E 01

TABLE IV. (CONT'D)

VI. CONCLUSIONS

Thermal pollution from nuclear reactor electrical generating facilities is a serious problem now. The most important consideration affecting the use of a district heating rejection method is the siting consideration. For example, the Palisades reactor, located along the shore of Lake Michigan, has a court injunction against operation due to thermal pollution of Lake Michigan. Use of the district heating rejection scheme is not feasible because the closest urban center is about thirty miles distant.

The conservationist group that backed the injunction has demanded that the returning coolant enter the lake with not more than one degree temperature rise from inlet to outlet. Consumers Power Corporation, the owner, is faced with the installation of cooling towers of the closed type[7]. The cost of the delay while cooling tower construction takes place is about $33,000.00 per day. The solution of this reactor's problem is still unresolved [30].

Table V is a summary of the results of the computer programs solutions for various distances from the reactor to the urban area. In compiling the data for the table, all of the input parameters except distance remained as in the typical problem described on page 40. As one can see from the table, a distance from the reactor to the urban center of greater than 5 miles yields a system that does not show a profit and greater than 8 miles yields a system whose gross income will not meet the annual operation expenses.

---

7. Closed cooling towers installation cost is 2.6 times the cost of open cooling towers. Open towers cannot be used at Palisades because of the proximity of an interstate highway.

TABLE V

COST DATA VERSUS DISTANCE FROM REACTOR TO URBAN AREA

Distance (Miles)	Installation* Costs	Annual** Financing Costs	Annual** Operating & Maintenance	Annual** Taxes	Return on Investment (Per Cent)
1	5.23	183.	517.	1363.	23
2	9.33	326.	770.	1033.	14
3	13.3	464.	1020.	713.	9
4	17.3	606.	1276.	386.	6
5	21.3	747.	1538.	60.	3
6	25.7	900.	1780.	-----	0
7	29.8	1042.	2038.	-----	-3
8	33.9	1186.	2291.	-----	-9
9	38.0	1329.	2398.	-----	.54&&
10	42.0	1473.	2799.	-----	.73&&

* Millions of dollars

** Thousands of dollars

&& Incremental cost increase to pay off plant in 30 years, $\$/10^6$ BTU

As previously mentioned, the district heating system must have a back-up method of supplying heat to the buildings. Dual reactor sites can provide this reliability especially if the scheduled shutdowns for maintenance and refueling are conducted at times of low heat demand. If a dual reactor site is not possible, an additional expense that is not included in the computer program would be incurred for a back-up system.

The population of the United States is facing a critical decision. A critical shortage of available fossil fuels is just starting to be apparent. To meet the energy demand requirements, the use of nuclear energy seems to be the only plausible solution. The shortage of cooling water, as exhibited in the Palisades case, is critical now. The question that the public must answer is: Does the severity of potential danger of nuclear reactors (thermal pollution and radioactive pollution, in particular) warrant the cessation of increasing the electrical power consumption? This question raises a direct conflict when applied to a nuclear reactor supplied district heating system. This system would minimize the thermal pollution. To be efficient, however, the reactor must be sited close to an urban center. The potential damage from a gross fission product release accident increases as the distance to an urban center decreases. The cost of electrical power generation will increase, in any case, as the anti-pollution legislation increases.

The ability to choose reactor sites close to cities that would meet the safety requirements with regard to radioactive pollution is the first problem that must be solved. Once this problem is solved, then use of the district heating rejection system will resolve the thermal pollution problem. Perhaps the Palisades case will cause increased investigation and experimentation in proximity siting and district heating. The computer code presented here is a tool for the utility to use for comparative analysis with other heat rejection systems. If the current trend in legislation is a valid trend, certainly this program will receive extensive use.

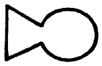
VII. APPENDICES

APPENDIX A

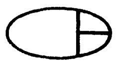
SYMBOLS USED

Standard abbreviations [12] are used throughout.

 Valve

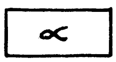
 Turbine Generator

 Pump

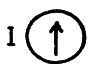
 Heat Exchanger (Condenser or Steam Generator)

 Summing Junction

Amplifier

 Feedback Gain

 Resistor



Current Source

 Voltage Source

W Mass flow rate, lbs./hr.

ρ Density, lbs./ft.^{3}

A Area normal to flow, ft.^{2}

$\overline{V}$ Average velocity of fluid, ft./sec.

Q Volumetric flow rate, ft.^{3}/sec.

H_ℓ Head loss, ft. of water

Δp Pressure drop, lbs./ft.^{2}

f Friction factor, dimensionless

L Length of piping, ft.

D Diameter of piping, ft.

g_c Gravitational constant, 32.17 ft-lb mass/lb force sec.^{2}

R_E Reynolds number, dimensionless

μ Viscosity, ft/lb-sec.

log Logarithm, base 10

BLOSS	Building loss, ft. of water
K1,K2,K(I)	Piping sizes, inches
r	Return on investment rate, $years^{-1}$
t	Time, years
BTU	British thermal unit

B. FORTRAN IV PROGRAM LISTING

```
      COMMON/A1/K1,K2,K3
      COMMON/A2/RHO,POIS
      COMMON/A4/MONY
      COMMON/A3/CPI(7)
      COMMON/A5/ NJ1,NJ2,NJ3,NJ4,NJ5
      COMMON /A6/ KK
      COMMON/A8/J1,J2,J3,J4,J5,J6,J7,J8,J9,I1,I2
       COMMON/A9/TPIPE(100)
       COMMON/A10/TCNDT(200)
      COMMON/A11/TPUMP(100)
      COMMON/A12/BASEW,BASEP,BASEE,BASEV,BASED,BASE$,BASEW$,BASEP$
      COMMON/A13/HOLCST,HOLFT
      COMMON/A14/ VELLIM,NNN
      COMMON/A15/J10,J11,J12,J13,J14,J15,J16,J17,J18,J19,J20
      COMMON/A16/ NODE(13),TCOST(100)
      COMMON/A17/ N,Q,H,DD,D,ZL,ZCOST,ZZCOST,ACOST
      COMMON/A18/ BCOST,CCOST,DCOST,ECOST,FCOST,GCOST
      COMMON/A19/ $2(4),$1(4),X1(4),X2(4)
      COMMON/A20/JJ1,JJ2,JJ3,JJ4,JJ5,JJ6,JJ7,JJ8,JJ9
      COMMON/A22/FCTRLD,BASEH$
      COMMON/A23/YEARS,SALVA$,FRINTR,T1,T2,T3,T4,T5,T6
      COMMON/A24/ T7,T8,T9,T10,T11,T12,T13,T14,T15,T16,T17,T18
      COMMON/A25/U1,U2,U3,U4,U5,U6,U7,U8,U9,U10,U11,U12,U13
      COMMON/A27/ INSULI
      COMMON/A28/U14,U15,U16,U17,U18,U19,U20,U21,U22,U23
      DATA NIN,NOUT /1,3/
    1 FORMAT(I10)
    2 FORMAT(I10,13I5)
   23 FORMAT(I2,8F9.2)
   25 FORMAT(6F10.2)
  107 FORMAT(////,' TOTAL COST IS:  $$$',F20.7,//)
  647 FORMAT('1',///////////////////////,T50,' COST OPTIMIZATION OF A
     1 ',/,T50,' DISTRICT HEATING PIPING',/,T59,' NETWORK',/,'1')
  701 FORMAT(' PATH  # OF  DIA.',4X,'PUMP',T35,'PIPE',T46,'EXCAVATION',T
     162,' INSULATION',T78,'MANHOLE',T94,'CONDUIT',T107,'PUMPING',/,
     2'  NO.  PIPES',T21,' COST',T35,'COST',T50,'COST',T65,'COST',T80,
     3'COST',T95,'COST',T110,'COST',//)
  705 FORMAT('1')
 4612 FORMAT(5I10)
      CALL ERRSET(208,260,-2,1)
      WRITE(NOUT,647)
      READ(NIN,4612) NJ1,NJ2,NJ3,NJ4,NJ5
      DEFINE FILE  11(1000,40,U,K400)
      DEFINE FILE  12(1000,40,U,K400)
      DEFINE FILE  13(1000,40,U,K400)
      DEFINE FILE  14(1000,40,U,K400)
      DEFINE FILE  15(1000,40,U,K400)
      CALL DRECON
      CALL DREAD
      CALL VELIN
      CALL ANHLIN
      CALL EXPOIN
      READ(NIN,23) N,Q,H,DD,D,ZHL,ZCOST,ZZCOST,ACOST
      CALL TLREAD
      CALL PRICEI
      READ(NIN,25) BCOST,CCOST,DCOST,ECOST,FCOST,GCOST
      BRCST=0.0
      L=0
```

```
      READ(NIN,1) NBRANH
      WRITE(NOUT,705)
      WRITE(NOUT,701)
    6 L=L+1
      SMCST= 0.0
      IF(L.GT.NBRANH) GO TO 69
      READ(NIN,10) INDIC,NPATHS,NPLLP,MONY
      IF(INDIC.EQ.0) GO TO 77
      IF(INDIC.EQ.1) GO TO 91
      IF(INDIC.EQ.2) GO TO 89
   77 CALL STRTFL((NPATHS+1),ZZCOST,ZHL,KK)
      SMCST=SMCST+ZZCOST
      GO TO 106
   91 CALL PLLP(NPATHS,INDIC,ZCOST,ZHL,KK)
      SMCST=SMCST+ZCOST
      GO TO 106
   89 CALL PLLP(NPLLP,INDIC,ZCOST,ZHL,KK)
      CALL STRTFL((NPATHS-NPLLP+1),ZZCOST,ZHL,KK)
      SMCST=SMCST+ZCOST+ZZCOST
      GO TO 106
  106 BRCST=BRCST+SMCST
      GO TO 6
   69 WRITE(NOUT,107) BRCST
   10 FORMAT(4I10)
      CALL WRITEO(KK)
      STOP
      END
```

```
C
      SUBROUTINE DREAD
C      THIS ROUTINE READS & WRITES INPUT DATA
      COMMON/A1/K1,K2,K3
      COMMON/A2/RHO,POIS
      COMMON/A3/CPI(7)
      COMMON /A6/ KK
      COMMON/A8/J1,J2,J3,J4,J5,J6,J7,J8,J9,I1,I2
      COMMON/A15/J10,J11,J12,J13,J14,J15,J16,J17,J18,J19,J20
      COMMON/A20/JJ1,JJ2,JJ3,JJ4,JJ5,JJ6,JJ7,JJ8,JJ9
      DATA NIN,NOUT /1,3/
      READ(NIN,2) J1,J2,J3,J4,J5,J6,J7,J8,J9,I1,I2
      READ(NIN,2) J10,J11,J12,J13,J14,J15,J16,J17,J18,J19,J20
      READ(NIN,1) JJ1,JJ2,JJ3,JJ4,JJ5,JJ6,JJ7,JJ8,JJ9
      IF(J1.GT.1) WRITE(NOUT,3)
      IF(J2.GT.1) WRITE(NOUT,3)
      IF(J5.GT.1) WRITE(NOUT,3)
      IF(J6.GT.1) WRITE(NOUT,3)
      IF(J3.GT.3) WRITE(NOUT,3)
      IF(J4.GT.3) WRITE(NOUT,3)
      IF(J8.GT.2) WRITE(NOUT,3)
      IF(J9.GT.1) WRITE(NOUT,3)
      IF(J7.GT.3) WRITE(NOUT,3)
      IF(J10.GT.1)  WRITE(NOUT,3)
      IF(J11.GT.1)  WRITE(NOUT,3)
      IF(J12.GT.1)  WRITE(NOUT,3)
      IF(J13.GT.1)  WRITE(NOUT,3)
      IF(J14.GT.1)  WRITE(NOUT,3)
      IF(J15.GT.1)  WRITE(NOUT,3)
      IF(J16.GT.1)  WRITE(NOUT,3)
      IF(J17.GT.1)  WRITE(NOUT,3)
      IF(J18.GT.1)  WRITE(NOUT,3)
      IF(J19.GT.1)  WRITE(NOUT,3)
      IF(J20.GT.2)  WRITE(NOUT,3)
      WRITE(NOUT,8026)
      IF(J10.EQ.1) WRITE(NOUT,4) J1,J2,J3,J4,J5,J6,J7,J8,J9,J10,J11,
     1J12,J13,J14,J15,J16,J17,J18,J19,J20
      WRITE(NOUT,8207) JJ1,JJ2,JJ3,JJ4,JJ5,JJ6,JJ7,JJ8,JJ9,I1,I2
      READ(NIN,5) K1,K2,K3
      IF(J11.EQ.1) WRITE(NOUT,6) K1,K2,K3
      READ(NIN,7) RHO,POIS
      IF(J12.EQ.1) WRITE(NOUT,8) RHO,POIS
      READ(NIN,9) CPI(1),CPI(2),CPI(3),CPI(4),CPI(5),CPI(6),CPI(7)
      IF(J13.EQ.1) WRITE(NOUT,10) CPI(1),CPI(2),CPI(3),CPI(4),CPI(5),
     1CPI(6),CPI(7)
      RETURN
    1 FORMAT(9I5)
    2 FORMAT( 11I5)
    3 FORMAT(//' ***** ERROR*** ONE OF THE J VALUES ARE TOO LARGE',//)
    4 FORMAT(20I5)
    5 FORMAT(3I10)
    6 FORMAT(//,' THE INPUT DIAMETER LIMITS ARE',3I10)
    7 FORMAT(2F20.7)
    8 FORMAT(//,' INPUT DENSITY AND VISCOSITY ARE:', 2F20.7)
    9 FORMAT(7F10.5)
   10 FORMAT(//,' COST PRICE INDICES ARE: ',/,7F15.7)
 8026 FORMAT('    J1    J2    J3    J4    J5    J6    J7    J8    J9   J10   J11
     1J12   J13   J14   J15   J16   J17   J18   J19   J20')
 8207 FORMAT('   JJ1   JJ2   JJ3   JJ4   JJ5   JJ6   JJ7   JJ8   JJ9    I1    I2',
     1 /,11I5)
      END
```

```
C
C
C
C
      SUBROUTINE PLLP(INDIC,NODEN,ZCOST,ZHL,KK)
C     THIS ROUTINE CONTROLS PARALLEL FLOW PATHS
      COMMON/A5/ NJ1,NJ2,NJ3,NJ4,NJ5
      COMMON/A7/LQ
      COMMON/A8/J1,J2,J3,J4,J5,J6,J7,J8,J9,I1,I2
      COMMON/A15/J10,J11,J12,J13,J14,J15,J16,J17,J18,J19,J20
      COMMON/A16/ NODE(13),TCOST(100)
      COMMON/A18/ BCOST,CCOST,DCOST,ECOST,FCOST,GCOST
      COMMON/A19/ S2(4),S1(4),X1(4),X2(4)
      COMMON/A20/JJ1,JJ2,JJ3,JJ4,JJ5,JJ6,JJ7,JJ8,JJ9
      COMMON/A27/ INSULI
      DATA NIN,NOUT /1,3/
      J=0
      ZZHL=0.
      SUM=0.
    1 J=J+1
      IF(J20.EQ.0) GO TO 1410
      IF(J20.EQ.1) GO TO 1411
      IF (J20.EQ.2) GO TO 1412
 1411 READ(NIN,1413) KK,INSULI,ZL,QHEAT,BLOSS
      W=QHEAT/30.
      DELTA=30.
      GO TO 1414
 1412 READ(NIN,982) KK,INSULI,W,ZL,QHEAT,BLOSS
      DELTA=QHEAT/W
      GO TO 1414
 1410 READ(NIN,982) KK,INSULI,W,ZL,BLOSS,DELTA
 1414 LQ=KK
      WRITE(NJ1'KK) W,ZL,BLOSS,DELTA
      IF(JJ3.EQ.0) CALL COPTIM(KK,W,ZL,BLOSS,DELTA,ZCOST,ZHL,DD)
      IF(JJ3.EQ.1) CALL TEMOP(KK,W,ZL,BLOSS,DELTA,ZCOST,ZHL,DD)
      SUM= SUM+ZCOST
      IF(ZHL.GE.ZZHL) ZZHL=ZHL
      IF(ZHL.LT.ZZHL) ZZHL=ZZHL
      IF(J.EQ.INDIC) GO TO 67
      IF(J.LT.INDIC) GO TO 1
   67 ZCOST=SUM
      ZHL=ZZHL
      RETURN
  982 FORMAT(2I5,4F15.7)
 1413 FORMAT(2I5,3F15.7)
      END
```

```
C
C
      SUBROUTINE STRTFL(NODEN,ZZCOST,ZZHL,KK)
C     THIS ROUTINE CONTROLS SERIES FLOW PATHS
      COMMON/A5/ NJ1,NJ2,NJ3,NJ4,NJ5
      COMMON/A7/LQ
      COMMON/A8/J1,J2,J3,J4,J5,J6,J7,J8,J9,I1,I2
      COMMON/A15/J10,J11,J12,J13,J14,J15,J16,J17,J18,J19,J20
      COMMON/A16/ NODE(13),TCOST(100)
      COMMON/A18/ BCOST,CCOST,DCOST,ECOST,FCOST,GCOST
      COMMON/A19/ $2(4),$1(4),X1(4),X2(4)
      COMMON/A20/JJ1,JJ2,JJ3,JJ4,JJ5,JJ6,JJ7,JJ8,JJ9
      COMMON/A27/ INSULI
      DATA NIN,NOUT /1,3/
      J=0
      SUM=0.0
      SUMLOS=0.0
    1 J=J+1
      IF(J20.EQ.0) GO TO 1410
      IF(J20.EQ.1) GO TO 1411
      IF (J20.EQ.2) GO TO 1412
 1411 READ(NIN,1413) KK,INSULI,ZL,QHEAT,BLOSS
      W=QHEAT/30.
      DELTA=30.
      GO TO 1414
 1412 READ(NIN,982) KK,INSULI,W,ZL,QHEAT,BLOSS
      DELTA=QHEAT/W
      GO TO 1414
 1410 READ(NIN,982) KK,INSULI,W,ZL,BLOSS,DELTA
 1414 LQ=KK
      WRITE(NJ1'KK) W,ZL,BLOSS,DELTA
      IF(JJ3.EQ.0) CALL COPTIM(KK,W,ZL,BLOSS,DELTA,ZCOST,ZHL,DD)
      IF(JJ3.EQ.1) CALL TEMOP(KK,W,ZL,BLOSS,DELTA,ZCOST,ZHL,DD)
      SUM= SUM+ZCOST
      SUMLOS= SUMLOS+ZHL
      IF(J.EQ.(NODEN-1)) GO TO 67
      IF(J.LT.(NODEN-1)) GO TO 1
   67 ZZCOST=SUM
      ZZHL=SUMLOS
      RETURN
  982 FORMAT(2I5,4F15.7)
 1413 FORMAT(2I5,4F15.7)
      END
```

```
C
C
C
      SUBROUTINE COPTIM(KK,W,ZL,BLOSS,DELTA,ZCOST,ZHL,DD)
C     THIS ROUTINE OPTIMIZES BASED ON INSTALLATION & PUMPING COST
      COMMON/A1/K1,K2,K3
      COMMON/A2/RHO,POIS
      COMMON/A3/CPI(7)
      COMMON/A4/MONY
      COMMON/A5/ NJ1,NJ2,NJ3,NJ4,NJ5
      COMMON/A8/J1,J2,J3,J4,J5,J6,J7,J8,J9,I1,I2
       COMMON/A9/TPIPE(100)
       COMMON/A10/TCNDT(200)
      COMMON/A11/TPUMP(100)
      COMMON/A12/BASEW,BASEP,BASEE,BASEV,BASED,BASE$,BASEW$,BASEP$
      COMMON/A13/HOLCST,HOLFT
      COMMON/A14/ VELLIM,NNN
      COMMON/A15/J10,J11,J12,J13,J14,J15,J16,J17,J18,J19,J20
      COMMON/A16/ NODE(13),TCOST(100)
      COMMON/A18/ BCOST,CCOST,DCOST,ECOST,FCOST,GCOST
      COMMON/A19/ $2(4),$1(4),X1(4),X2(4)
      COMMON /A20/JJ1,JJ2,JJ3,JJ4,JJ5,JJ6,JJ7,JJ8,JJ9
      COMMON/A27/ INSULI
      DATA NIN,NOUT /1,3/
      L=0
      LL=-1
      M=0
      K=K1
  121 L=L+1
  100 M=M+1
      IF(W.LT.0.)  GO TO 1001
  117 D=FLOAT(K)/12.
      CALL FLOCLC(W,ZL,D,BLOSS,Q,N,H)
      CALL CPUMP(N,Q,D,ACOST)
      CALL CPIPE(N,D,ZL,BCOST)
      CALL CEXCAV(N,D,ZL,CCOST)
      IF(INSULI.EQ.0) DCOST=0.0
      IF(INSULI.NE.0) CALL CINSUL(N,D,ZL,DCOST)
      CALL CMNHOL(N,ZL,FCOST)
      CALL CCONDT(N,D,ZL,ECOST)
      CALL PUMCST(H,Q,N,GCOST)
      CALL SUPCST(ACOST,BCOST,CCOST,DECOS,ECOST,FCOST,GCOST,D,ZL,Q,N,HCO
     1ST)
      IF(KK.NE.MONY) ACOST=0.0
      IDIAM=D*12.+0.5
      TCOST(K)= ACOST+BCOST+CCOST+DCOST+ECOST+FCOST+GCOST
      IF(LL.EQ.0) GO TO 803
      IF(LL.EQ.1) GO TO 804
      IF(LL.EQ.2) GO TO 673
      IF(M.EQ.1) K=K2
      IF(M.EQ.2) K=K3
      IF(M.EQ.3) GO TO 681
      IF(M.GT.3 ) GO TO 673
      GO TO 100
  681 KK1=K1
      KK2=K2
      KK3=K3
      GO TO 673
```

```
673 R= FLOAT(K3-K1)/(2.0**L)
      IF(((ABS(TCOST(KK1)-TCOST(KK2))).LT.50.).AND.((ABS(TCOST(KK2)-TCO
     1ST(KK3))).LT.50.)) GO TO 678
      IF((TCOST(KK1).GT.TCOST(KK2)).AND.(TCOST(KK2).GT.TCOST(KK3)))
     1 CALL WRONG(KK1,KK2,KK3,R,KK5,KK6,KK7,&807)
      IF((TCOST(KK3).GT.TCOST(KK2)).AND.(TCOST(KK2).GT.TCOST(KK1)))
     1 CALL WRONG(KK3,KK2,KK1,R,KK5,KK6,KK7,&807)
      IF((TCOST(KK3).GT.TCOST(KK2)).AND.(TCOST(KK1).GT.TCOST(KK2)))
     1CALL STANDD(KK1,KK2,KK3,R,KK5,KK6,KK7,&802)
      WRITE(NOUT,801)
801 FORMAT(//,' *****ERROR***  THE COST OF THE CENTER POINT IS GREATER
     1 THAT THE LIMIT POINTS.  THIS INDICATES A DISCONTINUOUS COST FUNCT
     2 ION.  ',//, ' RERUN PROBLEM WITH LIMITS SET BY 50% DIFFERENT FROM
     3THIS PROBLEM')
      GO TO 69
802 K=KK5
      LL=0
      GO TO 100
803 K=KK6
      LL=1
      GO TO 100
804 K=KK7
      LL=2
      IF((IABS(KK5-KK6)).LT.2) KK2=KK6
      IF((IABS(KK5-KK6)).LT.2) GO TO 678
      IF((IABS(KK6-KK7)).LT.2) KK2=KK6
      IF((IABS(KK6-KK7)).LT.2) GO TO 678
      KK1=KK5
      KK2=KK6
      KK3=KK7
      GO TO 121
678 ZCOST=TCOST(KK2)
      DD=KK2
      ZHL=H
      GO TO 1003
807 DO 808 J=KK5,KK7
      D=FLOAT(J)/12.
      CALL FLOCLC(W,ZL,D,BLOSS,Q,N,H)
      CALL CPUMP(N,Q,D,ACOST)
      CALL CPIPE(N,D,ZL,BCOST)
      CALL CEXCAV(N,D,ZL,CCOST)
      IF(INSULI.EQ.0) DCOST=0.0
      IF(INSULI.NE.0) CALL CINSUL(N,D,ZL,DCOST)
      CALL CMNHOL(N,ZL,ECOST)
      CALL CCONDT(N,D,ZL,FCOST)
      CALL PUMCST(H,Q,N,GCOST)
      CALL SUPCST(ACOST,BCOST,CCOST,DECOS,ECOST,FCOST,GCOST,D,ZL,Q,N,HCO
     1ST)
      IF(KK.NE.MONY) ACOST=0.0
      TCOST(J)= ACOST+BCOST+CCOST+DCOST+ECOST+FCOST+GCOST
      IF(J.EQ.KK5)     GO TO 808
      IF(J.EQ.(KK5+1)) JJ=KK5
      IF(TCOST(J).LT.TCOST(JJ)) SAVE=TCOST(J)
      IF(TCOST(JJ).LE.TCOST(J)) SAVE =TCOST(JJ)
      IF(TCOST(J).LT.TCOST(JJ)) JJ=J
808 CONTINUE
      DD=JJ
      D=JJ/12.
```

```
1003 CALL FLOCLC(W,ZL,(DD/12.),BLOSS,Q,N,H)
     CALL CPUMP(N,Q,D,ACOST)
     CALL CPIPE(N,D,ZL,BCOST)
     CALL CEXCAV(N,D,ZL,CCOST)
     IF(INSULI.EQ.0) DCOST=0.0
     IF(INSULI.NE.0) CALL CINSUL(N,D,ZL,DCOST)
     CALL CMNHOL(N,ZL,ECOST)
     CALL CCONDT(N,D,ZL,FCOST)
     CALL PUMCST(H,Q,N,GCOST)
     CALL SUPCST(ACOST,BCOST,CCOST,DCOST,ECOST,FCOST,GCOST,D,ZL,Q,N,HCO
    1ST)
     IF(KK.NE.MONY) ACOST=0.0
     PRINCP=ACOST+BCOST+CCOST+DCOST+ECOST+FCOST+HCOST
     ZCOST=PRINCP+GCOST
     CALL HEAT$(W,DELTA,$SOLD)
     IF(DELTA.LT.0) GO TO 707
     GO TO 708
 707 RETINV=0.0
 708 WRITE(NJ4'KK) PRINCP,$SOLD,ACOST,BCOST,CCOST,DCOST,ECOST,FCOST,GCO
    1ST,HCOST
     DD=JJ
     ZHL=H
     IDIAM=JJ
     WRITE(NOUT,712) KK,N,IDIAM,ACOST,BCOST,CCOST,DCOST,ECOST,FCOST,GCO
    2ST
     GO TO 1002
1001 ZCOST=0.
     ZHL=0.
     DD=0.
1002 RETURN
 712 FORMAT(//,3I5,7F15.2)
  69 STOP
     END
```

```
C
C
C
      SUBROUTINE TEMOP(KK,W,ZL,BLOSS,DELTA,ZCOST,ZHL,DD)
C      THIS ROUTINE OPTIMIZES BASED ON MAXIMUM PROFIT
      COMMON /A1/K1,K2,K3
      COMMON/A4/MONY
      COMMON/A5/ NJ1,NJ2,NJ3,NJ4,NJ5
      COMMON/A8/J1,J2,J3,J4,J5,J6,J7,J8,J9,I1,I2
      COMMON/A12/BASEW,BASEP,BASEE,BASEV,BASED,BASE$,BASEW$,BASEP$
      COMMON /A20/JJ1,JJ2,JJ3,JJ4,JJ5,JJ6,JJ7,JJ8,JJ9
      COMMON/A22/FCTRLD,BASEH$
      COMMON/A23/YEARS,SALVA$,FRINTR,T1,T2,T3,T4,T5,T6
      COMMON/A27/ INSULI
      COMMON/A28/U14,U15,U16,U17,U18,U19,U20,U21,U22,U23
      DATA NIN,NOUT/1,3/
      IF(W.LT.0) GO TO 146
      CALL HEAT$(W,DELTA,$SOLD)
      DO 29 LM=K1,K3
      CALL FLOCLC(W,ZL,(FLOAT(LM)/12.),BLOSS,Q,N,H)
      DIAM=FLOAT(LM)/12.
      CALL CPIPE(N,DIAM,ZL,BCOST)
      CALL CEXCAV(N,DIAM,ZL,CCOST)
      CALL PUMCST(H,Q,N,GCOST)
      PRINCP=(BCOST+CCOST)/YEARS
      CALL FINAN(PRINCP,FIN$)
      CALL OANDM(PRINCP,RETINV,OANDM$)
      GGCOST=PRINCP+OANDM$+FIN$+GCOST
      CALL HEAT$(W,DELTA,$SOLD)
      IF(LM.EQ.K1) GO TO 27
      IF(GGCOST.LT.SAVE) GO TO 27
      GO TO 29
   27 SAVE=GGCOST
   28 ISAVE=LM
   29 CONTINUE
      DIA=FLOAT(ISAVE)/12.
      D=DIA
      CALL FLOCLC(W,ZL,DIA,BLOSS,Q,N,H)
      CALL PUMCST(H,Q,N,GCOST)
      GO TO 118
  116 RETINV=0.0
  118 CALL CMNHOL(N,ZL,ECOST)
      CALL CPUMP(N,Q,DIA,ACOST)
      CALL CPIPE(N,DIA,ZL,BCOST)
      CALL CEXCAV(N,DIA,ZL,CCOST)
      IF(INSULI.EQ.0) DCOST=0.0
      IF(INSULI.NE.0) CALL CINSUL(N,D,ZL,DCOST)
      CALL CCONST(N,DIA,ZL,FCOST)
      CALL SUPCST(ACOST,BCOST,CCOST,DCOST,ECOST,FCOST,GCOST,D,ZL,Q,N,HCO
     1ST)
      IF(KK.NE.MONY) ACOST=0.0
      PRINCP=ACOST+BCOST+CCOST+DCOST+ECOST+FCOST+HCOST
      ZCOST=PRINCP+GCOST
      IDIAM=ISAVE
      WRITE(NOUT,712) KK,N,IDIAM,ACOST,BCOST,CCOST,DCOST,ECOST,FCOST,GCO
     1ST
  708 WRITE(NJ4'KK) PRINCP,$SOLD,ACOST,BCOST,CCOST,DCOST,ECOST,FCOST,GCO
     1ST,HCOST
```

```
      ZHL=H
      DD=DIA
      RETURN
  146 ZCOST=0.
      ZHL=0.
      DD=0.
      RETURN
  712 FORMAT(//,3I5,7F15.2)
      END
```

```
C
C
C
C
      SUBROUTINE VELIN
C      THIS ROUTINE INPUTS VELOCITY & # OF PIPES
      COMMON/A8/J1,J2,J3,J4,J5,J6,J7,J8,J9,I1,I2
      COMMON/A14/ VELLIM,NNN
      COMMON/A15/J10,J11,J12,J13,J14,J15,J16,J17,J18,J19,J20
      COMMON/A20/JJ1,JJ2,JJ3,JJ4,JJ5,JJ6,JJ7,JJ8,JJ9
      DATA NIN,NOUT /1,3/
      IF(J1.EQ.0) VELLIM=10.
      IF(J1.GT.0) READ(NIN,10) VELLIM
      IF(J19.EQ.1) WRITE(NOUT,13) VELLIM
      IF(JJ1.EQ.1) READ(NIN,11) NNN
      IF(JJ1.EQ.0) NNN=0
      NJ=NNN+1
      IF(JJ2.EQ.1) WRITE(NOUT,18) NJ
      RETURN
   10 FORMAT(F20.7)
   11 FORMAT(I5)
   13 FORMAT(/,' LIMITING VELOCITY IS : ', F20.7)
   18 FORMAT(//, ' THE MIN # OF PIPES IS :',I5)
      END
```

```
C
C
C
      SUBROUTINE ANHLIN
C       THIS ROUTINE INPUTS MANHOLE DATA
      COMMON/A8/J1,J2,J3,J4,J5,J6,J7,J8,J9,I1,I2
      COMMON/A13/HOLCST,HOLFT
      COMMON/A15/ J10,J11,J12,J13,J14,J15,J16,J17,J18,J19,J20
      DATA NIN,NOUT /1,3/
      IF(J7.EQ.0) RETURN
      IF(J7.EQ.1) GO TO 1
      IF(J7.EQ.2) GO TO 3
      IF(J7.EQ.3) GO TO 5
    1 READ(NIN,10) HOLCST
      HOLFT=1000.
      GO TO 19
    3 READ(NIN,10) HOLFT
      HOLCST=38.
      GO TO 19
    5 READ(NIN,11) HOLCST,HOLFT
   19 IF(J18.EQ.1) WRITE(NOUT,17) HOLCST,HOLFT
      RETURN
   10 FORMAT(F20.7)
   11 FORMAT(2F20.7)
   17 FORMAT(/,' MANHOLE COST IS : $ ',F20.7,'   A MANHOLE IS INSTALLED
     1EVERY ',F15.7,'FEET')
      END
```

```
C
C
      SUBROUTINE TLREAD
C       THIS ROUTINE INPUTS TABLE DATA
      COMMON/A8/J1,J2,J3,J4,J5,J6,J7,J8,J9,I1,I2
       COMMON/A9/TPIPE(100)
       COMMON/A10/TCNDT(200)
      COMMON/A11/TPUMP(100)
      COMMON/A15/J10,J11,J12,J13,J14,J15,J16,J17,J18,J19,J20
      DATA NIN,NOUT /1,3/
      IF(J3.EQ.2) GO TO 1
    2 IF(J4.EQ.2) GO TO 3
    4 IF(J8.EQ.1) GO TO 5
      RETURN
    1 IF(J16.EQ.1) WRITE(NOUT,44)
      DO 43 J=1,100
      READ(NIN,10) N,$PUMP
      IF(J16.EQ.1) WRITE(NOUT,45) N,$PUMP
      TPUMP(N)=$PUMP
   43 CONTINUE
      GO TO 2
    3 IF(J14.EQ.1) WRITE(NOUT,46)
       DO 20 J=1,100
      READ(NIN,10) N,$PIPE
      IF(J14.EQ.1) WRITE(NOUT,45) N,$PIPE
      TPIPE(N)=$PIPE
   20 CONTINUE
      GO TO 4
    5 IF(J15.EQ.1) WRITE(NOUT,47)
      DO 30 J=1,50
      READ(NIN,10) N,$CNDUT
      IF(J15.EQ.1) WRITE(NOUT,45) N,$CNDUT
      TCNDT(N)= $CNDUT
   30 CONTINUE
      RETURN
   10 FORMAT( I5,F20.7)
   44 FORMAT('1',' PUMP COST DATA')
   45 FORMAT(I5,F20.7)
   46 FORMAT('1',' PIPE COST DATA')
   47 FORMAT('1',' CONDUIT COST DATA')
      END
```

```
C
C
C
      SUBROUTINE PRICEI
C     THIS ROUTINE INPUTS COST DATA
      COMMON/A8/J1,J2,J3,J4,J5,J6,J7,J8,J9,I1,I2
      COMMON/A12/BASEW,BASEP,BASEE,BASEV,BASED,BASE$,BASEW$,BASEP$
      COMMON/A15/J10,J11,J12,J13,J14,J15,J16,J17,J18,J19,J20
      DATA NIN,NOUT /1,3/
      BASEW= 0.0
      BASEP= 0.0
      BASEE = 0.0
      BASEV = 0.0
      BASED = 0.0
      BASE$= 0.0
      BASEW$= 0.0
      BASEP$= 0.0
      IF(J3.EQ.1) GO TO 1
    2 IF(J4.EQ.1) GO TO 3
    4 IF(J5.EQ.1) GO TO 5
    6 IF(J6.EQ.1) GO TO 7
    8 IF(J9.EQ.1) GO TO 9
   12 IF(J17.EQ.1) WRITE(NOUT,49) BASEW,BASEW$,BASEP,BASEP$,BASEE
     1,BASEV,BASED,BASE$
      RETURN
    1 READ(NIN,11) BASEW,BASEW$
      GO TO 2
    3 READ(NIN,11) BASEP,BASEP$
      GO TO 4
    5 READ(NIN,10) BASEE
      GO TO 6
    7 READ(NIN,10) BASEV
      GO TO 8
    9 READ(NIN,11) BASED,BASE$
      IF(J17.EQ.1) WRITE(NOUT,49) BASEW,BASEW$,BASEP,BASEP$,BASEE,
     1BASEV,BASED,BASE$
      RETURN
   10 FORMAT(F20.7)
   11 FORMAT(2F20.7)
   49 FORMAT(/,' INPUT DATA     BASE COSTS',//,' BASE FLOW RATE  PUMP COS
     1T   BASE PIPE SIZE  PIPE COST EXCAVATION  INSULATION  BASE DAYS    $
     2$/KWH',/,8F12.3,//)
      END
```

```
C
C
C
      SUBROUTINE FLOCLC(W,ZL,D,BLOSS,Q,N,H)
C      THIS ROUTINE CALCULATES HEAD LOSS AND # OF PIPES
      COMMON/A1/K1,K2,K3
      COMMON/A2/RHO,POIS
      COMMON/A5/ NJ1,NJ2,NJ3,NJ4,NJ5
      COMMON /A6/ KK
      COMMON/A7/LQ
      COMMON/A8/J1,J2,J3,J4,J5,J6,J7,J8,J9,I1,I2
      COMMON/A14/ VELLIM,NNN
      COMMON/A19/ S2(4),S1(4),X1(4),X2(4)
      COMMON/A20/JJ1,JJ2,JJ3,JJ4,JJ5,JJ6,JJ7,JJ8,JJ9
      DATA NIN,NOUT/1,3/
      GC=32.17
      IF(JJ1.EQ.0) N=0
      IF(JJ1.GT.0) N=NNN
   20 N=N+1
      WT= W/ FLOAT(N)
      A= 3.14159*D**2/4.
      V= WT/(RHO*A*3600.)
      IF(V.GT.VELLIM) GO TO 20
      RE= D*V*RHO/POIS
       Q=A*V
      IF(RE.LT.2100.) F=16./RE
      IF((RE.GT.2100).AND.(RE.LT.1. E5)) F=0.186-.0026*ALOG10(RE)
      IF(RE.GE.1. E5) F=.0025
      HL=4.0*F*ZL*V**2/(2.0*GC*D)
      IF(BLOSS.LT.0.) GO TO 9515
      IF(J2.EQ.1) GO TO 35
      BLOSS= 0.4*HL
      GO TO 35
 9515 BLOSS=0.0
   35 H=HL+ BLOSS
      WRITE(NJ2'LQ) N,Q,H
      RETURN
      END
```

```
C
C
C
      SUBROUTINE CPUMP(NPUMP,Q,D,ACOST)
C      THIS ROUTINE CALCULATES PUMP COST
      COMMON/A3/CPI(7)
      COMMON/A8/J1,J2,J3,J4,J5,J6,J7,J8,J9,I1,I2
      COMMON/A11/TPUMP(100)
      COMMON/A12/BASEW,BASEP,BASEE,BASEV,BASED,BASE$,BASEW$,BASEP$
      COMMON/A19/ $2(4),$1(4),X1(4),X2(4)
      DATA NIN,NOUT/1,3/
      IF(J3.EQ.0) GO TO 1
      IF(J3.EQ.1) GO TO 2
      IF(J3.EQ.2) GO TO 3
      IF(J3.EQ.3) GO TO 4
C      TOTAL INSTALLED COST OF THE PUMPS
    1 WBASE= 400.0/(60.0*7.48)
      RATIO = Q/WBASE
      ACOST= CPI(1)*RATIO**0.98*1185.0*NPUMP
      GO TO 5
    2 RATIO= Q/BASEW
      ACOST= CPI(1)*RATIO**0.98*BASEW$*NPUMP
      GO TO 5
    3 NO=D*12.+.5
      ACOST=CPI(1)*TPUMP(NO)*NPUMP
      GO TO 5
    4 DIA=12.*D
      CALL CPOLE(1,DIA,$$$)
      ACOST=CPI(1)*$$$*NPUMP
      GO TO 5
    5 RETURN
      END
```

```
C
C
C
C
C
C
      SUBROUTINE CPIPE(NPIPE,D,ZLENTH,BCOST)
C     THIS ROUTINE CALCULATES PIPE COST
      COMMON/A3/CPI(7)
      COMMON/A8/J1,J2,J3,J4,J5,J6,J7,J8,J9,I1,I2
       COMMON/A9/TPIPE(100)
      COMMON/A12/BASEW,BASEP,BASEE,BASEV,BASED,BASE$,BASEW$,BASEP$
      COMMON/A19/ $2(4),$1(4),X1(4),X2(4)
      DATA NIN,NOUT/1,3/
      IF(J4.EQ.0) GO TO 1
      IF(J4.EQ.1) GO TO 2
      IF(J4.EQ.2) GO TO 3
      IF(J4.EQ.3) GO TO 4
    1 RATIO = 1.2*D
      BCOST= NPIPE*RATIO**1.15*ZLENTH*CPI(2)*30.
      GO TO 5
    2 RATIO = 12.0*D/BASEP
      BCOST=NPIPE*RATIO**1.15*ZLENTH*CPI(2)*BASEP$
      GO TO 5
    3 NO=D*12.+.5
      BCOST= NPIPE*ZLENTH*CPI(2)*TPIPE(NO)
      GO TO 5
    4 DIA=12.*D
      CALL CPOLE(2,DIA,$$$)
      BCOST= NPIPE*ZLENTH*CPI(2)*$$$
      GO TO 5
    5 RETURN
      END
```

```
C
C
C
      SUBROUTINE CEXCAV(NPIPE,D,ZLENTH,CCOST)
C     THIS ROUTINE CALCULATES EXCAVATION COST
      COMMON/A3/CPI(7)
      COMMON/A8/J1,J2,J3,J4,J5,J6,J7,J8,J9,I1,I2
      COMMON/A12/BASEW,BASEP,BASEE,BASEV,BASED,BASE$,BASEW$,BASEP$
      DATA NIN,NOUT/1,3/
      IF(J5.EQ.0) GO TO 1
      IF(J5.EQ.1) GO TO 2
    1 WIDTH= 2.0+NPIPE*D
      DEPTH = 3.0+D
       VOL= ZLENTH*WIDTH*DEPTH
      CCOST= CPI(3)*VOL*2.0
      GO TO 5
    2 WIDTH= 2.0+ NPIPE*D
      DEPTH= 3.0+D
      VOL= ZLENTH*WIDTH*DEPTH
      CCOST= CPI(3)*VOL*BASEE
      GO TO 5
    5 RETURN
      END
```

```
C
C
C
      SUBROUTINE CINSUL(NPIPE,D,ZLENTH,DCOST)
C     THIS ROUTINE CALCULATES INSULATION COST
      COMMON/A3/CPI(7)
      COMMON/A8/J1,J2,J3,J4,J5,J6,J7,J8,J9,I1,I2
      COMMON/A12/BASEW,BASEP,BASEE,BASEV,BASED,BASE$,BASEW$,BASEP$
      DATA NIN,NOUT/1,3/
      IF(J6.EQ.0) GO TO 1
      IF(J6.EQ.1) GO TO 2
    1 DCOST= CPI(4)*NPIPE*ZLENTH*D
      GO TO 5
    2 DCOST=CPI(4)*NPIPE*ZLENTH*BASEV*D
      GO TO 5
    5 RETURN
      END
```

```
C
C
C
      SUBROUTINE CMNHOL(NPIPE,ZLENTH,ECOST)
C     THIS ROUTINE CALCULATES MANHOLE COSTS
      COMMON/A3/CPI(7)
      COMMON/A8/J1,J2,J3,J4,J5,J6,J7,J8,J9,I1,I2
      COMMON/A13/HOLCST,HOLFT
      DATA NIN,NOUT/1,3/
      IF(J7.EQ.0) GO TO 1
      IF(J7.EQ.1) GO TO 2
      IF(J7.EQ.2) GO TO 3
      IF(J7.EQ.3) GO TO 4
    1 DEPTH=9.+ (NPIPE-2)*0.5
      ECOST= CPI(5)*ZLENTH*DEPTH*38./1000.
      GO TO 5
    2 DEPTH=9.+(NPIPE-2)*0.5
      ECOST=CPI(5)*ZLENTH*DEPTH*HOLCST/HOLFT
      GO TO 5
    3 DEPTH= 9.+ (NPIPE-2)*0.5
      ECOST=CPI(5)*ZLENTH*DEPTH*HOLCST/HOLFT
      GO TO 5
    4 DEPTH=9.+ (NPIPE-2)*0.5
      ECOST=CPI(5)*ZLENTH*DEPTH*HOLCST/HOLFT
      GO TO 5
    5 RETURN
      END
```

```
C
C
C
      SUBROUTINE CCONDT(NPIPE,D,ZLENTH,ECOST)
C     THIS ROUTINE CALCULATES CONDUIT COST
      COMMON/A3/CPI(7)
      COMMON/A8/J1,J2,J3,J4,J5,J6,J7,J8,J9,I1,I2
       COMMON/A10/TCNDT(200)
      COMMON/A19/ $2(4),$1(4),X1(4),X2(4)
      DATA NIN,NOUT/1,3/
      IF(J8.EQ.0) GO TO 1
      IF(J8.EQ.1) GO TO 2
      IF(J8.EQ.2) GO TO 4
    1 DIA=2.0*D+ (NPIPE-2)*D/2.
      RATIO= DIA/3.
      ECOST=CPI(6)*RATIO**0.6*ZLENTH*14.
       GO TO 5
    2 NO=(12.*D+2.)/4.
      NOO=4*NO
      IF(NOO.EQ.0) NOO=4
       ECOST=CPI(6)*ZLENTH*TCNDT(NOO)
      GO TO 5
    4 DIA=(2.0*D+(NPIPE-2)*D/2.0)*12.
      CALL CPOLE(3,DIA,$$$)
      ECOST=CPI(6)*ZLENTH*$$$
      GO TO 5
    5 RETURN
       END
```

```
C
C
      SUBROUTINE PUMCST(DELTAP,Q,NPIPE,GCOST)
C      THIS ROUTINE CALCULATES PUMPING POWER COST
      COMMON/A2/RHO,POIS
      COMMON/A3/CPI(7)
      COMMON/A8/J1,J2,J3,J4,J5,J6,J7,J8,J9,I1,I2
      COMMON/A12/BASEW,BASEP,BASEE,BASEV,BASED,BASE$,BASEW$,BASEP$
      DATA NIN,NOUT/1,3/
      HP=DELTAP*RHO*Q/(550.0*0.4)
      ZKW= HP/0.74548
      IF(J9.EQ.0) GO TO 1
      IF(J9.EQ.1) GO TO 2
    1 HRS= 300.0*24.
      WTHRS = ZKW*HRS
      TTLKWH = NPIPE*WTHRS
      GCOST= 0.010*CPI(7)*TTLKWH
      GO TO 24
    2 HRS= BASED*24.
      WTHRS= ZKW*HRS
      TTLKWH = NPIPE*WTHRS
      GCOST = BASE$*CPI(7)*TTLKWH
      GO TO 24
   24 RETURN
      END


C
C
      SUBROUTINE CPOLE(M,VARI,$$$)
      COMMON/A19/ $2(4),$1(4),X1(4),X2(4)
      EXPON=(ALOG10($2(M))-ALOG10($1(M)))/ALOG10(X2(M)/X1(M))
      $$$= $1(M)*(VARI/X1(M))**EXPON
      RETURN
      END
```

```
      SUBROUTINE EXPOIN
      COMMON/A8/J1,J2,J3,J4,J5,J6,J7,J8,J9,I1,I2
      COMMON/A19/ $2(4),$1(4),X1(4),X2(4)
      DATA NIN,NOUT/1,3/
      IF(J3.EQ.3) GO TO 1
    2 IF(J4.EQ.3) GO TO 3
    4 IF (J8.EQ.2) GO TO 5
      RETURN
    1 READ(NIN,8) X1(1),$1(1),X2(1),$2(1)
      GO TO 2
    3 READ(NIN,8) X1(2),$1(2),X2(2),$2(2)
      GO TO 4
    5 READ(NIN,8) X1(3),$1(3),X2(3),$2(3)
      RETURN
    8 FORMAT(4F20.7)
      END
```

```
C
C
C
      SUBROUTINE WRONG(KK1,KK2,KK3,R,KK5,KK6,KK7,*)
C     THIS ROUTINE CONTROLS WHEN CURVE ORIENTATION IS WRONG
      COMMON/A1/K1,K2,K3
      IF(KK1.GT.KK3) GO TO 46
      IF(KK1.LE.KK3) GO TO 47
   46 KK5=KK3
      K01=KK3-R/2.5
      IF(K01.GT.K1) KK5=K01
      KK6=0
       KK7=KK2
      RETURN 1
   47 KK5=KK2
      KK6=0
      KK7=KK2
      K01=KK2+R/2.
      IF(K01.LT.K3) KK7=K01
      RETURN 1
      END
```

```
C
C
C
      SUBROUTINE STANDD(KK1,KK2,KK3,R,KK5,KK6,KK7,*)
C     THIS ROUTINE CONTROLS WHEN CURVE ORIENTATION IS RIGHT
      KK5=KK2 -IFIX(R)/2
      KK6=KK2
      KK7=KK2 + IFIX(R)/2
      RETURN 1
       END
```

```
C
C
C
      SUBROUTINE HEAT$(W,DELTA,$SOLD)
      COMMON/A20/JJ1,JJ2,JJ3,JJ4,JJ5,JJ6,JJ7,JJ8,JJ9
      COMMON/A22/FCTRLD,BASEH$
      RETINV=$SOLD-GCOST
      IF(W.LT.0.) $SOLD=0.
      IF(W.LT.0.) GO TO 5
      IF(JJ4.EQ.1) GO TO 1
      IF(JJ4.EQ.2) GO TO 2
    1 $SOLD=W*FCTRLD*DELTA*.23/100000.
      GO TO 5
    2 $SOLD=W*DELTA*FCTRLD*BASEH$/1000000.
    5 RETURN
      END
```

```
C
C
      SUBROUTINE DRECON
C      THIS ROUTINE READS ECONOMIC DATA
      COMMON/A5/ NJ1,NJ2,NJ3,NJ4,NJ5
      COMMON /A6/ KK
      COMMON/A22/FCTRLD,BASEH$
      COMMON/A23/YEARS,SALVA$,FRINTR,T1,T2,T3,T4,T5,T6
      COMMON/A24/ T7,T8,T9,T10,T11,T12,T13,T14,T15,T16,T17,T18
      COMMON/A25/U1,U2,U3,U4,U5,U6,U7,U8,U9,U10,U11,U12,U13
      COMMON/A28/U14,U15,U16,U17,U18,U19,U20,U21,U22,U23
      DATA NIN,NOUT/1,3/
      READ(NIN,1) FCTRLD,BASEH$,YEARS,SALVA$,FRINTR
      READ(NIN,1) T1,T2,T3,T4,T5
      READ(NIN,1) T6,T7,T8,T9,T10
      READ(NIN,1)T11,T12,T13,T14,T15
      READ(NIN,1)T16,T17,T18,U1,U2
      READ(NIN,1)U3,U4,U5,U6,U7
      READ(NIN,1) U8,U9,U10,U11,U12
      READ(NIN,2) U13
      READ(NIN,1) U14,U15,U16,U17,U18
      READ(NIN,1) U19,U20,U21,U22,U23
      RETURN
    1 FORMAT(5F15.5)
    2 FORMAT(F15.5)
    3 FORMAT(4F15.5)
      END
```

```
C
C
C
      SUBROUTINE SUPCST(ACOST,BCOST,CCOST,DCOST,ECOST,FCOST,GCOST,D,ZL,
     1Q,N,HCOST)
      COMMON/A25/U1,U2,U3,U4,U5,U6,U7,U8,U9,U10,U11,U12,U13
      HCOST=U1*ACOST+U2*BCOST+U3*CCOST+U4*DCOST+U5*ECOST+U6*FCOST
     1+U7*GCOST+U9*D+U13+U10*ZL+U11*Q+U8+U12*N
      RETURN
      END
```

```
C
C
      SUBROUTINE DEPREC(M,PRINCP,DEPRE$)
      COMMON/A20/JJ1,JJ2,JJ3,JJ4,JJ5,JJ6,JJ7,JJ8,JJ9
      COMMON/A22/FCTRLD,BASEH$
      COMMON/A23/YEARS,SALVA$,FRINTR,T1,T2,T3,T4,T5,T6
      I=0
      IF(JJ5.EQ.0) GO TO 1
      IF(JJ5.EQ.1) GO TO 2
      IF(JJ5.EQ.2) GO TO 3
      IF(JJ5.EQ.3) GO TO 4
    1 DEPRE$=(PRINCP*(1.-SALVA$))/YEARS
      GO TO 5
    2 K=IFIX(YEARS)
      DO 7 J=1,K
    7 I=I+J
      DEPRE$=(2.0*(YEARS-FLOAT(M)+1.)*PRINCP*(1.-SALVA$))/(YEARS*(YEARS+
     11.))
      GO TO 5
    3 DEPRE$=(PRINCP*(1.-SALVA$)*FRINTR)/((1.+FRINTR)**M-1.)
      GO TO 5
    4 IF(M.EQ.1) DEPRE$=PRINCP*2.0*(1./YEARS)
      IF(M.EQ.1) GO TO 5
      FR=2.0*(1./YEARS)
      VA=PRINCP*(1.-SALVA$)*(1.-FR)**(M-1)
      DEPRE$=VA*FR
    5 RETURN
      END
```

```
      SUBROUTINE OANDM(PRINCP,RETINV,OANDM$)
      COMMON/A24/ T7,T8,T9,T10,T11,T12,T13,T14,T15,T16,T17,T18
      OANDM$=T7*PRINCP+T8*RETINV+T9
      RETURN
      END
C
C
      SUBROUTINE SUPPCS(PRINCP,RETINV,OANDM$,FIN$,DEPRE$,SUPP$)
      COMMON/A23/YEARS,SALVA$,FRINTR,T1,T2,T3,T4,T5,T6
      SUPP$=PRINCP*T1+RETINV*T2+OANDM$*T3+FIN$*T4+DEPRE$*T5+T6
      RETURN
      END
C
C
C
C
      SUBROUTINE FINAN(PRINCP,FIN$)
      COMMON/A24/ T7,T8,T9,T10,T11,T12,T13,T14,T15,T16,T17,T18
      FIN$=T10*PRINCP+T11
      RETURN
      END
C
C
C
      SUBROUTINE RTOWAY(KK,RTWAY$)
      COMMON/A5/ NJ1,NJ2,NJ3,NJ4,NJ5
      COMMON/A28/U14,U15,U16,U17,U18,U19,U20,U21,U22,U23
      ZLT=0.
      DO 1 J=1,KK
      READ(NJ1'J) W,ZL,BLOSS,DELTA
      IF(W.LT.0.) GO TO 1
      ZLT=ZLT+ZL
    1 CONTINUE
      RTWAY$=(ZLT-U14)*U15 +U18
      RETURN
      END
```

```
      SUBROUTINE ADJUST(XX1,XX2)
C      THIS ROUTINE COMPUTES THE ADJUSTMENTS TO BE APPLIED
      COMMON/A8/J1,J2,J3,J4,J5,J6,J7,J8,J9,I1,I2
      COMMON/A28/U14,U15,U16,U17,U18,U19,U20,U21,U22,U23
      IF(I2.EQ.0) GO TO 1
      IF(I2.EQ.1) GO TO 2
    1 IF(I1.EQ.0) GO TO 3
      IF(I1.EQ.1) GO TO 4
      IF(I1.EQ.2) GO TO 5
    3 XX1=U21*15.0+U23
      ZL=5280.
      W=500.0*U21
      BLOSS=0.0
      D=4.
      CALL FLOCLC(W,ZL,D,BLOSS,Q,N,H)
      CALL PUMCST(H,Q,N,GLCOST)
      XX2=GLCOST/2.
      GO TO 6
    4 XX1=U21*20.0*0.5+U23
    5 ZL=5280.
      W=500.0*U21
      BLOSS=0.
      D=4.
      CALL FLOCLC(W,ZL,D,BLOSS,Q,N,H)
      CALL PUMCST(H,Q,N,GLCOST)
      XX2=GLCOST
      IF(I1.EQ.1) GO TO 6
      A=U21*7.3
      V=5.0*A/1.5
      XX1=V*2.0/9.0+U21*7.5+A*0.25
      GO TO 6
    2 XX1=(1.-U22)*U19+U23
      XX2=(1.-U22)*U20
    6 RETURN
      END
```

```
      SUBROUTINE WRITEO(KK)
C      THIS IS THE OUTPUT AND ECONOMICS CONTROL ROUTINE
      COMMON/A1/K1,K2,K3
      COMMON/A2/RHO,POIS
      COMMON/A3/CPI(7)
      COMMON/A4/MONY
      COMMON/A5/ NJ1,NJ2,NJ3,NJ4,NJ5
      COMMON/A8/J1,J2,J3,J4,J5,J6,J7,J8,J9,I1,I2
       COMMON/A9/TPIPE(100)
       COMMON/A10/TCNDT(200)
      COMMON/A11/TPUMP(100)
      COMMON/A12/BASEW,BASEP,BASEE,BASEV,BASED,BASE$,BASEW$,BASEP$
      COMMON/A13/HOLCST,HOLFT
      COMMON/A14/ VELLIM,NNN
      COMMON/A16/ NODE(13),TCOST(100)
      COMMON/A17/ N,Q,H,DD,D,ZL,ZCOST,ZZCOST,ACOST
      COMMON/A18/ BCOST,CCOST,DCOST,ECOST,FCOST,GCOST
      COMMON/A20/JJ1,JJ2,JJ3,JJ4,JJ5,JJ6,JJ7,JJ8,JJ9
      COMMON/A22/FCTRLD,BASEH$
      COMMON/A23/YEARS,SALVA$,FRINTR,T1,T2,T3,T4,T5,T6
      COMMON/A24/ T7,T8,T9,T10,T11,T12,T13,T14,T15,T16,T17,T18
      COMMON/A25/U1,U2,U3,U4,U5,U6,U7,U8,U9,U10,U11,U12,U13
      COMMON/A28/U14,U15,U16,U17,U18,U19,U20,U21,U22,U23
      DIMENSION PVALUE(7),PSS(7)
      DATA NIN,NOUT/1,3/
      DATA SP,SA,SB,SC,SD,SE,SF,SG,S$/0.,0.,0.,0.,0.,0.,0.,0.,0./
      FIND(NJ1'1)
      FIND(NJ2'1)
      FIND(NJ3'1)
      SH=0.
      ILLK=0
      IF(JJ8.EQ.0) GO TO 13
      WRITE(NOUT,204)
   12 WRITE(NOUT,14) FCTRLD,BASEH$,YEARS,SALVA$,FRINTR
      WRITE(NOUT,15) T1,T2,T3,T4,T5
      WRITE(NOUT,16) T6,T7,T8,T9,T10
      WRITE(NOUT,17) T11,T12,T13,T14,T15
      WRITE(NOUT,18) T16,T17,T18
      WRITE(NOUT,19) U1,U2,U3,U4,U5
      WRITE(NOUT,20) U6,U7,U8,U9,U10
      WRITE(NOUT,21) U11,U12,U13
      WRITE(NOUT,22) U14,U15,U16,U17,U18
      WRITE(NOUT,23) U19,U20,U21,U22,U23
      GO TO 13
   13 IF(JJ6.EQ.0) GO TO 1
    5 IF (JJ6.EQ.0) GO TO 6
      IF(JJ6.EQ.2) GO TO 6
    1 WRITE(NOUT,2)
      DO 3 L=1,KK
      READ(NJ1'L) W,ZL,BLOSS,DELTA
      READ(NJ4'L) PRINCP,$SOLD,ACOST,BCOST,CCOST,DCOST,ECOST,FCOST,GCOST
     1,HCOST
      IF(W.LT.0.) GO TO 3
      WRITE(NOUT,4) L,ACOST,BCOST,CCOST,DCOST,ECOST,FCOST,GCOST,$SOLD
      SA=SA+ACOST
      SB=SB+BCOST
      SC=SC+CCOST
      SD=SD+DCOST
```

```
      SE=SE+ECOST
      SF=SF+FCOST
      S$=S$+$SOLD
      SG=SG+GCOST
      SP=SP+PRINCP
      SH=SH+HCOST
    3 CONTINUE
      WRITE(NOUT,205) SA,SB,SC,SD,SE,SF,SG,S$
 2832 IF(ILLK.EQ.2) GO TO 2322
      IF(ILLK.EQ.0) WRITE(NOUT,207)
      IF(ILLK.EQ.1) WRITE(NOUT,2831)
      MMI5=IFIX(YEARS+0.5)
      DO 220 M=1,MMI5
      WRITE(NOUT,221) M
      IF((ILLK.EQ.1).AND.(M.EQ.1)) CALL ADJUST(SPA,SGA)
      IF((ILLK.EQ.1).AND.(M.EQ.1)) SP=SP-SPA
      IF(SP.LT.0.) SP=0.
      WRITE(NOUT,206) SP
       WRITE(NOUT,2557) SH
      IF((ILLK.EQ.0).AND.(M.EQ.1)) S$=S$*360.0*24.
      WRITE(NOUT,208) S$
      CALL DEPREC(M,SP,DEPRE$)
      WRITE(NOUT,210) DEPRE$
      CALL OANDM(SP,S$,OANDM$)
      WRITE(NOUT,211) OANDM$
      CALL FINAN(SP,FIN$)
      WRITE(NOUT,209) FIN$
      IF((ILLK.EQ.1).AND.(M.EQ.1)) SG=SG-SGA
      IF(SG.LT.0.) SG=0.
      IF((J9.EQ.1).AND.(M.EQ.1)) SG=SG*360.0/BASED
      WRITE(NOUT,222) SG
      CALL SUPPCS(SP,S$,OANDM$,FIN$,DEPRE$,SUPP$)
      WRITE(NOUT,223) SUPP$
      TXSL=(T14+T15)*SP
      WRITE(NOUT,228) TXSL
      PIS=T16*SP+T17*SP +T18
      WRITE(NOUT,224) PIS
      CALL RTOWAY(KK,RTWAY$)
      RTWY$=RTWAY$/YEARS
      WRITE(NOUT,256) RTWY$
      PRFTBD=S$-OANDM$-FIN$-SG-SUPP$-PIS-TXSL-RTWAY$
      IF(PRFTBD.LT.0.0) WRITE(NOUT,225) YEARS
      IF(PRFTBD.LT.0.) GO TO 240
C      REACH HERE IS ONE IS GOING TO MAKE SOME SORT OF PROFIT
      WRITE(NOUT,226) PRFTBD
      PRFTAD=PRFTBD-DEPRE$
       IF(PRFTAD.LT.0.) CSFLNT=DEPRE$
       IF(PRFTAD.LT.0.) GO TO 6111
C     REACH HERE IS ONE IS REALLY GOING TO MAKE MONEY
      TXBLI=PRFTAD
      TXSF=(T12+T13)*TXBLI
      WRITE(NOUT,229) TXSF
      CSFLNT=(1.0-(T12+T13))*TXBLI+DEPRE$
 6111 WRITE(NJ5'M) CSFLNT
  220 CONTINUE
      WRITE(NOUT,230)
      DO 231 MMP=1,7
      RATE=0.05*MMP
```

```
      TIME=-1.
      FACTOR=(EXP(RATE)-1.0)/(EXP(RATE*TIME)*RATE*EXP(RATE))
      PVALUE(MMP)=-SP*FACTOR
      PSS(MMP)=PVALUE(MMP)
  231 CONTINUE
      WRITE(NOUT,232)(PVALUE(MMP),MMP=1,7)
      MMI5=IFIX(YEARS+0.5)
      DO 233 MMQ=1,MMI5
      DO 234 MMR=1,7
      READ(NJ5'MMQ) CSFLNT
      RATE=0.05*MMR
      TIME=MMQ
      FACTOR=-(EXP(-(RATE*TIME))-1.)/(RATE*TIME)
      PVALUE(MMR)=CSFLNT*FACTOR
      PSS(MMR)=PSS(MMR)+PVALUE(MMR)
  234 CONTINUE
      WRITE(NOUT,235)MMQ,(PVALUE(MMT),MMT=1,7)
  233 CONTINUE
      WRITE(NOUT,267) (PSS(MMU),MMU=1,7)
      WRITE(NOUT,6100)
      JINX=-51
 6107 JINX=JINX+1
      IF(JINX.EQ.0) FACTOR=1.0
      IF(JINX.EQ.0) GO TO 6108
      IF(JINX.EQ.100) WRITE(NOUT,6110)
      IF(JINX.EQ.100) GO TO 2321
      RATE=0.01*JINX
      TIME=-1
      FACTOR=(EXP(RATE)-1.0)/(EXP(RATE*TIME)*RATE*EXP(RATE))
 6108 PART=-SP*FACTOR
      PARTY=-SP*FACTOR
      MMI5=IFIX(YEARS+0.5)
      DO 6102 J=1,MMI5
      IF(JINX.EQ.0.) GO TO 6112
      FACTOR=(EXP(RATE)-1.)/(EXP(RATE*J)*RATE*EXP(RATE))
 6112 READ(NJ5'J) CSFLNT
      QUART=FACTOR*CSFLNT
      PART=PART+QUART
 6102 CONTINUE
      IF(PART.LT.0.) GO TO 6103
 6101 GO TO 6107
 6103 DO 6105 L=1,MMI5
      READ(NJ5'L) CSFLNT
      WRITE(NOUT,6106) L,CSFLNT
 6105 CONTINUE
      WRITE(NOUT,6207) JINX
      GO TO 241
  240 DEPRE$=SP/YEARS
      RQDINC=ABS(PRETBD)+DEPRE$
      IF(U16.GT.0.) GO TO 242
      IF(U16.LT.0.) GO TO 243
  242 IF(JJ4.EQ.1) QSOLD=S$/0.23
      IF(JJ4.EQ.0) QSOLD=S$/0.23
      IF(JJ4.EQ.2) QSOLD=S$/BASEH$
      $INCR=RQDINC/QSOLD
      WRITE(NOUT,244) YEARS,$INCR
      GO TO 2321
  243 $INCR=RQDINC/(360.0*24.0*U17*1000.)
```

```
      WRITE(NOUT,246) $INCR
      GO TO 2321
  241 RODYRS=SP/PRFTBD
      WRITE(NOUT,245) RODYRS
 2321 ILLK=ILLK+1
      GO TO 2832
 2322 IF(JJ6.EQ.1) GO TO 250
      IF(JJ6.EQ.0) GO TO 5
    6 WRITE(NOUT,8)
      DO 43 L=1,KK
      READ(NJ1'L) W,ZL,BLOSS,DELTA
      READ(NJ2'L) N,Q,H
      IF(W.LT.0.) GO TO 43
      WRITE(NOUT,44) L,N,W,ZL,BLOSS,DELTA,Q,H
   43 CONTINUE
  250 RETURN
    2 FORMAT('1',//,T40,' COST DATA AND TOTALS',///,'  PATH #',4X,'  PUM
     1P',T30,'PIPE',T40,'EXCAVATION',T54,'INSULATION',T71,'MANHOLE',T86,
     2   'CONDUIT',T101,'PUMPING',T113,'GROSS',/,T14,' COST',T30,'COST',
     3T40,'COST',T54,'COST',T71,'COST',T86,'COST',T101,'COST',T108,'INCO
     4ME/HOUR',//)
    4 FORMAT(I5,T8,F12.2,2F15.2,2F14.2,2F15.2,F12.2)
    8 FORMAT('1',T43,' FLOW EDIT',///,' PATH   # OF    FLOWRATE', T30,
     1'LENGTH',T45,'BUILDING LOSS',T60,'DELTA T', T75,'Q',T90,'HEAD LOSS
     2',/,'   #    PIPES',//)
   14 FORMAT(' LOAD FACTOR  SALE PRICE OF HEAT  EFFECTIVE LIFE  SALVAGE
     1VALUE  SINKING FUND RATE',/,5F15.5,//)
   15 FORMAT(' T1-T5 VALUES ARE :',/,5F15.5,//)
   16 FORMAT(' T6-T10 VALUES ARE:',/,5F15.5,//)
   17 FORMAT(' T11-T15 VALUES ARE:',/,5F15.5,//)
   18 FORMAT(' T16-T18 VALUES ARE:',/,3F15.5,//)
   19 FORMAT( ' U1-U5 VALUES ARE:',/,5F15.5,//)
   20 FORMAT(' U6-U10 VALUES ARE:',/,5F15.5,//)
   21 FORMAT(' U11,U12,U13 VALUES ARE:',/,3F15.5)
   22 FORMAT(//,' U14-U18 VALUES ARE:',/,5F15.5)
   23 FORMAT(//,' U19-U23 VALUES ARE:',//,5F15.5)
   44 FORMAT(2I5,6E15.7)
  204 FORMAT('1',///,' ECONOMIC INPUT DATA',//)
  205 FORMAT(' TOTALS',/,T8,F12.2,2F15.2,2F14.2,2F15.2,F12.2)
  206 FORMAT(//,' THE TOTAL INSTALLATION COST IS :',T58,'$$',F20.2)
  207 FORMAT('1',//,' THE FOLLOWING IS AN ECONOMIC ANALYSIS W/O ADJUSTME
     1NT',//)
  208 FORMAT(//,' THE GROSS ANNUAL INCOME IS :',T90,F20.2)
  209 FORMAT(//,' THE ANNUAL FINANCING AND SUPPLEMENTAL FINANCE COST IS:
     1',T60,F20.2)
  210 FORMAT(//,' THE DEPRECIATION IS :', T60,F20.2)
  211 FORMAT(//,' THE ANNUAL OPERATING AND MAINTENANCE EXPENCE IS :',T60
     1,F20.2)
  221 FORMAT('1',//,' YEAR',I3,T65,'OUTFLOWS',T90,'INFLOWS',//)
  222 FORMAT(//,' THE ANNUAL PUMPING COST IS:',T60,F20.2)
  223 FORMAT(//,' THE ANNUAL SUPPLEMENTARY COSTS ARE:',T60,F20.2)
  224 FORMAT(//,' THE ANNUAL INSURANCE CHARGES ARE:',T60,F20.2)
  225 FORMAT(////,T20,' THE SUM OF THE ANNUAL OPERATING EXPENSES IS GREA
     1TER',/,T20,' THAN THE GROSS INCOME, THUS THERE WILL ALWAYS BE AN',
     2/,T20,' OPERATING EXPENSE FOR THIS SYSTEM.  THE FOLLOWING ',/,T20,
     3' WILL BE AN ANALYSIS OF THE REQUIREMENTS TO JUST PAY',/,T20,' OFF
     4 THE PLANT IN',F10.0,'YEARS')
  226 FORMAT(//,' THE NET ANNUAL INCOME, BEFORE TAXES AND DEPRECIATION I
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      1S:',T75,F20.2)
  227 FORMAT(//,T20,' THE ANNUAL NET INCOME, INCLUDING THE',/,T20,' ANNU
     1AL DEPRECIATION CHARGE INDICATES A LOSS.  THEREFORE, THE ',/,T20,'
     2 FOLLOWING WILL BE AN ESTIMATION OF THE NUMBER OF ',/,T20,' YEARS
     3TO PAY OFF THE PLANT AT THE SPECIFIED RATE OF INCOME')
  228 FORMAT(//,' THE PROPERTY TAXES ARE:',T60,F20.2)
  229 FORMAT(//,' THE FEDERAL AND STATE INCOME TAXES ARE:',T60,F20.2)
  230 FORMAT('1',' A CASH FLOW SUMMARY FOLLOWS',//,' YEAR',T8,'NET CASH
     1FLOW',T22,'  5%',T36,'10%',T50,'15%',T64,'20%',T78,'25%',T102,'30%'
     2,T112,'35%')
  232 FORMAT(' ',' -1',T8,7F14.2)
  235 FORMAT(I8,T22,7F14.2)
  267 FORMAT(//,' TOTALS',T22,7F14.2)
  244 FORMAT(//,' THE INCREMENTAL SELLING INCREASE REQUIRED($/1. E6 BTU)
     1 TO PAY OFF THE PLANT IN',F10.1,'YEARS IS:',F20.2)
  245 FORMAT(//,' THE PAY OUT TIME AT  CURRENT RATE IS:',1PE15.7)
  246 FORMAT(//,' THE REQUIRED INCREASE IN ELECTRICITY COSTS, $/KWH IS:'
     1,E15.7)
  256 FORMAT(//,' THE ANNUAL RIGHT-OF-WAY COST IS:',T60,F20.2)
 2557 FORMAT(//,' THE TOTAL SUPPLEMENTARY INSTALLATION COST IS:',T60,F20
     1.2)
 2831 FORMAT('1',//,' ADJUSTED ECONOMIC ANALYSIS',//)
 6100 FORMAT('1',//,' A LISTING OF THE NET CASH FLOW FOLLOWS:',
     1/,'  YEAR AFTER START-UP',T35,' NET CASH FLOW')
 6106 FORMAT(I30,F20.2)
 6207 FORMAT(////,' THE RETURN ON INVESTMENT IS :',I3,' PER CENT')
 6110 FORMAT(///,' THE RETURN ON INVESTMENT CANNOT BE FOUND BETWEEN -50
     1 AND 100 PER CENT ')
      END
```

APPENDIX C

SUBROUTINE LISTING

The digital computer program is written in the Fortran IV, level G language for the IBM 360-50 computer system. The program consists of a main program and 31 subroutines.

Following is a listing of the subroutine names, the functions of the subroutines, the subroutines that are called and the subroutines that call the named subroutine. (I/O means input or output device.)

Name	Function	Subroutines Called		Subroutine Called By
MAIN	Flow Control;	STRTFL	PLLP	-----
	I/O	DRECON	DREAD	
		VELIN	ANHLIN	
		EXPOIN	PRICEI	
		TLREAD	WRITEO	
STRTFL	Flow Control of	COPTIM		MAIN
	Series Circuit	TEMOP		
PLLP	Flow Control of	COPTIM		MAIN
	Parallel Circuit	TEMOP		
COPTIM	Optimization by	FLOCLC	CINSUL	STRTFL
	minimizing in-	CPUMP	CMNHOL	PLLP
	stallation and	CPIPE	CCONDT	
	pumping costs	CEXCAV	PUMCST	
		SUPCST	WRONG	
		RIGHT	HEAT$	

TEMOP	Optimization by Maximization of Annual Rate of Return	HEAT$ FLOCLC CPIPE CEXCAV PUMCST OANDM FINAN CMNHOL CPUMP CINSUL CCONDT SUPCST	STRTFL PLLP
DRECON	I/O Economics Data	-----------	MAIN
DREAD	I/O OPTIONS	---------	MAIN
VELIN	I/O Velocity & Number of Pipes	---------	MAIN
ANHLIN	I/O Manhole Data	---------	MAIN
EXPOIN	I/O Exponent Data	---------	MAIN
TLREAD	I/O Table Data	---------	MAIN
PRICEI	I/O Cost Data	---------	MAIN
FLOCLC	Pressure Drop; Number of Pipes	---------	TEMOP COPTIM ADJUST
CPUMP	Pump Cost	CPOLE	TEMOP COPTIM
CPIPE	Pipe Cost	CPOLE	TEMOP COPTIM ADJUST
CEXCAV	Excavation Cost	---------	TEMOP COPTIM ADJUST
CINSUL	Insulation Cost	---------	TEMOP COPTIM

CMNHOL	Manhole Cost	---------	TEMOP COPTIM
CCONDT	Conduit Cost	---------	TEMOP COPTIM
PUMCST	Pumping Cost	---------	TEMOP COPTIM ADJUST
SUPCST	Supplemental Cost	---------	TEMOP COPTIM
WRONG	Curve Orientation	---------	COPTIM
STANDD	Curve Orientation	---------	COPTIM
HEAT$	Income from Sale of Heat	---------	COPTIM TEMOP
OANDM	Operation and Maintenance Cost	---------	TEMOP WRITEO
FINAN	Financing Charges	---------	TEMOP WRITEO
CPOLE	Computes Exponent for Cost Extrapolation	---------	CPUMP CPIPE CCONDT
WRITEO	Output; Flow Control; Economics	ADJUST DEPREC OANDM FINAN SUPPCS RTOWAY	MAIN
ADJUST	Computes Adjustment and Comparative Cost Data	FLOCLC PUMCST	WRITEO
DEPREC	Calculates Depreciation	---------	WRITEO
SUPPCS	Supplemental Annual Costs	---------	WRITEO
RTOWAY	Right-of-Way Costs	---------	WRITEO

The program can compute optimum sizes for as many as 999 flowpaths and piping diameters from one inch to 100 inches. Five tape or disk storage units are utilized, each containing 1000 records of 40 words each. 130,000 bytes of core storage are required in the execution of this program.

The program consists of some 1200 computer cards. Compilation time for the program is on the order of 3 minutes. The example problem computation required 5 minutes of computer time; a problem with 999 flowpaths executed in 50 minutes.

APPENDIX D

INPUT INSTRUCTIONS

The input data is separated into four sections: economic data, fixed point and mandatory data, optional data and flow path data. In each case, the required format is given. All data that is mandatory is coded (M) and optional data is coded (O).

A. ECONOMIC DATA

Card 01	Column 1-15	Overall plant load factor. If not available, input 0.8. (F15.5)(M)
	Col 16-30	Selling price of heat, $\$/10^6$ BTU (F15.5)(M)
	Col 31-45	Effective plant life, years (F15.5)(M)
	Col 46-60	Salvage value of plant as a fraction of the initial investment. A value from 0.00 to 0.25 is recommended. (F15.5)(M)
	Col 61-75	Sinking fund interest rate. Required only if sinking fund depreciation is selected. (F15.5)(M)

The next six data values are used in a supplemental cost routine for cash flow analysis. This permits the investigator to change varying interest rates on the capital cost, return on investment, operating and maintenance costs, financing costs, depreciation costs, and an independent supplemental cost. Thus, a cost such as operating capital (which is not included elsewhere) could be input as a percentage of the investment; labor cost as an independent cost, etc.

Card 02	T1	Column 1-15	Supplemental cost, fraction of installation cost. (F15.5)(0)
	T2	Col 16-30	Supplemental cost, fraction of gross income. (F15.5)(0)
	T3	Col 31-45	Supplemental cost, fraction of operating and maintenance costs (F15.5)(0)
	T4	Col 46-60	Supplemental cost, fraction of financing costs. (F15.5)(0)
	T5	Col 61-75	Supplemental cost, fraction of depreciation cost. (F15.5)(0)
Card 03	T6	Col 1-15	Supplemental cost, independent. ($/year) (F15.5)(0)
	T7	Col 16-30	Annual operating and maintenance costs, fraction of installation costs. (F15.5)(0)
	T8	Col 31-45	Annual operating/maintenance costs- fraction of installation costs. (F15.5)(0)
	T9	Col 46-60	Operation and Maintenance costs, independent input. ($/year)(F15.5)(0)
	T10	Col 61-75	Annual financing charge interest rate (expressed as a fraction). (F15.5)(0)

Card 04	T11	Column	1-15	Financing cost, independent. ($/year) (F15.5)(0)
	T12	Col	16-30	Federal income tax rate (fraction). (F15.5)(0)
	T13	Col	31-45	State income tax rate (fraction). (F15.5)(0)
	T14	Col	46-60	County tax rate (computed considering investment costs only). (fraction) (F15.5)(0)
	T15	Col	61-75	City tax rate (computed considering investment costs only). (fraction) (F15.5)(0)
Card 05	T16	Col	1-15	Liability insurance rate (computed on investment cost only). (fraction) (F15.5)(0)
	T17	Col	31-45	Independent insurance costs (annual). (F15.5)(0)

The remainder of this card and the next few cards are used to input percentages of the component costs. This can be used, for example, as a reliability input by using 1.5 or 2.0 for the pump cost. (Note: The effect of these inputs are added to the total installation costs for computing the total installation costs.)

Card 05 (cont'd)	U1	Column	46-60	Supplemental cost-fraction of the pump cost. (F15.5)(0)
	U2	Col	61-75	Supplemental cost-fraction of piping cost. (F15.5)(0)

Card 06	U3	Column 1-15	Supplemental cost-fraction of excavation cost. (F15.5)(0)
	U4	Col 16-30	Supplemental cost-fraction of insulation cost. (F15.5)(0)
	U5	Col 31-45	Supplemental cost-fraction of manhole cost. (F15.5)(0)
	U6	Col 46-60	Supplemental cost-fraction of conduit cost. (F15.5)(0)
	U7	Col 61-75	Supplemental cost-fraction of pumping cost. (F15.5)(0)
Card 07	U8	Column 1-15	Supplemental cost-independent. (F15.5)(0)
	U9	Col 16-30	Supplemental cost-multiple of diameter. (F15.5)(0)
	U10	Col 31-45	Supplemental cost-multiple of length. (F15.5)(0)
	U11	Col 46-60	Supplemental cost-multiple of volumetric flowrate. (F15.5)(0)
	U12	Col 61-75	Supplemental cost-multiple of the number of pipes. (F15.5)(0)
Card 08	U13	Col 1-15	Supplemental cost-independent. (F15.5)(0)

The following data is used to input right of way costs, easement costs, and an indicator for adjustment calculations.

Card 09	U14	Column 1-15	Input length of pipe installed in lakes, rivers (no right of way costs for this length), ft. (F15.5)(0)

	U15	Col 16-30	Input $$/foot of right of way cost. (F15.5)(0)
	U16	Col 31-45	If greater than 0, computes any increase in selling price in terms of $$/10^6 BTU increase. (F15.5)(0) If less than 0, computes the increase in selling price required in $$/Kilo-watt-hour. (F15.5)(0)
	U17	Col 46-60	Megawatt electrical rating of the plant. (F15.5)(0)
	U18	Col 61-75	Easement costs, $/year. (F15.5)(0)

The next card contains the data required for the adjusted cost analysis. The input data determines the type of conventional system for the comparative analysis.

Card 10	U19	Column 1-15	Installation cost of the piping of the conventional condensing system. (F15.5)(0)
	U20	Col 16-30	Annual pumping cost, $$/year (for condensing system). (F15.5)(0)
	U21	Col 31-45	Flowrate of conventional cooling system in gallons per minute. (F15.5)(0)
	U22	Col 46-60	Fractional cost expenditure required (fraction of size of conventional equipment and operating cost). (F15.5)(0)

U23	Col	61-75	Cost of installation of conventional condensing system (physical plant). (F15.5)(0)

B. FIXED POINT AND MANDATORY DATA

The following data cards are the control cards for the program. Most of the data in this section must be supplied.

Card 1	J1	Column 5		Input=0::limiting velocity is 10 ft/sec Input=1::limiting velocity is supplied
	J2	Col	10	Input=0::building loss is calculated Input=1::building loss is supplied
	J3	Col	15	Input=0::pump cost is calculated (1962 dollars) Input=1::base size, base price to be input for exponential Input=2::100 values of pipe size, pipe cost to be supplied Input=3::input two sizes, two costs for exponential fit
	J4	Col	20	Input=0::pipe cost is calculated (1962 dollars) Input=1::input base size, base price for exponential Input=2::100 values of pipe sizes and costs to be supplied Input=3::input two sizes, two costs for exponential fit
	J5	Col	25	Input=0::excavation cost is calculated

			Input=1::input BASEE, $/ft^3 excavated
J6	Col	30	Input=0::calculates insulation cost (1962 dollars)
			Input=1::input BASEV, $/ft insulation cost
J7	Col	35	Input=0::calculates manhole cost (1962 dollars)
			Input=1::input the hole cost ($/ft. depth)
			Input=2::input the hole cost and the hole spacing (feet)
J8	Col	40	Input=0::calculates the conduit cost (1962 dollars)
			Input=1::50 values of size, cost of conduit to be supplied
			Input=2::input cost, size for exponential
J9	Col	45	Input=0::calculate pumping power cost (1962 dollars)
			Input=1::input BASED and BASE$ (base days and base cost of electricity, $/KWH)
I1	Col	50	Input=0::a standard condenser is the comparison base
			Input=1::a cooling tower is the comparison base
			Input=2::a cooling pond is the comparison base
I2	Col	55	Input=0::use program calculations

Input=1::calculates for system characterized by I1

Format(11I5), all (M)

Card 2	J10	Column 5	Input=0::the input fixed point data is not printed	
			Input=1::the input fixed point data is printed	
	J11	Col 10	Input=0::the limiting radii are not printed	
			Input=1::the limiting radii are printed	
	J12	Col 15	Input=0::density and viscosity are not printed	
			Input=1::density and viscosity are printed	
	J13	Col 20	Input=0::the cost-price indices are not printed	
			Input=1::the cost-price indices are printed	
	J14	Col 25	Input=0::no pipe table cost data output	
			Input=1::pipe data table is output (this option only available if J4=2)	
	J15	Col 30	Input=0::no conduit table cost data output	
			Input=1::conduit cost data is output (this option only available is J8=1)	

	J16	Col 35	Input=0::no pump table cost data output Input=1::pump cost data table is output (this option only available if J3=2)
	J17	Col 40	Input=0::base values from optional data cards are not printed Input=1::base values from optional data cards are printed
	J18	Col 45	Input=0::manhole cost data not printed Input=1::manhole cost data is printed
	J19	Col 50	Input=0::limiting velocity is not printed Input=1::limiting velocity is printed
	J20	Col 55	Input=0::flow rate, length, building loss, and building delta temperature for each path are input Input=1::length, heat requirement (BTU/hr) and building loss for each path are input Input=2::flow rate, length, heat requirement and building loss for each path are input

Format(11I5), all (M)

Card 3	JJ1	Column 5	Input=0::finds true optimum Input=1::finds optimum for specified minimum number of pipes
	JJ2	Col 10	Input=0::the minimum number of pipes is not output

			Input=1::the minimum number of pipes is output
JJ3	Col	15	Input=0::minimizes the installation and pumping cost for a specified time interval
			Input=1::maximizes the rate of investment return
JJ4	Col	20	Input=0::uses \$0.23/10^6 BTU as the selling price of heat
			Input=1::input sale price of heat
JJ5	Col	25	Input=0::straight line depreciation
			Input=1::sum of the years digits depreciation
			Input=2::sinking fund depreciation
			Input=3::declining balance depreciation
JJ6	Col	30	Input=0::outputs economics and flow edit
			Input=1::outputs economic edit only
			Input=2::outputs flow edit only
JJ7	Col	35	Input=0::sale price required to break even not computed
			Input=1::sale price required to break even is computed
JJ8	Col	40	Input=0::economics input data is not printed
			Input=1::economics data is printed

Format(11I5), all (M)

Card 4	K1,K2,K3	Input the lower limit, mean and upper limit on pipe sizes under consideration (integers, inches) (3I10)(M)
Card 5	Rho, Pois	Input the density and viscosity of the fluid under consideration (lbs/ft^3) (lbs/ft-sec) (2F20.7)(M)
Card 6	CPI(7)	Input the cost price indices (7) in the following order: 1 Pump 2 Pipe 3 Excavation 4 Insulation 5 Manhole 6 Conduit 7 Pumping cost

These values are used to adjust the program values of 1962 dollars (or the value of costs that the programmer inputs) to the year the programmer desires. For example, if CPI(1) is input as 1.36 and J3 is 0, then the 1962 dollars used in the program are adjusted to about the 1970 cost of the pump. (7F10.5) (M)

C. OPTIONAL DATA

Card 1	If J1 is 0, this card is not used. If J1 is 1, input limiting velocity (ft/sec) (F20.7)(O)
Card 2	If JJ1 is 0, this card is not used If JJ1 is 1, input (minimum pipes -1) (I5)(O)

Card 3	If J7 is 0, this card is not used
	If J7 is 1, input the hole cost ($/ft. depth) (F20.7)(0)
	If J7 is 2, input the hole spacing (feet) (F20.7)(0)
	If J7 is 3, input the hole cost and hole spacing (2F20.7)(0)
Card(s) 4 (4A)	If J3 is 3, input lower diameter in inches, lower cost, upper diameter and upper cost of <u>pumps</u> for exponential fit. (4F20.7)(0)
(Maximum of 3 cards) (4B)	If J4 is 3, input lower diameter in inches, lower cost, upper diameter and upper cost of <u>piping</u> for exponential fit. (4F20.7)(0)
(4C)	If J8 is 2, input lower diameter in inches, lower cost, upper diameter in inches, and upper cost of <u>conduit</u> for exponential fit. (4F20.7)(0)
Card 5	Blank (M)
Card(s) 6	If J3 is 2, input 100 cards with values of pump size and pump cost (1 inch to 100 inches). (I5,F20.7)(0)
(Maximum of 250 cards)	If J4 is 2, input 100 cards with values of pipe size and pipe cost (1 inch to 100 inches). (I5,F20.7)(0)
	If J8 is 1, input 50 values of conduit cost (from 4 inches to 200 inches by 4 inch increments). (I5,F20.7)(0)

Card(s) 7 (7A) If J3 is 1, input base pump size (ft^3/min) and base pump cost. (2F20.7)(O)

(Maximum of 5 cards)

(7B) If J4 is 1, input base pipe size and base pipe cost (inches). (2F20.7)(O)

(7C) If J5 is 1, input base excavation cost ($\$/ft^3$). (F20.7)(O)

(7D) If J6 is 1, input base insulation cost ($/ft). (F20.7)(O)

(7E) If J9 is 1, input base days of operation for pumping cost analysis and base cost of electricity ($/KWH). (2F20.7)(O)

Card 8 Blank (M)

Extreme care must be used in supplying the input data above. For example, if J3 is 2 and only 99 data cards are supplied, the program will not get correct results. (An error will result also.)

D. FLOW PATH DATA

The input contained in this section is the most difficult to organize and is the most critical part of the program. To code this portion, it is recommended that an electrical analog be set up and the network reduced starting with the furthest point from the pumps (current source).

Card 1 Input the number of branches (I10)(M)

This card indicates to the program the number of sets of input data to follow. Each branch will be coded later as to the type of branch (series, parallel or series-parallel) and the number of paths in the branch.

To clarify the input required, Figure 13 shows three example circuits. Circuit A has one branch, three paths and is a series circuit. Circuit B has one branch, five paths, and is a parallel circuit. Circuit C has two branches, I and II. Branch I is a series branch with 3 paths; branch II is a series-parallel branch consisting of <u>three</u> parallel paths and <u>three</u> series paths. (The third series path is the parallel network.)

The parallel network, when calculated in the series path, is coded with a negative flowrate to insure that duplicate calculations are not performed.

Card 2	Column 10	Input=0::series circuit Input=1::parallel circuit Input=2::series-parallel circuit
	Col 11-20	The total number of paths in the branch.
	Col 21-30	The number of parallel paths in a parallel or series parallel network.
	Col 31-40	The path number which contains the pumps.

Format (4I10),(M)

This card for branch I of circuit C (Figure 13) would read:

Column	10	20	30	40
	0	3	0	33

There will be one card 2 supplied for each branch.

Card(s) 3 Flowpath data cards.

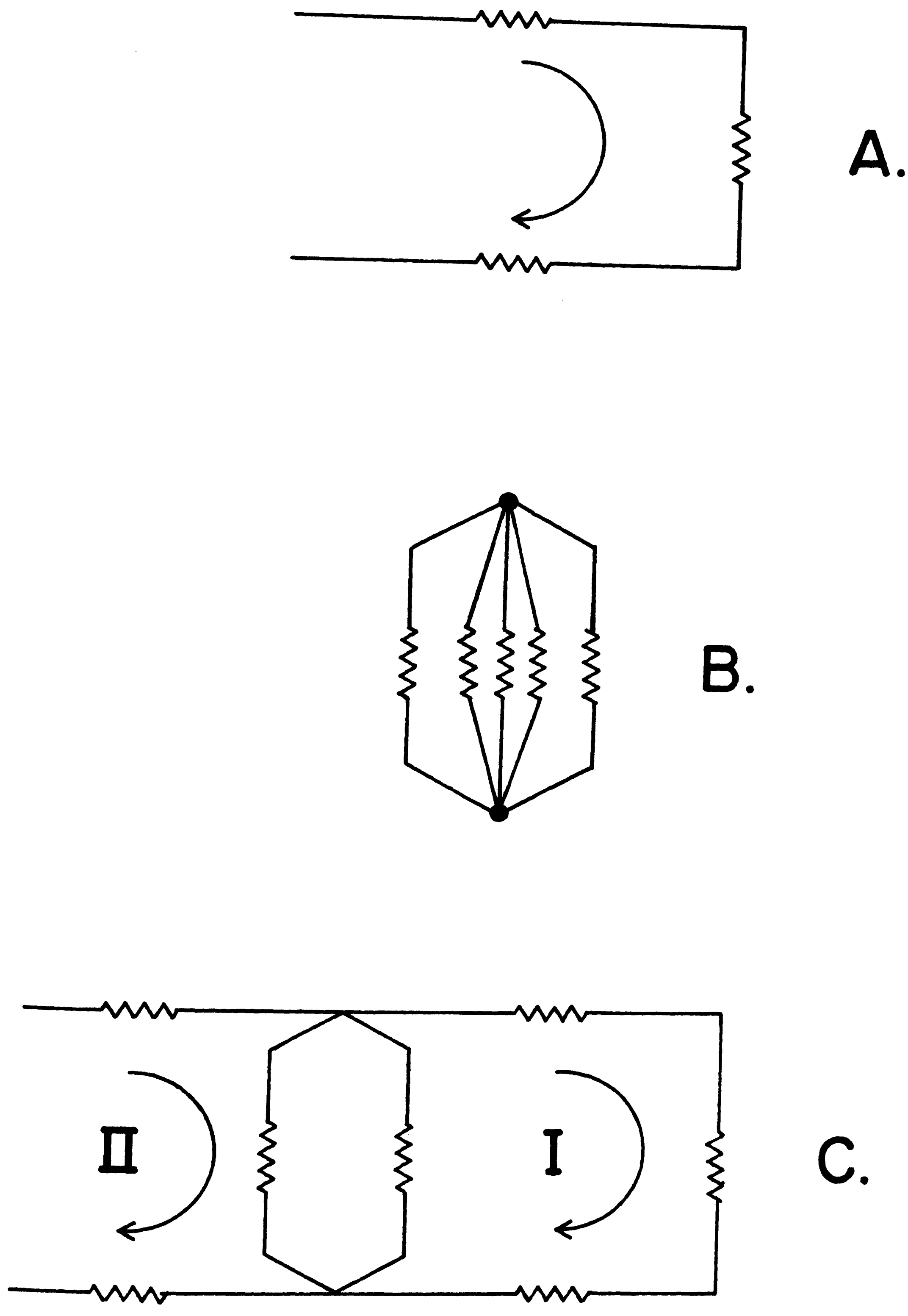

FIGURE 13. THREE EXAMPLE CIRCUITS

The inputs on this card are variable depending on J20. The variables that may be input are:

KK	The path number. Must be sequential from 1 to a maximum of 1000. The paths with negative flowrates must be coded in sequence. It is absolutely mandatory that the last data card input KK as the greatest value (equals the total number of paths analyzed) for this is the index on the Economic Analysis printout.
W	The mass flowrate, lbs/hr. If this is input as a negative value, no cost calculations are performed nor printout given for this path.
ZL	The length of piping in the path (feet).
BLOSS	The building loss in feet of water head. If this is input as a negative number, there is no building on the leg of piping under consideration.
DELTA	The temperature drop across the building that is caused by the heat demand of the building. If this is input as 0.0, no heat is sold.
QHEAT	The amount of heat required by the building on the path, BTU/hour.
INSULI	Indicator to tell program if the path is to be insulated or uninsulated. (If = 0, path is not insulated, if = 1, path is insulated.)

These quantities are input in the following manner:

If J20 is 1, input KK, INSULI, W, ZL, BLOSS, DELTA

(2I5,4F15.5).

If J20 is 2, input KK, INSULI, ZL, QHEAT, BLOSS (2I5,3F15.5).

If J20 is 3, input KK, INSULI, W, ZL, QHEAT, BLOSS (2I5,4F15.5).

It is recommended that J20 equal to 2 be used.

The order of cards for this data set is:

Card 1

Card 2

Card(s) 3 For series flow, the number of cards equals the number of paths. For parallel flows, the number of paths equals the number of cards. For series-parallel, input the parallel paths first; then series paths. Total cards = total number of paths plus 1, the additional path having a negative flowrate.

Card 1

Card 2

Card(s) 3

etc. until there are as many card number 2 data cards as specified on card 1.

APPENDIX E

BALANCE SHEETS

The following pages show the annual balance sheets that the computer program calculated for the typical problem of section V. These are given from years 2-30 for the non-adjusted economic analysis and years 2-30 for the adjusted economic analysis.

YEAR 2		OUTFLOWS	INFLOWS	
THE TOTAL INSTALLATION COST IS :	$$	26897824.00		
THE TOTAL SUPPLEMENTARY INSTALLATION COST IS:		4452744.00		
THE GROSS ANNUAL INCOME IS :				3787770.00
THE DEPRECIATION IS :		1593623.00		
THE ANNUAL OPERATING AND MAINTENANCE EXPENCE IS :		268978.13		
THE ANNUAL FINANCING AND SUPPLEMENTAL FINANCE COST IS:		941423.69		
THE ANNUAL PUMPING COST IS:		2199313.00		
THE ANNUAL SUPPLEMENTARY COSTS ARE:		12000.00		
THE PROPERTY TAXES ARE:		2689.78		
THE ANNUAL INSURANCE CHARGES ARE:		7623.00		
THE ANNUAL RIGHT-OF-WAY COST IS:		2056.00		
THE NET ANNUAL INCOME, BEFORE TAXES AND DEPRECIATION IS:			294061.19	

YEAR 3		OUTFLOWS	INFLOWS
THE TOTAL INSTALLATION COST IS :	$$	26897824.00	
THE TOTAL SUPPLEMENTARY INSTALLATION COST IS:		4452744.00	
THE GROSS ANNUAL INCOME IS :			3787770.00
THE DEPRECIATION IS :		1538671.00	
THE ANNUAL OPERATING AND MAINTENANCE EXPENCE IS :		268978.13	
THE ANNUAL FINANCING AND SUPPLEMENTAL FINANCE COST IS:		941423.69	
THE ANNUAL PUMPING COST IS:		2199313.00	
THE ANNUAL SUPPLEMENTARY COSTS ARE:		12000.00	
THE PROPERTY TAXES ARE:		2689.78	
THE ANNUAL INSURANCE CHARGES ARE:		7623.00	
THE ANNUAL RIGHT-OF-WAY COST IS:		2056.00	
THE NET ANNUAL INCOME, BEFORE TAXES AND DEPRECIATION IS:			294061.19

YEAR 4		OUTFLOWS	INFLOWS	
THE TOTAL INSTALLATION COST IS :	$$	26897824.00		
THE TOTAL SUPPLEMENTARY INSTALLATION COST IS:		4452744.00		
THE GROSS ANNUAL INCOME IS :				3787770.00
THE DEPRECIATION IS :		1483718.00		
THE ANNUAL OPERATING AND MAINTENANCE EXPENCE IS :		268978.13		
THE ANNUAL FINANCING AND SUPPLEMENTAL FINANCE COST IS:		941423.69		
THE ANNUAL PUMPING COST IS:		2199313.00		
THE ANNUAL SUPPLEMENTARY COSTS ARE:		12000.00		
THE PROPERTY TAXES ARE:		2689.78		
THE ANNUAL INSURANCE CHARGES ARE:		7623.00		
THE ANNUAL RIGHT-OF-WAY COST IS:		2056.00		
THE NET ANNUAL INCOME, BEFORE TAXES AND DEPRECIATION IS:			294061.19	

YEAR 5

		OUTFLOWS	INFLOWS
THE TOTAL INSTALLATION COST IS :	$$	26897824.00	
THE TOTAL SUPPLEMENTARY INSTALLATION COST IS:		4452744.00	
THE GROSS ANNUAL INCOME IS :			3787770.00
THE DEPRECIATION IS :		1428766.00	
THE ANNUAL OPERATING AND MAINTENANCE EXPENCE IS :		268978.13	
THE ANNUAL FINANCING AND SUPPLEMENTAL FINANCE COST IS:		941423.69	
THE ANNUAL PUMPING COST IS:		2199313.00	
THE ANNUAL SUPPLEMENTARY COSTS ARE:		12000.00	
THE PROPERTY TAXES ARE:		2689.78	
THE ANNUAL INSURANCE CHARGES ARE:		7623.00	
THE ANNUAL RIGHT-OF-WAY COST IS:		2056.00	
THE NET ANNUAL INCOME, BEFORE TAXES AND DEPRECIATION IS:			294061.19

YEAR 6

		OUTFLOWS	INFLOWS
THE TOTAL INSTALLATION COST IS :	$$	26897824.00	
THE TOTAL SUPPLEMENTARY INSTALLATION COST IS:		4452744.00	
THE GROSS ANNUAL INCOME IS :			3787770.00
THE DEPRECIATION IS :		1373813.00	
THE ANNUAL OPERATING AND MAINTENANCE EXPENCE IS :		268978.13	
THE ANNUAL FINANCING AND SUPPLEMENTAL FINANCE COST IS:		941423.69	
THE ANNUAL PUMPING COST IS:		2199313.00	
THE ANNUAL SUPPLEMENTARY COSTS ARE:		12000.00	
THE PROPERTY TAXES ARE:		2689.78	
THE ANNUAL INSURANCE CHARGES ARE:		7623.00	
THE ANNUAL RIGHT-OF-WAY COST IS:		2056.00	
THE NET ANNUAL INCOME, BEFORE TAXES AND DEPRECIATION IS:			294061.19

YEAR 7		OUTFLOWS	INFLOWS	
THE TOTAL INSTALLATION COST IS :	$$	26897824.00		
THE TOTAL SUPPLEMENTARY INSTALLATION COST IS:		4452744.00		
THE GROSS ANNUAL INCOME IS :				3737770.00
THE DEPRECIATION IS :		1318861.00		
THE ANNUAL OPERATING AND MAINTENANCE EXPENCE IS :		268978.13		
THE ANNUAL FINANCING AND SUPPLEMENTAL FINANCE COST IS:		941423.69		
THE ANNUAL PUMPING COST IS:		2199313.00		
THE ANNUAL SUPPLEMENTARY COSTS ARE:		12000.00		
THE PROPERTY TAXES ARE:		2689.78		
THE ANNUAL INSURANCE CHARGES ARE:		7623.00		
THE ANNUAL RIGHT-OF-WAY COST IS:		2056.00		
THE NET ANNUAL INCOME, BEFORE TAXES AND DEPRECIATION IS:			294061.19	

YEAR 3

		OUTFLOWS	INFLOWS	
THE TOTAL INSTALLATION COST IS :	$$	26897824.00		
THE TOTAL SUPPLEMENTARY INSTALLATION COST IS:		4452744.00		
THE GROSS ANNUAL INCOME IS :				3787770.00
THE DEPRECIATION IS :		1263908.00		
THE ANNUAL OPERATING AND MAINTENANCE EXPENCE IS :		268978.13		
THE ANNUAL FINANCING AND SUPPLEMENTAL FINANCE COST IS:		941423.69		
THE ANNUAL PUMPING COST IS:		2199313.00		
THE ANNUAL SUPPLEMENTARY COSTS ARE:		12000.00		
THE PROPERTY TAXES ARE:		2689.78		
THE ANNUAL INSURANCE CHARGES ARE:		7623.00		
THE ANNUAL RIGHT-OF-WAY COST IS:		2056.00		
THE NET ANNUAL INCOME, BEFORE TAXES AND DEPRECIATION IS:			294061.19	

YEAR 9

		OUTFLOWS	INFLOWS
THE TOTAL INSTALLATION COST IS :	$$	26897824.00	
THE TOTAL SUPPLEMENTARY INSTALLATION COST IS:		4452744.00	
THE GROSS ANNUAL INCOME IS :			3787770.00
THE DEPRECIATION IS :		1208955.00	
THE ANNUAL OPERATING AND MAINTENANCE EXPENCE IS :		268978.13	
THE ANNUAL FINANCING AND SUPPLEMENTAL FINANCE COST IS:		941423.69	
THE ANNUAL PUMPING COST IS:		2199313.00	
THE ANNUAL SUPPLEMENTARY COSTS ARE:		12000.00	
THE PROPERTY TAXES ARE:		2689.78	
THE ANNUAL INSURANCE CHARGES ARE:		7623.00	
THE ANNUAL RIGHT-OF-WAY COST IS:		2056.00	
THE NET ANNUAL INCOME, BEFORE TAXES AND DEPRECIATION IS:			294061.19

YEAR 10

		OUTFLOWS	INFLOWS
THE TOTAL INSTALLATION COST IS :	$$	26897824.00	
THE TOTAL SUPPLEMENTARY INSTALLATION COST IS:		4452744.00	
THE GROSS ANNUAL INCOME IS :			3787770.00
THE DEPRECIATION IS :		1154003.00	
THE ANNUAL OPERATING AND MAINTENANCE EXPENCE IS :		268978.13	
THE ANNUAL FINANCING AND SUPPLEMENTAL FINANCE COST IS:		941423.69	
THE ANNUAL PUMPING COST IS:		2199313.00	
THE ANNUAL SUPPLEMENTARY COSTS ARE:		12000.00	
THE PROPERTY TAXES ARE:		2689.78	
THE ANNUAL INSURANCE CHARGES ARE:		7623.00	
THE ANNUAL RIGHT-OF-WAY COST IS:		2056.00	
THE NET ANNUAL INCOME, BEFORE TAXES AND DEPRECIATION IS:			294061.19

YEAR 11

		OUTFLOWS	INFLOWS
THE TOTAL INSTALLATION COST IS :	$$	26897824.00	
THE TOTAL SUPPLEMENTARY INSTALLATION COST IS:		4452744.00	
THE GROSS ANNUAL INCOME IS :			3787770.00
THE DEPRECIATION IS :		1099050.00	
THE ANNUAL OPERATING AND MAINTENANCE EXPENCE IS :		268978.13	
THE ANNUAL FINANCING AND SUPPLEMENTAL FINANCE COST IS:		941423.69	
THE ANNUAL PUMPING COST IS:		2199313.00	
THE ANNUAL SUPPLEMENTARY COSTS ARE:		12000.00	
THE PROPERTY TAXES ARE:		2689.78	
THE ANNUAL INSURANCE CHARGES ARE:		7623.00	
THE ANNUAL RIGHT-OF-WAY COST IS:		2056.00	
THE NET ANNUAL INCOME, BEFORE TAXES AND DEPRECIATION IS:			294061.19

YEAR 12

		OUTFLOWS	INFLOWS	
THE TOTAL INSTALLATION COST IS :	$$	26897824.00		
THE TOTAL SUPPLEMENTARY INSTALLATION COST IS:		4452744.00		
THE GROSS ANNUAL INCOME IS :				3787770.00
THE DEPRECIATION IS :		1044097.88		
THE ANNUAL OPERATING AND MAINTENANCE EXPENCE IS :		268978.13		
THE ANNUAL FINANCING AND SUPPLEMENTAL FINANCE COST IS:		941423.69		
THE ANNUAL PUMPING COST IS:		2199313.00		
THE ANNUAL SUPPLEMENTARY COSTS ARE:		12000.00		
THE PROPERTY TAXES ARE:		2689.78		
THE ANNUAL INSURANCE CHARGES ARE:		7623.00		
THE ANNUAL RIGHT-OF-WAY COST IS:		2056.00		
THE NET ANNUAL INCOME, BEFORE TAXES AND DEPRECIATION IS:			294061.19	

YEAR 13

		OUTFLOWS	INFLOWS
THE TOTAL INSTALLATION COST IS :	$$	26897824.00	
THE TOTAL SUPPLEMENTARY INSTALLATION COST IS:		4452744.00	
THE GROSS ANNUAL INCOME IS :			3787770.00
THE DEPRECIATION IS :		989145.44	
THE ANNUAL OPERATING AND MAINTENANCE EXPENCE IS :		268978.13	
THE ANNUAL FINANCING AND SUPPLEMENTAL FINANCE COST IS:		941423.69	
THE ANNUAL PUMPING COST IS:		2199313.00	
THE ANNUAL SUPPLEMENTARY COSTS ARE:		12000.00	
THE PROPERTY TAXES ARE:		2689.78	
THE ANNUAL INSURANCE CHARGES ARE:		7623.00	
THE ANNUAL RIGHT-OF-WAY COST IS:		2056.00	
THE NET ANNUAL INCOME, BEFORE TAXES AND DEPRECIATION IS:			294061.19

YEAR 14		OUTFLOWS	INFLOWS
THE TOTAL INSTALLATION COST IS :	$$	26897824.00	
THE TOTAL SUPPLEMENTARY INSTALLATION COST IS:		4452744.00	
THE GROSS ANNUAL INCOME IS :			3787770.00
THE DEPRECIATION IS :		934192.94	
THE ANNUAL OPERATING AND MAINTENANCE EXPENCE IS :		268978.13	
THE ANNUAL FINANCING AND SUPPLEMENTAL FINANCE COST IS:		941423.69	
THE ANNUAL PUMPING COST IS:		2199313.00	
THE ANNUAL SUPPLEMENTARY COSTS ARE:		12000.00	
THE PROPERTY TAXES ARE:		2689.78	
THE ANNUAL INSURANCE CHARGES ARE:		7623.00	
THE ANNUAL RIGHT-OF-WAY COST IS:		2056.00	
THE NET ANNUAL INCOME, BEFORE TAXES AND DEPRECIATION IS:			294061.19

YEAR 15		OUTFLOWS	INFLOWS	
THE TOTAL INSTALLATION COST IS :	$$	26897824.00		
THE TOTAL SUPPLEMENTARY INSTALLATION COST IS:		4452744.00		
THE GROSS ANNUAL INCOME IS :				3787770.00
THE DEPRECIATION IS :		879240.50		
THE ANNUAL OPERATING AND MAINTENANCE EXPENCE IS :		268978.13		
THE ANNUAL FINANCING AND SUPPLEMENTAL FINANCE COST IS:		941423.69		
THE ANNUAL PUMPING COST IS:		2199313.00		
THE ANNUAL SUPPLEMENTARY COSTS ARE:		12000.00		
THE PROPERTY TAXES ARE:		2689.78		
THE ANNUAL INSURANCE CHARGES ARE:		7623.00		
THE ANNUAL RIGHT-OF-WAY COST IS:		2056.00		
THE NET ANNUAL INCOME, BEFORE TAXES AND DEPRECIATION IS:			294061[illegible]9	

YEAR 16

		OUTFLOWS	INFLOWS
THE TOTAL INSTALLATION COST IS :	$$	26897824.00	
THE TOTAL SUPPLEMENTARY INSTALLATION COST IS:		4452744.00	
THE GROSS ANNUAL INCOME IS :			3787770.00
THE DEPRECIATION IS :		824287.75	
THE ANNUAL OPERATING AND MAINTENANCE EXPENCE IS :		268978.13	
THE ANNUAL FINANCING AND SUPPLEMENTAL FINANCE COST IS:		941423.69	
THE ANNUAL PUMPING COST IS:		2199313.00	
THE ANNUAL SUPPLEMENTARY COSTS ARE:		12000.00	
THE PROPERTY TAXES ARE:		2689.78	
THE ANNUAL INSURANCE CHARGES ARE:		7623.00	
THE ANNUAL RIGHT-OF-WAY COST IS:		2056.00	
THE NET ANNUAL INCOME, BEFORE TAXES AND DEPRECIATION IS:			294061.19

YEAR 17

		OUTFLOWS	INFLOWS
THE TOTAL INSTALLATION COST IS :	$$	26897824.00	
THE TOTAL SUPPLEMENTARY INSTALLATION COST IS:		4452744.00	
THE GROSS ANNUAL INCOME IS :			3787770.00
THE DEPRECIATION IS :		769335.31	
THE ANNUAL OPERATING AND MAINTENANCE EXPENCE IS :		268978.13	
THE ANNUAL FINANCING AND SUPPLEMENTAL FINANCE COST IS:		941423.69	
THE ANNUAL PUMPING COST IS:		2199313.00	
THE ANNUAL SUPPLEMENTARY COSTS ARE:		12000.00	
THE PROPERTY TAXES ARE:		2689.78	
THE ANNUAL INSURANCE CHARGES ARE:		7623.00	
THE ANNUAL RIGHT-OF-WAY COST IS:		2056.00	
THE NET ANNUAL INCOME, BEFORE TAXES AND DEPRECIATION IS:			294061.19

YEAR 18

	OUTFLOWS	INFLOWS
THE TOTAL INSTALLATION COST IS : $$	26837824.00	
THE TOTAL SUPPLEMENTARY INSTALLATION COST IS:	4452744.00	
THE GROSS ANNUAL INCOME IS :		3787770.00
THE DEPRECIATION IS :	714382.81	
THE ANNUAL OPERATING AND MAINTENANCE EXPENCE IS :	268978.13	
THE ANNUAL FINANCING AND SUPPLEMENTAL FINANCE COST IS:	941423.69	
THE ANNUAL PUMPING COST IS:	2199313.00	
THE ANNUAL SUPPLEMENTARY COSTS ARE:	12000.00	
THE PROPERTY TAXES ARE:	2689.78	
THE ANNUAL INSURANCE CHARGES ARE:	7623.00	
THE ANNUAL RIGHT-OF-WAY COST IS:	2056.00	
THE NET ANNUAL INCOME, BEFORE TAXES AND DEPRECIATION IS:		294061.19

YEAR 19

		OUTFLOWS	INFLOWS
THE TOTAL INSTALLATION COST IS :	$$	26897824.00	
THE TOTAL SUPPLEMENTARY INSTALLATION COST IS:		4452744.00	
THE GROSS ANNUAL INCOME IS :			3787770.00
THE DEPRECIATION IS :		659430.38	
THE ANNUAL OPERATING AND MAINTENANCE EXPENCE IS :		268978.13	
THE ANNUAL FINANCING AND SUPPLEMENTAL FINANCE COST IS:		941423.69	
THE ANNUAL PUMPING COST IS:		2199313.00	
THE ANNUAL SUPPLEMENTARY COSTS ARE:		12000.00	
THE PROPERTY TAXES ARE:		2689.78	
THE ANNUAL INSURANCE CHARGES ARE:		7623.00	
THE ANNUAL RIGHT-OF-WAY COST IS:		2056.00	
THE NET ANNUAL INCOME, BEFORE TAXES AND DEPRECIATION IS:			294061.19

YEAR 20

	OUTFLOWS	INFLOWS
THE TOTAL INSTALLATION COST IS : $$	26897824.00	
THE TOTAL SUPPLEMENTARY INSTALLATION COST IS:	4452744.00	
THE GROSS ANNUAL INCOME IS :		3787770.00
THE DEPRECIATION IS :	604477.63	
THE ANNUAL OPERATING AND MAINTENANCE EXPENCE IS :	268978.13	
THE ANNUAL FINANCING AND SUPPLEMENTAL FINANCE COST IS:	941423.69	
THE ANNUAL PUMPING COST IS:	2199313.00	
THE ANNUAL SUPPLEMENTARY COSTS ARE:	12000.00	
THE PROPERTY TAXES ARE:	2689.78	
THE ANNUAL INSURANCE CHARGES ARE:	7623.00	
THE ANNUAL RIGHT-OF-WAY COST IS:	2056.00	
THE NET ANNUAL INCOME, BEFORE TAXES AND DEPRECIATION IS:		294061.19

YEAR 21

		OUTFLOWS	INFLOWS
THE TOTAL INSTALLATION COST IS :	$$	26897824.00	
THE TOTAL SUPPLEMENTARY INSTALLATION COST IS:		4452744.00	
THE GROSS ANNUAL INCOME IS :			3787770.00
THE DEPRECIATION IS :		549525.19	
THE ANNUAL OPERATING AND MAINTENANCE EXPENCE IS :		268978.13	
THE ANNUAL FINANCING AND SUPPLEMENTAL FINANCE COST IS:		941423.69	
THE ANNUAL PUMPING COST IS:		2199313.00	
THE ANNUAL SUPPLEMENTARY COSTS ARE:		12000.00	
THE PROPERTY TAXES ARE:		2689.78	
THE ANNUAL INSURANCE CHARGES ARE:		7623.00	
THE ANNUAL RIGHT-OF-WAY COST IS:		2056.00	
THE NET ANNUAL INCOME, BEFORE TAXES AND DEPRECIATION IS:			294[illegible]61.19

YEAR 22

		OUTFLOWS	INFLOWS	
THE TOTAL INSTALLATION COST IS :	$$	26897824.00		
THE TOTAL SUPPLEMENTARY INSTALLATION COST IS:		4452744.00		
THE GROSS ANNUAL INCOME IS :				3787770.00
THE DEPRECIATION IS :		494572.69		
THE ANNUAL OPERATING AND MAINTENANCE EXPENCE IS :		268978.13		
THE ANNUAL FINANCING AND SUPPLEMENTAL FINANCE COST IS:		941423.69		
THE ANNUAL PUMPING COST IS:		2199313.00		
THE ANNUAL SUPPLEMENTARY COSTS ARE:		12000.00		
THE PROPERTY TAXES ARE:		2689.78		
THE ANNUAL INSURANCE CHARGES ARE:		7623.00		
THE ANNUAL RIGHT-OF-WAY COST IS:		2056.00		
THE NET ANNUAL INCOME, BEFORE TAXES AND DEPRECIATION IS:			294061.19	

YEAR 23

		OUTFLOWS	INFLOWS	
THE TOTAL INSTALLATION COST IS :	$$	26897824.00		
THE TOTAL SUPPLEMENTARY INSTALLATION COST IS:		4452744.00		
THE GROSS ANNUAL INCOME IS :				3787770.00
THE DEPRECIATION IS :		439620.25		
THE ANNUAL OPERATING AND MAINTENANCE EXPENCE IS :		268978.13		
THE ANNUAL FINANCING AND SUPPLEMENTAL FINANCE COST IS:		96 423.69		
THE ANNUAL PUMPING COST IS:		2199313.00		
THE ANNUAL SUPPLEMENTARY COSTS ARE:		12000.00		
THE PPOPERTY TAXES ARE:		2689.78		
THE ANNUAL INSURANCE CHARGES ARE:		7623.00		
THE ANNUAL RIGHT-OF-WAY COST IS:		2056.00		
THE NET ANNUAL INCOME, BEFORE TAXES AND DEPRECIATION IS:			294061.19	

YEAR 24

		OUTFLOWS	INFLOWS	
THE TOTAL INSTALLATION COST IS :	$$	26897824.00		
THE TOTAL SUPPLEMENTARY INSTALLATION COST IS:		4452744.00		
THE GROSS ANNUAL INCOME IS :				3787770.00
THE DEPRECIATION IS :		384667.50		
THE ANNUAL OPERATING AND MAINTENANCE EXPENCE IS :		268978.13		
THE ANNUAL FINANCING AND SUPPLEMENTAL FINANCE COST IS:		941423.69		
THE ANNUAL PUMPING COST IS:		2199313.00		
THE ANNUAL SUPPLEMENTARY COSTS ARE:		12000.00		
THE PROPERTY TAXES ARE:		2689.78		
THE ANNUAL INSURANCE CHARGES ARE:		7623.00		
THE ANNUAL RIGHT-OF-WAY COST IS:		2056.00		
THE NET ANNUAL INCOME, BEFORE TAXES AND DEPRECIATION IS:			294061.19	

YEAR 25

		OUTFLOWS	INFLOWS
THE TOTAL INSTALLATION COST IS :	$$	26897824.00	
THE TOTAL SUPPLEMENTARY INSTALLATION COST IS:		4452744.00	
THE GROSS ANNUAL INCOME IS :			3787770.00
THE DEPRECIATION IS :		329715.00	
THE ANNUAL OPERATING AND MAINTENANCE EXPENCE IS :		268978.13	
THE ANNUAL FINANCING AND SUPPLEMENTAL FINANCE COST IS:		941423.69	
THE ANNUAL PUMPING COST IS:		2199313.00	
THE ANNUAL SUPPLEMENTARY COSTS ARE:		12000.00	
THE PROPERTY TAXES ARE:		2689.78	
THE ANNUAL INSURANCE CHARGES ARE:		7623.00	
THE ANNUAL RIGHT-OF-WAY COST IS:		2056.00	
THE NET ANNUAL INCOME, BEFORE TAXES AND DEPRECIATION IS:			294061.19

YEAR 26

		OUTFLOWS	INFLOWS	
THE TOTAL INSTALLATION COST IS :	$$	26897824.00		
THE TOTAL SUPPLEMENTARY INSTALLATION COST IS:		4452744.00		
THE GROSS ANNUAL INCOME IS :				3787770.00
THE DEPRECIATION IS :		274762.63		
THE ANNUAL OPERATING AND MAINTENANCE EXPENCE IS :		268978.13		
THE ANNUAL FINANCING AND SUPPLEMENTAL FINANCE COST IS:		941423.69		
THE ANNUAL PUMPING COST IS:		2199313.00		
THE ANNUAL SUPPLEMENTARY COSTS ARE:		12000.00		
THE PROPERTY TAXES ARE:		2689.78		
THE ANNUAL INSURANCE CHARGES ARE:		7623.00		
THE ANNUAL RIGHT-OF-WAY COST IS:		2056.00		
THE NET ANNUAL INCOME, BEFORE TAXES AND DEPRECIATION IS:			294061.19	
THE FEDERAL AND STATE INCOME TAXES ARE:		9649.28		

YEAR 27		OUTFLOWS	INFLOWS	
THE TOTAL INSTALLATION COST IS :	$$	26897824.00		
THE TOTAL SUPPLEMENTARY INSTALLATION COST IS:		4452744.00		
THE GROSS ANNUAL INCOME IS :				3787770.00
THE DEPRECIATION IS :		219810.13		
THE ANNUAL OPERATING AND MAINTENANCE EXPENCE IS :		268978.13		
THE ANNUAL FINANCING AND SUPPLEMENTAL FINANCE COST IS:		941423.69		
THE ANNUAL PUMPING COST IS:		2199313.00		
THE ANNUAL SUPPLEMENTARY COSTS ARE:		12000.00		
THE PROPERTY TAXES ARE:		2689.78		
THE ANNUAL INSURANCE CHARGES ARE:		7623.00		
THE ANNUAL RIGHT-OF-WAY COST IS:		2056.00		
THE NET ANNUAL INCOME, BEFORE TAXES AND DEPRECIATION IS:			294061.19	
THE FEDERAL AND STATE INCOME TAXES ARE:		37125.53		

YEAR 28

		OUTFLOWS	INFLOWS
THE TOTAL INSTALLATION COST IS :	$$	26897824.00	
THE TOTAL SUPPLEMENTARY INSTALLATION COST IS:		4452744.00	
THE GROSS ANNUAL INCOME IS :			3787770.00
THE DEPRECIATION IS :		164857.63	
THE ANNUAL OPERATING AND MAINTENANCE EXPENCE IS :		268978.13	
THE ANNUAL FINANCING AND SUPPLEMENTAL FINANCE COST IS:		941423.69	
THE ANNUAL PUMPING COST IS:		2199313.00	
THE ANNUAL SUPPLEMENTARY COSTS ARE:		12000.00	
THE PROPERTY TAXES ARE:		2689.78	
THE ANNUAL INSURANCE CHARGES ARE:		7623.00	
THE ANNUAL RIGHT-OF-WAY COST IS:		2056.00	
THE NET ANNUAL INCOME, BEFORE TAXES AND DEPRECIATION IS:			294061.19
THE FEDERAL AND STATE INCOME TAXES ARE:		64601.78	

YEAR 29		OUTFLOWS	INFLOWS	
THE TOTAL INSTALLATION COST IS :	$$	26897824.00		
THE TOTAL SUPPLEMENTARY INSTALLATION COST IS:		4452744.00		
THE GROSS ANNUAL INCOME IS :				3787770.00
THE DEPRECIATION IS :		109905.06		
THE ANNUAL OPERATING AND MAINTENANCE EXPENCE IS :		268978.13		
THE ANNUAL FINANCING AND SUPPLEMENTAL FINANCE COST IS:		941423.69		
THE ANNUAL PUMPING COST IS:		2199313.00		
THE ANNUAL SUPPLEMENTARY COSTS ARE:		12000.00		
THE PROPERTY TAXES ARE:		2689.78		
THE ANNUAL INSURANCE CHARGES ARE:		7623.00		
THE ANNUAL RIGHT-OF-WAY COST IS:		2056.00		
THE NET ANNUAL INCOME, BEFORE TAXES AND DEPRECIATION IS:			294061.19	
THE FEDERAL AND STATE INCOME TAXES ARE:		92078.06		

YEAR 30

		OUTFLOWS		INFLOWS
THE TOTAL INSTALLATION COST IS :	$$	26897824.00		
THE TOTAL SUPPLEMENTARY INSTALLATION COST IS:		4452744.00		
THE GROSS ANNUAL INCOME IS :				3787770.00
THE DEPRECIATION IS :		54952.53		
THE ANNUAL OPERATING AND MAINTENANCE EXPENCE IS :		268978.13		
THE ANNUAL FINANCING AND SUPPLEMENTAL FINANCE COST IS:		941423.69		
THE ANNUAL PUMPING COST IS:		2199313.00		
THE ANNUAL SUPPLEMENTARY COSTS ARE:		12000.00		
THE PROPERTY TAXES ARE:		2689.78		
THE ANNUAL INSURANCE CHARGES ARE:		7623.00		
THE ANNUAL RIGHT-OF-WAY COST IS:		2056.00		
THE NET ANNUAL INCOME, BEFORE TAXES AND DEPRECIATION IS:			294061.19	
THE FEDERAL AND STATE INCOME TAXES ARE:		119554.31		

YEAR 2

		OUTFLOWS	INFLOWS
THE TOTAL INSTALLATION COST IS :	$$	21345824.00	
THE TOTAL SUPPLEMENTARY INSTALLATION COST IS:		4452744.00	
THE GROSS ANNUAL INCOME IS :			3787770.00
THE DEPRECIATION IS :		1264682.00	
THE ANNUAL OPERATING AND MAINTENANCE EXPENCE IS :		213458.19	
THE ANNUAL FINANCING AND SUPPLEMENTAL FINANCE COST IS:		747103.75	
THE ANNUAL PUMPING COST IS:		1315456.00	
THE ANNUAL SUPPLEMENTARY COSTS ARE:		12000.00	
THE PROPERTY TAXES ARE:		2134.58	
THE ANNUAL INSURANCE CHARGES ARE:		7623.00	
THE ANNUAL RIGHT-OF-WAY COST IS:		2056.00	
THE NET ANNUAL INCOME, BEFORE TAXES AND DEPRECIATION IS:			1428313.00
THE FEDERAL AND STATE INCOME TAXES ARE:		81815.50	

YEAR 3

		OUTFLOWS	INFLOWS
THE TOTAL INSTALLATION COST IS :	$$	21345824.00	
THE TOTAL SUPPLEMENTARY INSTALLATION COST IS:		4452744.00	
THE GROSS ANNUAL INCOME IS :			3787770.00
THE DEPRECIATION IS :		1221072.00	
THE ANNUAL OPERATING AND MAINTENANCE EXPENCE IS :		213458.19	
THE ANNUAL FINANCING AND SUPPLEMENTAL FINANCE COST IS:		747103.75	
THE ANNUAL PUMPING COST IS:		1315456.00	
THE ANNUAL SUPPLEMENTARY COSTS ARE:		12000.00	
THE PROPERTY TAXES ARE:		2134.58	
THE ANNUAL INSURANCE CHARGES ARE:		7623.00	
THE ANNUAL RIGHT-OF-WAY COST IS:		2056.00	
THE NET ANNUAL INCOME, BEFORE TAXES AND DEPRECIATION IS:			1428313.00
THE FEDERAL AND STATE INCOME TAXES ARE:		103620.50	

YEAR 4

		OUTFLOWS	INFLOWS	
THE TOTAL INSTALLATION COST IS :	$$	21345824.00		
THE TOTAL SUPPLEMENTARY INSTALLATION COST IS:		4452744.00		
THE GROSS ANNUAL INCOME IS :				3787770.00
THE DEPRECIATION IS :		1177462.00		
THE ANNUAL OPERATING AND MAINTENANCE EXPENCE IS :		213458.19		
THE ANNUAL FINANCING AND SUPPLEMENTAL FINANCE COST IS:		747103.75		
THE ANNUAL PUMPING COST IS:		1315456.00		
THE ANNUAL SUPPLEMENTARY COSTS ARE:		12000.00		
THE PROPERTY TAXES ARE:		2134.58		
THE ANNUAL INSURANCE CHARGES ARE:		7623.00		
THE ANNUAL RIGHT-OF-WAY COST IS:		2056.00		
THE NET ANNUAL INCOME, BEFORE TAXES AND DEPRECIATION IS:			1428313.00	
THE FEDERAL AND STATE INCOME TAXES ARE:		125425.50		

YEAR 5		OUTFLOWS	INFLOWS
THE TOTAL INSTALLATION COST IS :	$$	21345824.00	
THE TOTAL SUPPLEMENTARY INSTALLATION COST IS:		4452744.00	
THE GROSS ANNUAL INCOME IS :			3787770.00
THE DEPRECIATION IS :		1133853.00	
THE ANNUAL OPERATING AND MAINTENANCE EXPENCE IS :		213458.19	
THE ANNUAL FINANCING AND SUPPLEMENTAL FINANCE COST IS:		747103.75	
THE ANNUAL PUMPING COST IS:		1315456.00	
THE ANNUAL SUPPLEMENTARY COSTS ARE:		12000.00	
THE PROPERTY TAXES ARE:		2134.58	
THE ANNUAL INSURANCE CHARGES ARE:		7623.00	
THE ANNUAL RIGHT-OF-WAY COST IS:		2056.00	
THE NET ANNUAL INCOME, BEFORE TAXES AND DEPRECIATION IS:			1428313.00
THE FEDERAL AND STATE INCOME TAXES ARE:		147230.00	

YEAR 6

		OUTFLOWS	INFLOWS
THE TOTAL INSTALLATION COST IS :	$$	21345824.00	
THE TOTAL SUPPLEMENTARY INSTALLATION COST IS:		4452744.00	
THE GROSS ANNUAL INCOME IS :			3787770.00
THE DEPRECIATION IS :		1090243.00	
THE ANNUAL OPERATING AND MAINTENANCE EXPENCE IS :		213458.19	
THE ANNUAL FINANCING AND SUPPLEMENTAL FINANCE COST IS:		747103.75	
THE ANNUAL PUMPING COST IS:		1315456.00	
THE ANNUAL SUPPLEMENTARY COSTS ARE:		12000.00	
THE PROPERTY TAXES ARE:		2134.58	
THE ANNUAL INSURANCE CHARGES ARE:		7623.00	
THE ANNUAL RIGHT-OF-WAY COST IS:		2056.00	
THE NET ANNUAL INCOME, BEFORE TAXES AND DEPRECIATION IS:			1428313.00
THE FEDERAL AND STATE INCOME TAXES ARE:		169035.00	

YEAR 7

		OUTFLOWS	INFLOWS
THE TOTAL INSTALLATION COST IS :	$$	21345824.00	
THE TOTAL SUPPLEMENTARY INSTALLATION COST IS:		4452744.00	
THE GROSS ANNUAL INCOME IS :			3787770.00
THE DEPRECIATION IS :		1046633.94	
THE ANNUAL OPERATING AND MAINTENANCE EXPENCE IS :		213458.19	
THE ANNUAL FINANCING AND SUPPLEMENTAL FINANCE COST IS:		747103.75	
THE ANNUAL PUMPING COST IS:		1315456.00	
THE ANNUAL SUPPLEMENTARY COSTS ARE:		12000.00	
THE PROPERTY TAXES ARE:		2134.58	
THE ANNUAL INSURANCE CHARGES ARE:		7623.00	
THE ANNUAL RIGHT-OF-WAY COST IS:		2056.00	
THE NET ANNUAL INCOME, BEFORE TAXES AND DEPRECIATION IS:			1428313.00
THE FEDERAL AND STATE INCOME TAXES ARE:		190839.50	

YEAR 9		OUTFLOWS	INFLOWS	
THE TOTAL INSTALLATION COST IS :	$$	21345824.00		
THE TOTAL SUPPLEMENTARY INSTALLATION COST IS:		4452744.00		
THE GROSS ANNUAL INCOME IS :				3787770.00
THE DEPRECIATION IS :		1003023.94		
THE ANNUAL OPERATING AND MAINTENANCE EXPENCE IS :		213458.19		
THE ANNUAL FINANCING AND SUPPLEMENTAL FINANCE COST IS:		747103.75		
THE ANNUAL PUMPING COST IS:		1315456.00		
THE ANNUAL SUPPLEMENTARY COSTS ARE:		12000.00		
THE PROPERTY TAXES ARE:		2134.58		
THE ANNUAL INSURANCE CHARGES ARE:		7623.00		
THE ANNUAL RIGHT-OF-WAY COST IS:		2056.00		
THE NET ANNUAL INCOME, BEFORE TAXES AND DEPRECIATION IS:			1428313.00	
THE FEDERAL AND STATE INCOME TAXES ARE:		212644.50		

YEAR 9		OUTFLOWS	INFLOWS	
THE TOTAL INSTALLATION COST IS :	$$	21345824.00		
THE TOTAL SUPPLEMENTARY INSTALLATION COST IS:		4452744.00		
THE GROSS ANNUAL INCOME IS :				3787770.00
THE DEPRECIATION IS :		959414.19		
THE ANNUAL OPERATING AND MAINTENANCE EXPENCE IS :		213458.19		
THE ANNUAL FINANCING AND SUPPLEMENTAL FINANCE COST IS:		747103.75		
THE ANNUAL PUMPING COST IS:		1315456.00		
THE ANNUAL SUPPLEMENTARY COSTS ARE:		12000.00		
THE PROPERTY TAXES ARE:		2134.58		
THE ANNUAL INSURANCE CHARGES ARE:		7623.00		
THE ANNUAL RIGHT-OF-WAY COST IS:		2056.00		
THE NET ANNUAL INCOME, BEFORE TAXES AND DEPRECIATION IS:			1428313.00	
THE FEDERAL AND STATE INCOME TAXES ARE:		234449.38		

YEAR 10		OUTFLOWS	INFLOWS
THE TOTAL INSTALLATION COST IS :	$$	21345824.00	
THE TOTAL SUPPLEMENTARY INSTALLATION COST IS:		4452744.00	
THE GROSS ANNUAL INCOME IS :			3787770.00
THE DEPRECIATION IS :		915804.44	
THE ANNUAL OPERATING AND MAINTENANCE EXPENCE IS :		213458.19	
THE ANNUAL FINANCING AND SUPPLEMENTAL FINANCE COST IS:		747103.75	
THE ANNUAL PUMPING COST IS:		1315456.00	
THE ANNUAL SUPPLEMENTARY COSTS ARE:		12000.00	
THE PROPERTY TAXES ARE:		2134.58	
THE ANNUAL INSURANCE CHARGES ARE:		7623.00	
THE ANNUAL RIGHT-OF-WAY COST IS:		2056.00	
THE NET ANNUAL INCOME, BEFORE TAXES AND DEPRECIATION IS:			1428313.00
THE FEDERAL AND STATE INCOME TAXES ARE:		256254.25	

YEAR 11

		OUTFLOWS	INFLOWS	
THE TOTAL INSTALLATION COST IS :	$$	21345824.00		
THE TOTAL SUPPLEMENTARY INSTALLATION COST IS:		4452744.00		
THE GROSS ANNUAL INCOME IS :				3787770.00
THE DEPRECIATION IS :		872194.75		
THE ANNUAL OPERATING AND MAINTENANCE EXPENCE IS :		213458.19		
THE ANNUAL FINANCING AND SUPPLEMENTAL FINANCE COST IS:		747103.75		
THE ANNUAL PUMPING COST IS:		1315456.00		
THE ANNUAL SUPPLEMENTARY COSTS ARE:		12000.00		
THE PROPERTY TAXES ARE:		2134.58		
THE ANNUAL INSURANCE CHARGES ARE:		7623.00		
THE ANNUAL RIGHT-OF-WAY COST IS:		2056.00		
THE NET ANNUAL INCOME, BEFORE TAXES AND DEPRECIATION IS:			1428313.00	
THE FEDERAL AND STATE INCOME TAXES ARE:		278059.13		

YEAR 12		OUTFLOWS	INFLOWS	
THE TOTAL INSTALLATION COST IS :	$$	21345824.00		
THE TOTAL SUPPLEMENTARY INSTALLATION COST IS:		4452744.00		
THE GROSS ANNUAL INCOME IS :				3787770.00
THE DEPRECIATION IS :		828585.00		
THE ANNUAL OPERATING AND MAINTENANCE EXPENCE IS :		213458.19		
THE ANNUAL FINANCING AND SUPPLEMENTAL FINANCE COST IS:		747103.75		
THE ANNUAL PUMPING COST IS:		1315456.00		
THE ANNUAL SUPPLEMENTARY COSTS ARE:		12000.00		
THE PROPERTY TAXES ARE:		2134.58		
THE ANNUAL INSURANCE CHARGES ARE:		7623.00		
THE ANNUAL RIGHT-OF-WAY COST IS:		2056.00		
THE NET ANNUAL INCOME, BEFORE TAXES AND DEPRECIATION IS:			1428313.00	
THE FEDERAL AND STATE INCOME TAXES ARE:		299864.00		

YEAR 13

		OUTFLOWS	INFLOWS
THE TOTAL INSTALLATION COST IS :	$$	21345824.00	
THE TOTAL SUPPLEMENTARY INSTALLATION COST IS:		4452744.00	
THE GROSS ANNUAL INCOME IS :			3787770.00
THE DEPRECIATION IS :		784975.25	
THE ANNUAL OPERATING AND MAINTENANCE EXPENCE IS :		213458.19	
THE ANNUAL FINANCING AND SUPPLEMENTAL FINANCE COST IS:		747103.75	
THE ANNUAL PUMPING COST IS:		1315456.00	
THE ANNUAL SUPPLEMENTARY COSTS ARE:		12000.00	
THE PROPERTY TAXES ARE:		2134.58	
THE ANNUAL INSURANCE CHARGES ARE:		7623.00	
THE ANNUAL RIGHT-OF-WAY COST IS:		2056.00	
THE NET ANNUAL INCOME, BEFORE TAXES AND DEPRECIATION IS:			1428313.00
THE FEDERAL AND STATE INCOME TAXES ARE:		321668.88	

YEAR 14		OUTFLOWS	INFLOWS	
THE TOTAL INSTALLATION COST IS :	$$	21345824.00		
THE TOTAL SUPPLEMENTARY INSTALLATION COST IS:		4452744.00		
THE GROSS ANNUAL INCOME IS :				3787770.00
THE DEPRECIATION IS :		741365.50		
THE ANNUAL OPERATING AND MAINTENANCE EXPENCE IS :		213458.19		
THE ANNUAL FINANCING AND SUPPLEMENTAL FINANCE COST IS:		747103.75		
THE ANNUAL PUMPING COST IS:		1315456.00		
THE ANNUAL SUPPLEMENTARY COSTS ARE:		12000.00		
THE PROPERTY TAXES ARE:		2134.58		
THE ANNUAL INSURANCE CHARGES ARE:		7623.00		
THE ANNUAL RIGHT-OF-WAY COST IS:		2056.00		
THE NET ANNUAL INCOME, BEFORE TAXES AND DEPRECIATION IS:			1428313.00	
THE FEDERAL AND STATE INCOME TAXES ARE:		343473.75		

YEAR 15

		OUTFLOWS		INFLOWS
THE TOTAL INSTALLATION COST IS :	$$	21345824.00		
THE TOTAL SUPPLEMENTARY INSTALLATION COST IS:		4452744.00		
THE GROSS ANNUAL INCOME IS :				3787770.00
THE DEPRECIATION IS :		697755.75		
THE ANNUAL OPERATING AND MAINTENANCE EXPENCE IS :		213458.19		
THE ANNUAL FINANCING AND SUPPLEMENTAL FINANCE COST IS:		747103.75		
THE ANNUAL PUMPING COST IS:		1315456.00		
THE ANNUAL SUPPLEMENTARY COSTS ARE:		12000.00		
THE PROPERTY TAXES ARE:		2134.58		
THE ANNUAL INSURANCE CHARGES ARE:		7623.00		
THE ANNUAL RIGHT-OF-WAY COST IS:		2056.00		
THE NET ANNUAL INCOME, BEFORE TAXES AND DEPRECIATION IS:			1428313.00	
THE FEDERAL AND STATE INCOME TAXES ARE:		365278.63		

YEAR 16

		OUTFLOWS	INFLOWS
THE TOTAL INSTALLATION COST IS :	$$	21345824.00	
THE TOTAL SUPPLEMENTARY INSTALLATION COST IS:		4452744.00	
THE GROSS ANNUAL INCOME IS :			3787770.00
THE DEPRECIATION IS :		654145.75	
THE ANNUAL OPERATING AND MAINTENANCE EXPENCE IS :		213458.19	
THE ANNUAL FINANCING AND SUPPLEMENTAL FINANCE COST IS:		747103.75	
THE ANNUAL PUMPING COST IS:		1315456.00	
THE ANNUAL SUPPLEMENTARY COSTS ARE:		12000.00	
THE PROPERTY TAXES ARE:		2134.58	
THE ANNUAL INSURANCE CHARGES ARE:		7623.00	
THE ANNUAL RIGHT-OF-WAY COST IS:		2056.00	
THE NET ANNUAL INCOME, BEFORE TAXES AND DEPRECIATION IS:			1428313.00
THE FEDERAL AND STATE INCOME TAXES ARE:		387093.63	

YEAR 17

		OUTFLOWS	INFLOWS
THE TOTAL INSTALLATION COST IS :	$$	21345824.00	
THE TOTAL SUPPLEMENTARY INSTALLATION COST IS:		4452744.00	
THE GROSS ANNUAL INCOME IS :			3787770.00
THE DEPRECIATION IS :		610536.31	
THE ANNUAL OPERATING AND MAINTENANCE EXPENCE IS :		213458.19	
THE ANNUAL FINANCING AND SUPPLEMENTAL FINANCE COST IS:		747103.75	
THE ANNUAL PUMPING COST IS:		1315456.00	
THE ANNUAL SUPPLEMENTARY COSTS ARE:		12000.00	
THE PROPERTY TAXES ARE:		2134.58	
THE ANNUAL INSURANCE CHARGES ARE:		7623.00	
THE ANNUAL RIGHT-OF-WAY COST IS:		2056.00	
THE NET ANNUAL INCOME, BEFORE TAXES AND DEPRECIATION IS:			1428313.00
THE FEDERAL AND STATE INCOME TAXES ARE:		408888.31	

YEAR 18

		OUTFLOWS	INFLOWS	
THE TOTAL INSTALLATION COST IS :	$$	21345824.00		
THE TOTAL SUPPLEMENTARY INSTALLATION COST IS:		4452744.00		
THE GROSS ANNUAL INCOME IS :				3787770.00
THE DEPRECIATION IS :		566926.56		
THE ANNUAL OPERATING AND MAINTENANCE EXPENCE IS :		213458.19		
THE ANNUAL FINANCING AND SUPPLEMENTAL FINANCE COST IS:		747103.75		
THE ANNUAL PUMPING COST IS:		1315456.00		
THE ANNUAL SUPPLEMENTARY COSTS ARE:		12000.00		
THE PROPERTY TAXES ARE:		2134.58		
THE ANNUAL INSURANCE CHARGES ARE:		7623.00		
THE ANNUAL RIGHT-OF-WAY COST IS:		2056.00		
THE NET ANNUAL INCOME, BEFORE TAXES AND DEPRECIATION IS:			1428313.00	
THE FEDERAL AND STATE INCOME TAXES ARE:		430693.19		

YEAR 19		OUTFLOWS	INFLOWS	
THE TOTAL INSTALLATION COST IS :	$$	21345824.00		
THE TOTAL SUPPLEMENTARY INSTALLATION COST IS:		4452744.00		
THE GROSS ANNUAL INCOME IS :				3787770.00
THE DEPRECIATION IS :		523316.81		
THE ANNUAL OPERATING AND MAINTENANCE EXPENCE IS :		213458.19		
THE ANNUAL FINANCING AND SUPPLEMENTAL FINANCE COST IS:		747103.75		
THE ANNUAL PUMPING COST IS:		1315456.00		
THE ANNUAL SUPPLEMENTARY COSTS ARE:		12000.00		
THE PROPERTY TAXES ARE:		2134.58		
THE ANNUAL INSURANCE CHARGES ARE:		7623.00		
THE ANNUAL RIGHT-OF-WAY COST IS:		2056.00		
THE NET ANNUAL INCOME, BEFORE TAXES AND DEPRECIATION IS:			1428313.00	
THE FEDERAL AND STATE INCOME TAXES ARE:		452498.06		

YEAR 20

		OUTFLOWS	INFLOWS
THE TOTAL INSTALLATION COST IS :	$$	21345824.00	
THE TOTAL SUPPLEMENTARY INSTALLATION COST IS:		4452744.00	
THE GROSS ANNUAL INCOME IS :			3787770.00
THE DEPRECIATION IS :		479706.81	
THE ANNUAL OPERATING AND MAINTENANCE EXPENCE IS :		213458.19	
THE ANNUAL FINANCING AND SUPPLEMENTAL FINANCE COST IS:		747103.75	
THE ANNUAL PUMPING COST IS:		1315456.00	
THE ANNUAL SUPPLEMENTARY COSTS ARE:		12000.00	
THE PROPERTY TAXES ARE:		2134.58	
THE ANNUAL INSURANCE CHARGES ARE:		7623.00	
THE ANNUAL RIGHT-OF-WAY COST IS:		2056.00	
THE NET ANNUAL INCOME, BEFORE TAXES AND DEPRECIATION IS:			1428313.00
THE FEDERAL AND STATE INCOME TAXES ARE:		474303.06	

YEAR 21

	OUTFLOWS	INFLOWS
THE TOTAL INSTALLATION COST IS : $$	21345824.00	
THE TOTAL SUPPLEMENTARY INSTALLATION COST IS:	4452744.00	
THE GROSS ANNUAL INCOME IS :		3787770.00
THE DEPRECIATION IS :	436097.06	
THE ANNUAL OPERATING AND MAINTENANCE EXPENCE IS :	213458.19	
THE ANNUAL FINANCING AND SUPPLEMENTAL FINANCE COST IS:	747103.75	
THE ANNUAL PUMPING COST IS:	1315456.00	
THE ANNUAL SUPPLEMENTARY COSTS ARE:	12000.00	
THE PROPERTY TAXES ARE:	2134.58	
THE ANNUAL INSURANCE CHARGES ARE:	7623.00	
THE ANNUAL RIGHT-OF-WAY COST IS:	2056.00	
THE NET ANNUAL INCOME, BEFORE TAXES AND DEPRECIATION IS:		1428313.00
THE FEDERAL AND STATE INCOME TAXES ARE:	496107.94	

YEAR 22

		OUTFLOWS	INFLOWS
THE TOTAL INSTALLATION COST IS :	$$	21345924.00	
THE TOTAL SUPPLEMENTARY INSTALLATION COST IS:		4452744.00	
THE GROSS ANNUAL INCOME IS :			3787770.00
THE DEPRECIATION IS :		392487.63	
THE ANNUAL OPERATING AND MAINTENANCE EXPENCE IS :		213458.19	
THE ANNUAL FINANCING AND SUPPLEMENTAL FINANCE COST IS:		747103.75	
THE ANNUAL PUMPING COST IS:		1315456.00	
THE ANNUAL SUPPLEMENTARY COSTS ARE:		12000.00	
THE PROPERTY TAXES ARE:		2134.58	
THE ANNUAL INSURANCE CHARGES ARE:		7623.00	
THE ANNUAL RIGHT-OF-WAY COST IS:		2056.00	
THE NET ANNUAL INCOME, BEFORE TAXES AND DEPRECIATION IS:			1428313.00
THE FEDERAL AND STATE INCOME TAXES ARE:		517912.69	

YEAR 23		OUTFLOWS		INFLOWS
THE TOTAL INSTALLATION COST IS :	$$	21345824.00		
THE TOTAL SUPPLEMENTARY INSTALLATION COST IS:		4452744.00		
THE GROSS ANNUAL INCOME IS :				3787770.00
THE DEPRECIATION IS :		348877.88		
THE ANNUAL OPERATING AND MAINTENANCE EXPENCE IS :		213458.19		
THE ANNUAL FINANCING AND SUPPLEMENTAL FINANCE COST IS:		747103.75		
THE ANNUAL PUMPING COST IS:		1315456.00		
THE ANNUAL SUPPLEMENTARY COSTS ARE:		12000.00		
THE PROPERTY TAXES ARE:		2134.58		
THE ANNUAL INSURANCE CHARGES ARE:		7623.00		
THE ANNUAL RIGHT-OF-WAY COST IS:		2056.00		
THE NET ANNUAL INCOME, BEFORE TAXES AND DEPRECIATION IS:			1428313.00	
THE FEDERAL AND STATE INCOME TAXES ARE:		539717.50		

YEAR 24

		OUTFLOWS	INFLOWS
THE TOTAL INSTALLATION COST IS :	$$	21345824.00	
THE TOTAL SUPPLEMENTARY INSTALLATION COST IS:		4452744.00	
THE GROSS ANNUAL INCOME IS :			3787770.00
THE DEPRECIATION IS :		305267.88	
THE ANNUAL OPERATING AND MAINTENANCE EXPENCE IS :		213458.19	
THE ANNUAL FINANCING AND SUPPLEMENTAL FINANCE COST IS:		747103.75	
THE ANNUAL PUMPING COST IS:		1315456.00	
THE ANNUAL SUPPLEMENTARY COSTS ARE:		12000.00	
THE PROPERTY TAXES ARE:		2134.58	
THE ANNUAL INSURANCE CHARGES ARE:		7623.00	
THE ANNUAL RIGHT-OF-WAY COST IS:		2056.00	
THE NET ANNUAL INCOME, BEFORE TAXES AND DEPRECIATION IS:			1428313.00
THE FEDERAL AND STATE INCOME TAXES ARE:		561522.50	

YEAR 25		OUTFLOWS	INFLOWS	
THE TOTAL INSTALLATION COST IS :	$$	21345824.00		
THE TOTAL SUPPLEMENTARY INSTALLATION COST IS:		4452744.00		
THE GROSS ANNUAL INCOME IS :				3787770.00
THE DEPRECIATION IS :		261658.44		
THE ANNUAL OPERATING AND MAINTENANCE EXPENCE IS :		213458.19		
THE ANNUAL FINANCING AND SUPPLEMENTAL FINANCE COST IS:		747103.75		
THE ANNUAL PUMPING COST IS:		1315456.00		
THE ANNUAL SUPPLEMENTARY COSTS ARE:		12000.00		
THE PROPERTY TAXES ARE:		2134.58		
THE ANNUAL INSURANCE CHARGES ARE:		7623.00		
THE ANNUAL RIGHT-OF-WAY COST IS:		2056.00		
THE NET ANNUAL INCOME, BEFORE TAXES AND DEPRECIATION IS:			1428313.00	
THE FEDERAL AND STATE INCOME TAXES ARE:		583327.00		

YEAR 26

	OUTFLOWS	INFLOWS
THE TOTAL INSTALLATION COST IS : $$	21345824.00	
THE TOTAL SUPPLEMENTARY INSTALLATION COST IS:	4452744.00	
THE GROSS ANNUAL INCOME IS :		3787770.00
THE DEPRECIATION IS :	218048.69	
THE ANNUAL OPERATING AND MAINTENANCE EXPENCE IS :	213458.19	
THE ANNUAL FINANCING AND SUPPLEMENTAL FINANCE COST IS:	747103.75	
THE ANNUAL PUMPING COST IS:	1315456.00	
THE ANNUAL SUPPLEMENTARY COSTS ARE:	12000.00	
THE PROPERTY TAXES ARE:	2134.58	
THE ANNUAL INSURANCE CHARGES ARE:	7623.00	
THE ANNUAL RIGHT-OF-WAY COST IS:	2056.00	
THE NET ANNUAL INCOME, BEFORE TAXES AND DEPRECIATION IS:		1428313.00
THE FEDERAL AND STATE INCOME TAXES ARE:	605132.00	

YEAR 27

		OUTFLOWS	INFLOWS
THE TOTAL INSTALLATION COST IS :	$$	21345874.00	
THE TOTAL SUPPLEMENTARY INSTALLATION COST IS:		4452744.00	
THE GROSS ANNUAL INCOME IS :			3787770.00
THE DEPRECIATION IS :		174438.94	
THE ANNUAL OPERATING AND MAINTENANCE EXPENCE IS :		213458.19	
THE ANNUAL FINANCING AND SUPPLEMENTAL FINANCE COST IS:		747103.75	
THE ANNUAL PUMPING COST IS:		1315456.00	
THE ANNUAL SUPPLEMENTARY COSTS ARE:		12000.00	
THE PROPERTY TAXES ARE:		2134.59	
THE ANNUAL INSURANCE CHARGES ARE:		7623.00	
THE ANNUAL RIGHT-OF-WAY COST IS:		2056.00	
THE NET ANNUAL INCOME, BEFORE TAXES AND DEPRECIATION IS:			1428313.00
THE FEDERAL AND STATE INCOME TAXES ARE:		626937.00	

YEAR 28		OUTFLOWS	INFLOWS	
THE TOTAL INSTALLATION COST IS :	$$	21345824.00		
THE TOTAL SUPPLEMENTARY INSTALLATION COST IS:		4452744.00		
THE GROSS ANNUAL INCOME IS :				3787770.00
THE DEPRECIATION IS :		130829.19		
THE ANNUAL OPERATING AND MAINTENANCE EXPENCE IS :		213458.19		
THE ANNUAL FINANCING AND SUPPLEMENTAL FINANCE COST IS:		747103.75		
THE ANNUAL PUMPING COST IS:		1315456.00		
THE ANNUAL SUPPLEMENTARY COSTS ARE:		12000.00		
THE PROPERTY TAXES ARE:		2134.58		
THE ANNUAL INSURANCE CHARGES ARE:		7623.00		
THE ANNUAL RIGHT-OF-WAY COST IS:		2056.00		
THE NET ANNUAL INCOME, BEFORE TAXES AND DEPRECIATION IS:			1428313.00	
THE FEDERAL AND STATE INCOME TAXES ARE:		648741.50		

YEAR 22

		OUTFLOWS	INFLOWS
THE TOTAL INSTALLATION COST IS :	$$	21345824.00	
THE TOTAL SUPPLEMENTARY INSTALLATION COST IS:		4452744.00	
THE GROSS ANNUAL INCOME IS :			3787770.00
THE DEPRECIATION IS :		87219.44	
THE ANNUAL OPERATING AND MAINTENANCE EXPENCE IS :		213458.19	
THE ANNUAL FINANCING AND SUPPLEMENTAL FINANCE COST IS:		747103.75	
THE ANNUAL PUMPING COST IS:		1315456.00	
THE ANNUAL SUPPLEMENTARY COSTS ARE:		12000.00	
THE PROPERTY TAXES ARE:		2134.58	
THE ANNUAL INSURANCE CHARGES ARE:		7623.00	
THE ANNUAL RIGHT-OF-WAY COST IS:		2056.00	
THE NET ANNUAL INCOME, BEFORE TAXES AND DEPRECIATION IS:			1428313.00
THE FEDERAL AND STATE INCOME TAXES ARE:		670546.50	

YEAR 30

	OUTFLOWS	INFLOWS
THE TOTAL INSTALLATION COST IS : $$	21345824.00	
THE TOTAL SUPPLEMENTARY INSTALLATION COST IS:	4452744.00	
THE GROSS ANNUAL INCOME IS :		3787770.00
THE DEPRECIATION IS :	43609.73	
THE ANNUAL OPERATING AND MAINTENANCE EXPENCE IS :	213458.19	
THE ANNUAL FINANCING AND SUPPLEMENTAL FINANCE COST IS:	747103.75	
THE ANNUAL PUMPING COST IS:	1315456.00	
THE ANNUAL SUPPLEMENTARY COSTS ARE:	12000.00	
THE PROPERTY TAXES ARE:	2134.58	
THE ANNUAL INSURANCE CHARGES ARE:	7623.00	
THE ANNUAL RIGHT-OF-WAY COST IS:	2056.00	
THE NET ANNUAL INCOME, BEFORE TAXES AND DEPRECIATION IS:		1428313.00
THE FEDERAL AND STATE INCOME TAXES ARE:	692351.50	

VIII. BIBLIOGRAPHY

[1] Anonymous, "Guide for Economic Evaluation of Nuclear Reactor Plant Designs," NUS Corporation, Rockville, Maryland, January 1969 (NUS 531).

[2] Anonymous, "Nuclear Energy Centers Industrial and Agro Industrial Complexes," Oak Ridge National Laboratories, Clearinghouse for Scientific and Technical Information, National Bureau of Standards, Springfield, Virginia, November 1968.

[3] Anonymous, "Status of the Application of Nuclear Reactors in the Process Industries," Division of Reactor Development, Atomic Energy Commission, 1961.

[4] Anonymous, "Sterilization of Sewage Containing Pathogenic Microorganisms. Nuclear Reactors," Addendum to Report No. 9, Chicago: Illinois Institute of Technology, May, 1956.

[5] Anonymous, "Underground Stations Pondered in Sweden," Nuclear News, 13(6): 26, May, 1970.

[6] Bygs, J.G., "Nuclear Station Waste Heat Can Extend the Saint Lawrence Seaway Season," Atomic Energy of Canada Limited, Clearinghouse for Scientific and Technical Information, U.S. National Bureau of Standards, Springfield, Virginia, November, 1967. (CONF 680601-25)

[7] Blomberg, Pehr and Vogt, Jan, "Agesta," Nuclear News, 13(2) 37-42, February, 1970.

[8] Dietz, Albert G.H., "Proceedings of a Symposium/Workshop on Underground Heat Distribution Systems," Publication 1412, Washington: National Academy of Sciences, National Research Council, 1966.

[9] Dillon, Robert M., et al, "Evaluation of Components for Underground Heat Distribution Systems," Publication 828, Washington: National Academy of Sciences, National Research Council, 1960.

[10] Drobish, William E., et al, "Course Notes for Electrical Circuits and Applications," unpublished, U.S. Naval Nuclear Power School, Bainbridge, Maryland, January, 1963.

[11] Frank, Howard and Frisch, Ivan T., "Network Analysis," Scientific American, 233(1): 94-106, July, 1970.

[12] Gaum, Carl G., et al, Report Writing, New Jersey: Prentice Hall Incorporated, 1950.

[13] Gerringer, Paul L. and Goodfuaid, Morton J., "Potential Application of Nuclear Energy for Process and Space Heat in the United States," New York: American Hydrotherm Corporation, 1958 (NYO 2332).

[14] Glasstone, Samuel and Sisonske, Alexander, Nuclear Reactor Engineering, New Jersey: D. Van Nostrand, Inc., 1963.

[15] Godfrey, Robert S., editor, Building Construction Cost Data - 1962, Duxburg, Mass.: Robert Snow Means Co., 1963.

[16] Govan, Francis A., High Temperature Water for Heating and Light Process Loads, Publication 753, Washington: National Academy of Sciences, National Research Council, 1959.

[17] Hammond, S.B., Electrical Engineering, New York: McGraw-Hill Book Company, Inc., 1961.

[18] Hendricks, James R., "Submarine Qualification Notebook," unpublished, 1968.

[19] Jaske, R.T., "An Independent View of the Thermal Effects and Radioactive Pollution from Nuclear Power Plants." Clearinghouse for Federal Scientific and Technical Information, National Bureau of Standards, Springfield, Virginia, 1969.

[20] McCabe, Warren, L. and Smith, Julian C., Unit Operations of Chemical Engineering, New York: McGraw-Hill Book Company, Inc., 1956.

[21] Mead, William B., "Fight is on Against Thermal Pollution," Associated Press New Service, Rolla Daily News, Rolla, Missouri, September 28, 1970.

[22] Miller, A.S., "Space Heating in Urban Environments," Clearinghouse for Federal Scientific and Technical Information, National Bureau of Standards, Springfield, Virginia, 1969.

[23] Mitteman, Joseph, Circuit Theory Analysis, New York: Hayden Book Company, Inc., 1964.

[24] Penman, H.L., "The Water Cycle," Scientific American, 233(3): 99-108, September, 1970.

[25] Perry, John H., Editor, Chemical Engineering Handbook, Fourth Edition, New York: McGraw-Hill Book Company, Inc., 1963.

[26] Peters, Max S., Plant Design and Economics for Chemical Engineers, New York: McGraw-Hill Book Company, Inc., 1958.

[27] Sandstrom, S., "Operating Experience at the Agesta Nuclear Power Station," Artiebolajet Atomenergi, Stockholm, Sweden, September, 1966.

[28] Siegel, Sideny, et al, "Application of Nuclear Energy to Large Scale Power and Desalting Plants," Engineering Design, 4(10): 225-232, October, 1966.

[29] Tyler, Chaplin and Winter, C.H., Chemical Engineering Economics, Fourth Edition, New York: McGraw-Hill Book Company, Inc., 1959.

[30] Wallace, Richard, Personnel Manager, Consumers Power Corporation, personal interview.

[31] Wiostad, I., "ADAM - A 75 MW Nuclear Energy Plant for House Heating Purposes," paper presented at the Second United Nations International Conference on Peaceful Uses of the Atom, Sweden, June, 1958.

[32] Underwood, G., Estimating Construction Costs, New York: McGraw-Hill Book Company, Inc., 1930.

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X. VITA

James Richard Hendricks was born on December 20, 1942 in Selinsgrove, Pennsylvania. After completing his high school education in Selinsgrove, he attended The Pennsylvania State University from 1960 until 1964, when he received a Bachelor of Science degree in Chemical Engineering.

He received a commission in the United States Navy in September, 1964. From 1964 until December, 1969, he served in the Naval Reactors Power Program, attaining the rank of Lieutenant and qualifying as Chief Engineer for Naval Nuclear Propulsion Plants.

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