Fall 1981

Assessing the Economic Feasibility of Synthetic Natural Gas Under Conditions of Uncertainty

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ASSESSING THE ECONOMIC FEASIBILITY OF SYNTHETIC NATURAL GAS UNDER CONDITIONS OF UNCERTAINTY

BY

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THESIS

Submitted in partial fulfillment of the requirements
for the Master of Arts degree in Applied Economics
in the Graduate Studies Program of the College of Business Administration
University of Central Florida
Orlando, Florida

Fall Semester
1981

ABSTRACT

The science of synthetic fuel production began in the seventeenth century. However, large-scale production of synthetic fuels started in the early 1900's and, for several decades, gas manufactured from coal significantly contributed to the U.S. economy. The production of synthetic fuels declined due to increases in the price of coal and discoveries of predominantly methane natural gas.

Today, an extensive network of pipelines is used to transmit and distribute natural gas for industrial and residential applications. The decline of natural gas reserves in the United States, in conjunction with the availability of very large coal reserves, has provided the incentive for development of coal gasification plants. Synthetic fuels are expected to contribute significantly to the supply of energy before the end of this century, and coal will be the primary source for production of these fuels.

By many accounts, difficulties in raising the high amount of initial capital and future uncertainties with regard to fuel and operating costs have made development of synthetic fuels economically infeasible. However, as the prices of oil and natural gas increase, synthetic fuels production becomes a more attractive alternative. The purpose of this

study is to evaluate the economics of synthetic natural gas with the current state of technology and to determine its future role as prices of oil and gas increase.

In this report, a general methodology of production of synthetic natural gas is explained. For the economic analysis, the Lurgi Model was selected because it has been the most common model used for commercial production of high BTU gases. An extensive analytical model is described in which inflated capital, fuel, and operating and maintenance costs were accounted for and the equivalent annual cost of cash flows over the project life was calculated. The risk analysis was accomplished by applying Monte Carolo techniques through a simulation model which handles risks associated with various input parameters. SLAM, a FORTRAN-based language, was selected as the simulation language. Based on the results, all the cost elements were evaluated and the sensitivity of the total cost to each element was examined. This study was extended to the calculation of costs associated with the generation of electricity by burning synthetic natural gas. The results were then compared to the respective costs related to oil-burning power plants. The results show that high cost of synthetic high BTU gas makes it difficult to compete with natural gas at current prices. Coal feed stocks represent a major portion of the total cost of synthetic gases. The cost of capital, which is a critical factor at the developing stage, constitutes a relatively small portion of the total cost over the plant life. A

similar observation was made for operating and maintenance costs. However, the future regulations regarding pollution control could have a strong impact on this portion of the cost. For power generation, oil was found to be far more economical than using synthetic natural gas. The computer simulation also revealed that the total cost of each alternative is very sensitive to this fuel cost. The conclusion of this study points to the fuel costs as the dominant factor in the choice of fuel alternatives in the future.

ACKNOWLEDGMENTS

My special thanks go to the members of my committee who guided me through these efforts. Dr. James Xander, chairman, and Dr. Douglas McNiel were always available for advice and guidance. Dr. Djehanne Hosni has my gratitude for her encouragement and her efforts in my behalf. John Reed's friendship and help will always be remembered. To each of them go my sincere thanks.

To my mother, Seighe' Bagom, whose support and love have brought enthusiasm for my work and success in my life.

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INTRODUCTION

During the 1970's, increases in the price of oil followed by energy shortages revealed the economic vulnerability of the United States to sudden curtailments in energy availability. Thus, culminating in Project Independence, the goal of reaching greater security in and more control of energy supplies was established. In addition, the apparent setback in nuclear energy caused by the Three-Mile Island incident put focus on utilizing other abundant domestic natural resources. Coal gasification and the extraction of liquid fuels from both coal and oil shale constitute two of the most promising alternative energy sources for the medium term future. Synthetic fuels are expected to significantly contribute to energy supplied before the end of this century; and with the development of proposed projects, supported by the government, synthetic fuels will be equivalent to two million barrels of oil a day by 1992.

By many accounts, given the current stage of technology, most synthetic fuel plants are not economically attractive. However, such plants could become more attractive if oil and natural gas prices rise significantly, or if regulations forbid certain types of industrial installations to use oil and gas. The purpose of this study is to evaluate the economics of synthetic natural

gas to fuel plants for electric power generation. It assumes the current state of technology and examines SNG's future role as prices of oil and natural gas increase.

In Chapter 2, a brief history of coal gasification and a general explanation of the applied process is explained. The properties and applications of different types of gas produced from the coal gasification process are discussed. The environmental impacts of producing gas from coal is also discussed and compared to direct coal combustion.

Chapter 3 provides a description of the cost and risk analysis models. All costs during the construction and operational periods are identified and probability distributions applied to the factors subject to uncertainty are discussed.

In Chapter 4, the coal gasification process selected for this study and the input data for the cost analysis are explained.

The results of risk analysis are shown in Chapter 5. In this chapter, the distributions related to the equivalent annual cost of producing synthetic natural gas are shown. Also, the distributions corresponding to each of the variables subject to uncertainty are shown and discussed.

This study is extended to the calculation of costs associated with the generation of electricity by burning synthetic natural gas. The expected cost of generating electricity by using SNG is compared to the expected cost when oil is used and the cost distributions of the two alternatives resulting from risk analysis are

compared for the two alternatives. By using the distribution of the difference in cost of the two alternatives the probability that the SNG power plant is more economical can be determined. The cost elements of both alternatives are evaluated and sensitivity of the total costs to the fuel cost is examined. A summary and conclusions of the study along with recommendations for future research are discussed in Chapter 6.

CHAPTER 2

COAL GASIFICATION AS A SYNTHETIC FUEL PROCESS

Synthetic fuels are expected to significantly contribute to the energy supply before the end of this century. Fossil fuels which took thousands of years to develop in the earth's crust are being exhausted at increasing rates. Of all the fossil fuels, natural gas shows the first sign of approaching some shortages. These shortages are overcome by the transfer of gases from areas with surpluses to the regions experiencing deficits. However, long-run solutions must be sought in substitution and/or supplementation of natural gas.

Coal is an abundant resource in this country and is considered the primary fuel for production of synthetic fuels. Conversion of coal to gas normally involves a controlled partial-oxidation reaction where the heat required is provided by combustion of the coal itself or by an external heat source.

Pollution control expenses constitute a substantial portion of the total cost of burning fuels. The Clean Air Act of 1977 tightened regulations for controlling pollutants, especially the sulfur oxides, requiring their removal by scrubbers. The cost of removing pollutants is less for coal gasification compared to direct combustion. It is more expensive to scrub sulfur oxides

from the flue gas produced by a coal-fired boiler than it is to strip hydrogen sulfide and other sulfur compounds from the fuel gas made by a commercial gasification plant. The reduction of contaminants to the environment when low BTU gas is produced is very significant. In this case, the reduction is estimated to be 90 percent in sulfur dioxides, nearly 100 percent in particulates, and a high portion of NO_x. [1]

The development of a synthetic fuel industry which is primarily comprised of coal conversion requires large quantities of water. This is a critical issue in the West where many coal conversion plants are likely to be located and water resources are already heavily committed. [2]

Electric utilities have a great deal of interest in medium BTU gas production. The gasifiction process would be integrated with the new combined cycle plants, which many utilities think may be the backbone of their generating system in the future.

By many accounts, with the current state of technology, most synthetic fuel plants are not economically attractive. Raising the high amount of initial capital and coping with future uncertainties in fuel and operating costs are serious concerns when developing synthetic fuel plants. However, such plants could become more attractive if oil and gas prices rise sufficiently, or if regulations forbid certain types of industrial installations to use oil and gas. High BTU gas, a natural gas substitute, could be used to supplement and extend natural gas supplies by using the extensive natural gas

transmission and distribution systems already in existence. In the past twenty years, research and development has been conducted in order to devise fuel conversion methods using less costly and more environmentally acceptable processes.

Recently, synthetic fuels legislation has been passed which is expected to create great enthusiasm for the creation of domestic synthetic fuels industry. This year, a total of $17.5 billion in government subsidies has been offered to oil companies for the developing of this industry. These companies have made proposals for the building of seventeen coal gasification plants, nineteen coal liquification plants, fourteen oil shale projects, eight plants to produce oil from tar sands, and three plants to produce other fuels. It is believed that if all the projects were built, the country would be able to reach the goal of producing the equivalent of two million barrels of oil daily by 1992, about one-third of the current volume of imported oil. Assuming $30/barrel, more than $20 billion would be removed from the balance of payments deficit. [3]

History of Coal Gasification

In 1670, Reverend John Clayton, a Yorkshire clergyman, reported the generation of a luminous gas when coal was heated in a chemical retort. This was the start of the history of coal gasification. A century later in 1722, William Murdoch, a Scotsman, obtained a gas by distilling coal in an iron retort.

Larger scale production of synthetic fuels started in 1910 with the invention of the Fischer-Tropsch Process in Germany. This was

followed by the invention of several other methods of coal gasification. During the first part of the twentieth century, gas manufactured from coal significantly contributed to the U.S. economy. In the 1920's, some 20,000 gasifiers supplied energy to both utility and industrial plants. In 1933, the gas manufactured for sale by utilities produced 1.82 quadrillion BTUs (quads). This value increased to 1.99 quads at the start of World War II and peaked at 2.68 quads in 1949. [1]

During the 1920's, Welman reactors were used to supply 50 percent of the industrial market with low BTU gas. The decline of coal gasification began in 1948. Two major factors contributed to this decline: 1) the rise in the price of coal after World War II to a level well above that of imported liquid petroleum fuels, and 2) discoveries of predominantly methane natural gas which was readily available at lower prices. These became widely used substitutes for coal gas in many applications. However, today, numerous coal gasification models are available and in operation around the world. Some of these models are used to produce feedstocks for liquid fuel and ammonia. The most common models are Welman-Calusha, Winkler, Koppers-Torek, and numerous models of Lurgi. For production of high BTU gas, the Lurgi model is the most efficient of all and, today, more than 50 units of this type are in operation around the world.

Description of Coal Gasification Process

The methods of producing gas from coal are numerous. Some common steps are included in most of these methods, depending on the properties of the feed coal.

Step 1: Pretreatment. The caking properties which are characteristic in most bituminous coals cause difficulties in gasification. These properties are eliminated by a mild oxidation which also results in a loss of heating value in the range of 10 to 15 percent of that of the original coal.

Step 2: Gasification. After the coal is put into the gasifier, these steps take place:

1. Drying and heating. Some water is held in the submicroscopic pores of the coal, which is called "bound-water." By raising the temperature to a value above the boiling point of water, this water, along with the "free-water" is removed.
2. Distillation. With heating temperatures below the softening temperature of the coal, hydrocarbons, water vapor, and other light gases are extracted from coal.
3. Chemical reaction. The most important step in manufacturing gas from coal is the conversion of carbon oxides into methane by reaction with hydrogen over a catalyst. The following steps occur:

a. $C(coal) + H_2O(Steam) \longrightarrow CO + H_2$

b. $CO + H_2O(Steam) \longrightarrow H_2 + CO_2$

c. $C + 2H_2 \longrightarrow CH_4$ Methanation

A very high temperature (805° C) as well as catalysts are required for achieving a reasonable production rate. The most effective catalysts are nickel and iron. The main difference between methods of manufacturing synthetic natural gas (SNG) is the type of catalyst used in the methanation process. Several by-products are generated in addition to pipeline quality gas. These include tar, tardic, naptha, crude phenol, sulfur and ammonia, which are all saleable products.

The process of coal gasification may be categorized in several ways. However, it is most commonly done by the product type.

The following discusses characteristics of the three types of synthetic gas that can be produced from coal.

1. Low BTU Gas

Low BTU gas contains low quantities of CH_4. It primarily consists of CO, H_2, and N_2. The heating value range of low gas is defined to be 80-250 BTU/standard cubic feet (SCF). Due to the low heat value and the cost of transportation,productions,and applications of this type of gas, it is only economical on the site where the production takes place. This fuel, free of sulfur compounds and particulates, is environmentally a very ideal fuel. However, it is not economically feasible to produce gas from coal just to meet environmental standards. This type of gas made from coal could be used

at commercial installations that require a clean fuel for process reasons or at utility plants using combined cycles for generating electricity. [2]

Underground gasification, still in the research stage, produces low BTU gas. This method of gas production, if proven to be feasible, would solve many problems with the production and utilization of coal. Studies have been conducted in Russia, England, and the United States at various times since the 1930's. The most recent U.S. work was done in field tests at Hanna, Wyoming, and low BTU gas (175 BTU/Ft^3) has been produced. [1]

2. Medium BTU Gas

Medium BTU gas is defined as a gas with heat value of range 300 to 600 BTU/Ft^3. The cost associated with producing this type of gas is more than that of the low BTU gas due to the construction of an oxygen-producing plant which is required for the process as well as a significant increase in the minimum economic size of operations. The major components of medium BTU gas are CO, H_2, and CO_2. This type of gas can be utilized for the generation of electricity, production of methane, and higher hydrocarbons.

3. High BTU Gas

High BTU gas (900-1,000 BTU/Ft^3) is a substitute for natural gas. The multitude of natural gas applications has created the need for this substitute natural gas (SNG). The conversion of home and industries from locally produced "town gas" to natural gas resulted

in this country in the construction of a system including over 260,000 miles of gas transmission pipelines serving 41 million commercial and industrial customers. Based on estimates, natural gas supplies one-fourth of the current energy needs and, in 1980, 20 trillion cubic feet of this fuel were burned.[1],[4] The output of plants which are located at the point of coal production is targeted for national energy distribution and could easily be transported by the available pipeline system.

The block diagram of production of SNG is shown in Figure 1. The process shown in this figure correlates with the general steps of coal gasification discussed previously in this chapter.

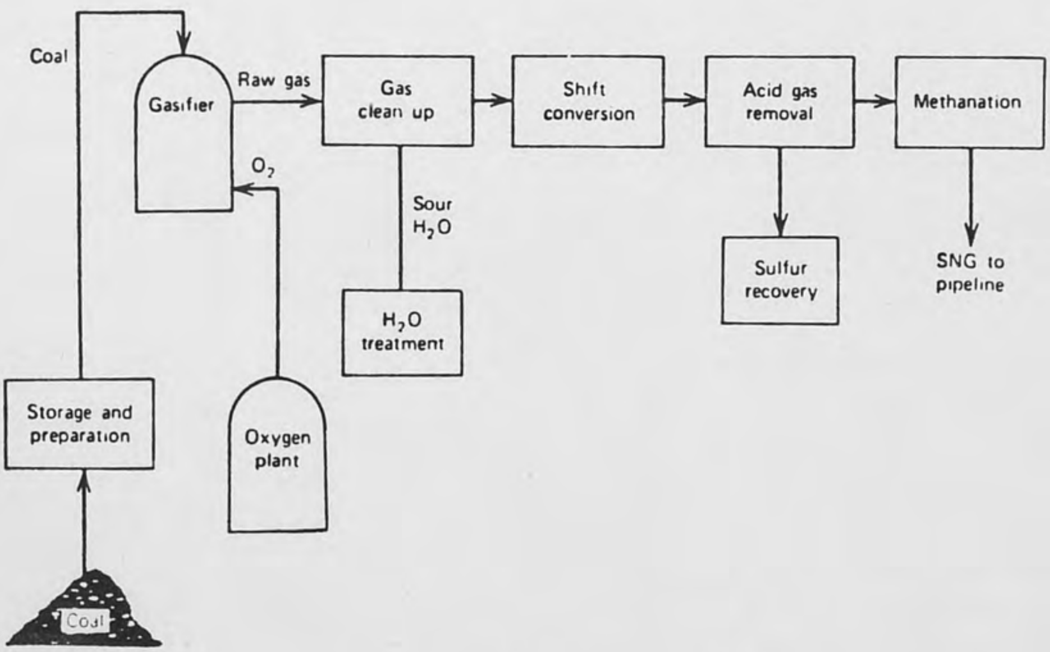

Fig. 1. Generic block diagram of the production of substitute natural gas.
Source: Larry L. Anderson and David A. Tillman, Synthetic Fuels from Coal (New York: John Wiley & Sons, 1979), p. 98.

Selection of Coal Gasification Model

The Lurgi Gasifier Model is selected for this study. The high BTU gas produced by this model is a proper fuel for generating of electricity. This model was developed by Lurgi Minerol-technick Bmgh, of West Germany; and since then, its application has expanded in the coal gasification industry. It is the only commercially available model which mainly produces a high BTU gas as the final product. It also provides other saleable by-products which substantially add to the revenue.

Figure 2 shows the schematic diagram of the Lurgi Gasifier. The block diagram for this type of gasifier is shown in Figure 3 where the characteristics of the process are illustrated in detail (note the similarities to the Figure 1 diagram).

The gasifier is a water-jacketed vessel with an inside diameter of about 12 feet and a height of 25 feet. The pressure in the gasifier is about 450 psi with a temperature of 1150 to 1400°F. Sized coal enters from above by lock hoppers. The coal feeds downward over a distributor and into the gasifier. As a result, a high BTU raw gas is produced, which includes CO_2, H_2, CH_4. Part of this raw gas moves to crude gas shift conversion where the H_2/CO ratio optimal for the methanation step is achieved.

The crude gases are cooled in waste heat boilers which generate steam at 60 psi's. These gases are then sent to the low temperature purification process.

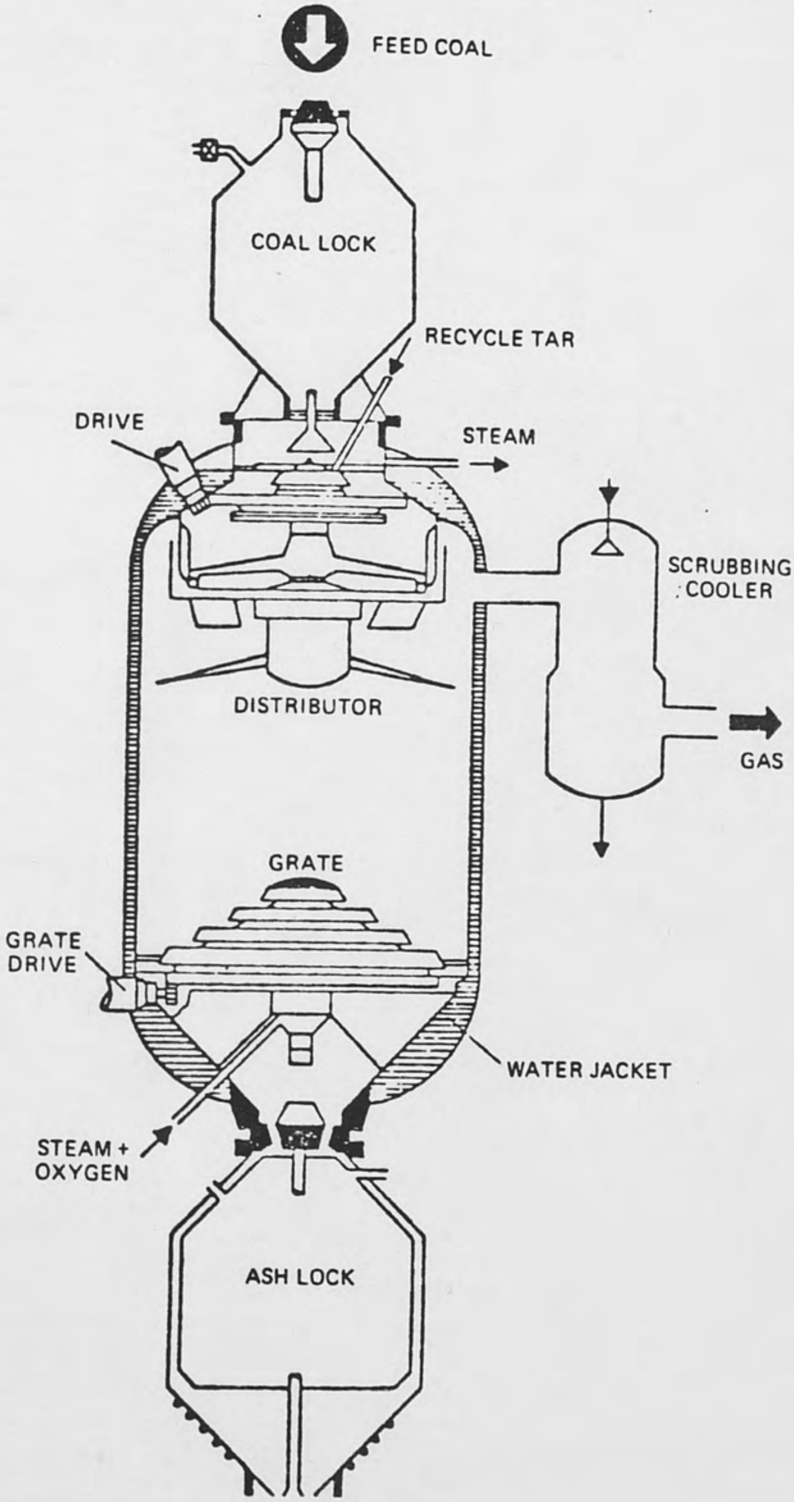

Fig. 2. Schematic diagram of Lurgi gasifier

Source: U.S. Department of Interior, Federal Energy Administration. Task Force Report - Synthetic Fuels from Coal: 1974, (Washington, D.C.: U.S. Government Printing Office, 1974), p. 49.

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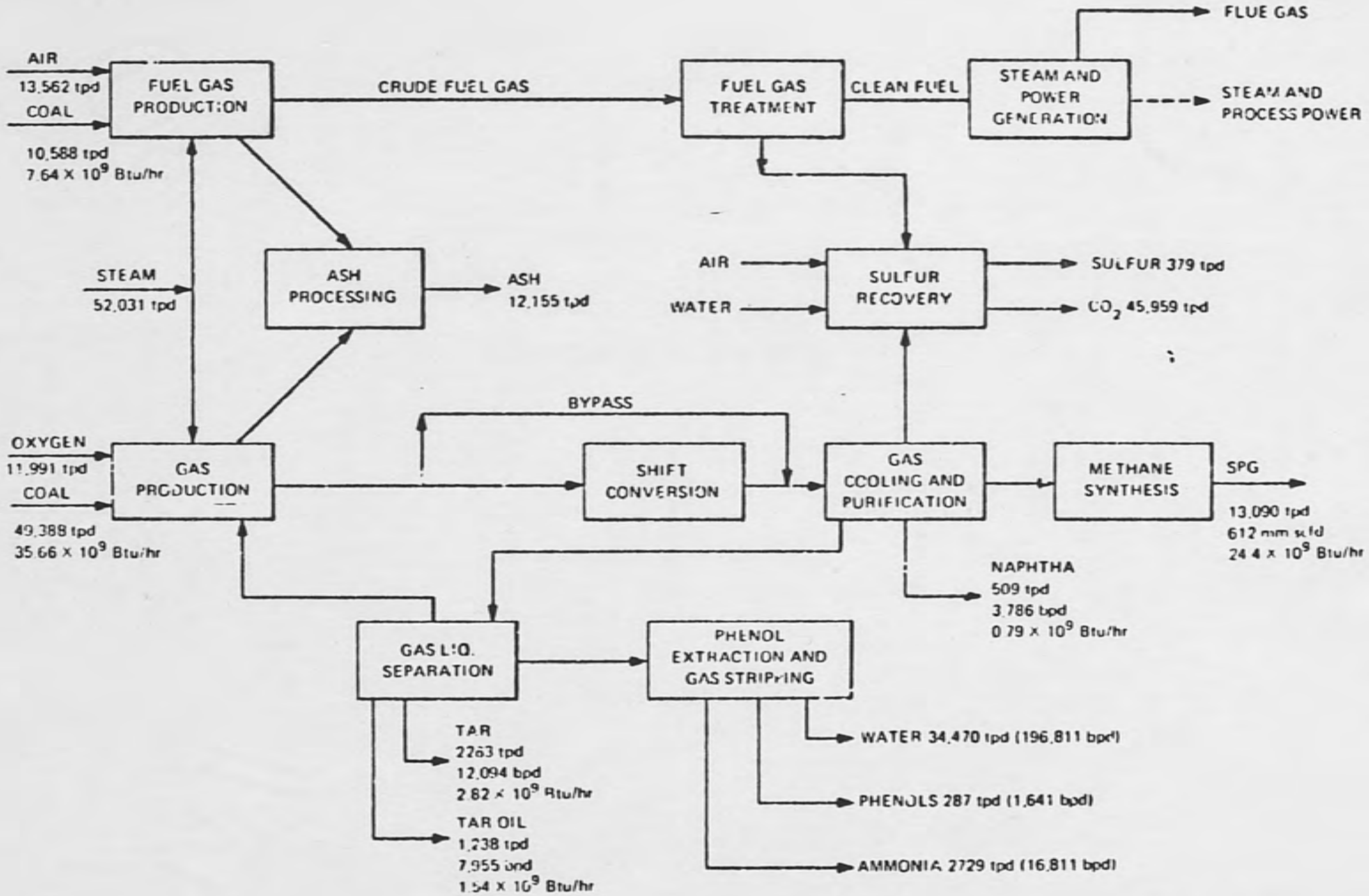


Fig. 3. Plant block diagram - Lurgi pipeline gas process

Source: D. S. Wiggins and J. J. Williams, Assessment of Very High Temperature Reactors in Process Applications (Oak Ridge: Oak Ridge National Laboratory, 1977), Sec. 4-7.

Low temperature methanol is used in the Lurgi Rectisol process where gas purification takes place. A major portion of H_2S and CO_2 is removed and the purified gas stream which mainly consists of CO and H_2 is then passed through the methanation step where the final product is formed.

In designing coal gasification processors, energy efficiency is considered as a very important factor. From 10 to 20 percent of the coal used in the conversion plant is burned directly to provide the steam, heat, and power required for the process. The non-recoverable heat is in this part of the process. The overall efficiency of the Lurgi process is approximately 68 to 70 percent. This is defined as the ratio between the energy in the useful products and the energy contained in the coal, which is actually converted to the product.

CHAPTER 3

COST MODELING AND RISK ANALYSIS

In this chapter, an analytical model for the evaluation of the economic cost of power generation is presented. Since cost decisions are not made with perfect foresight, the cost analysis is modified to account for risk inherent in the decision-making process.

Cost-Analysis Model

Figure 4 depicts the analytical model for economic evaluation of power plants. As shown in this figure, the model consists of two phases. In Phase I, the capital costs occurring during the construction period are calculated and in Phase II, capital cost, depreciation charges and generation costs occurring throughout the entire plant service life are computed. Equity finance cost, debt finance cost, insurance cost and ad valorem taxes constitute the costs incurred during the construction period. The costs related to the operational period are classified into three categories: capital costs, production costs and depreciation costs. Capital costs consist of debt and equity finance costs and ad valorem taxes. Production costs include the cost of fuel, operations and maintenance, less the revenues gained from selling the by-products. The salvage value is included in the depreciation

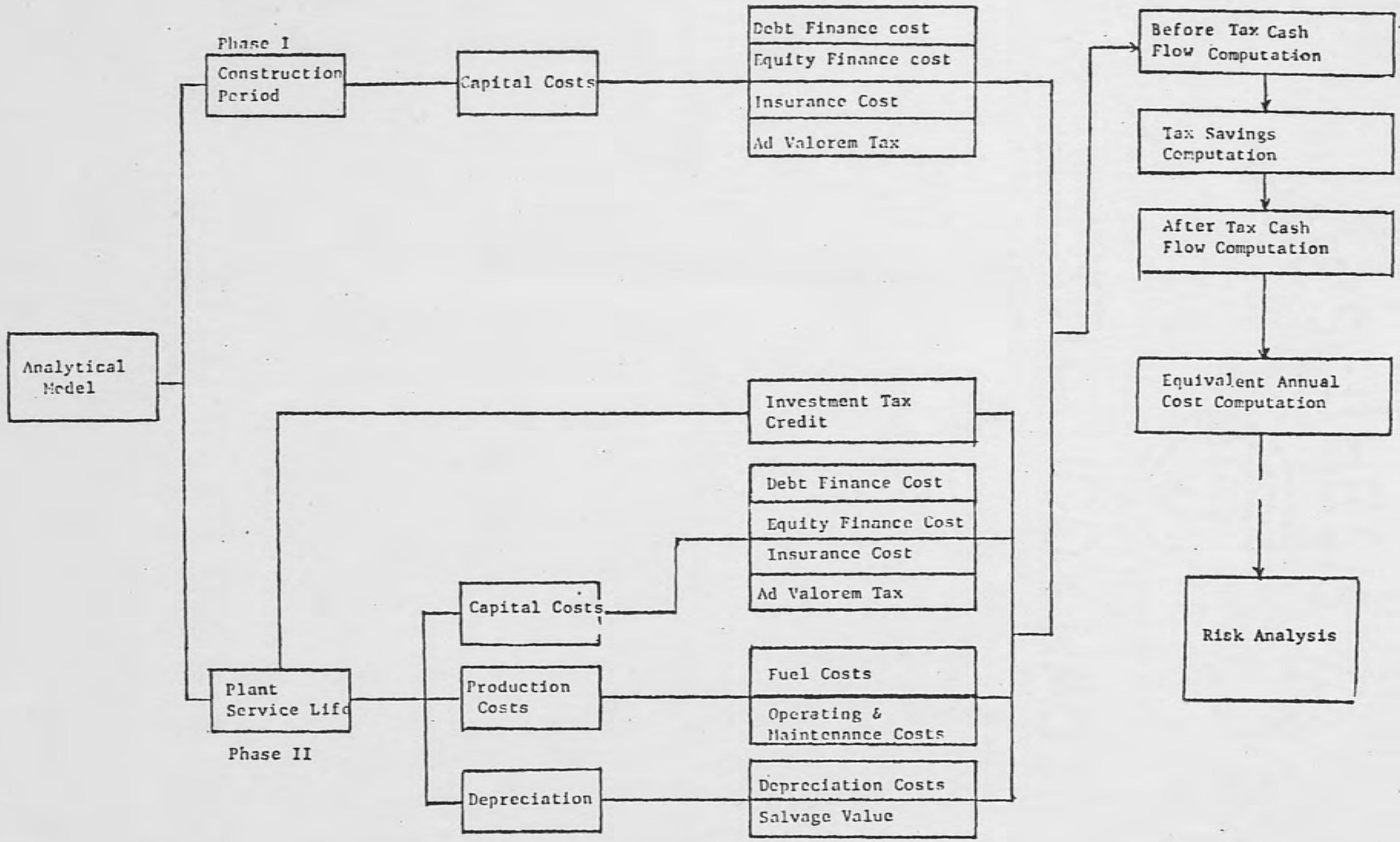


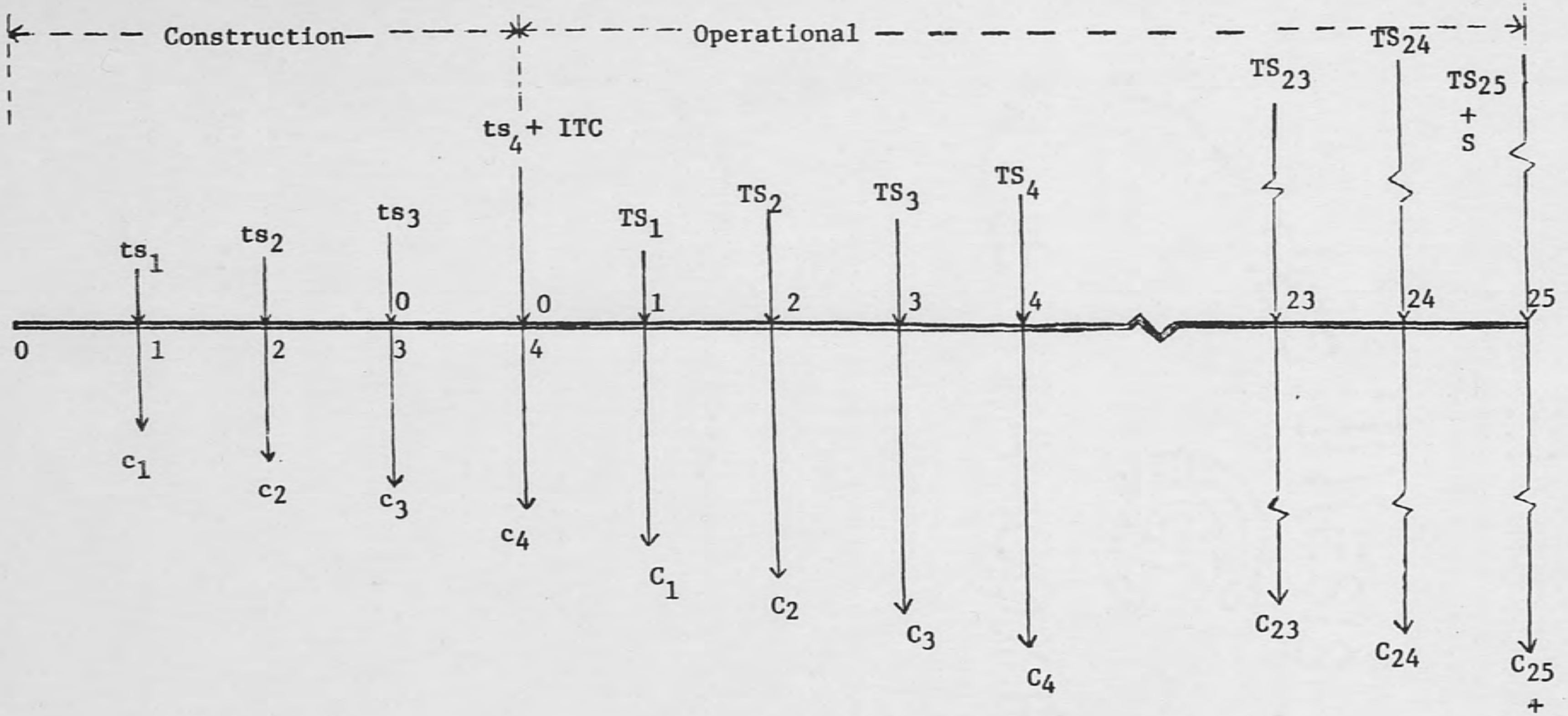
Fig. 4. Systematic model building process
Source: Iranmanesh, Mohammad M. Risk Analysis - An Economic Comparison of Oil and Coal Power Plants, Unpublished Research report. (University of Central Florida, 1980).

cost. Investment tax credit is received at the end of the construction period. Tax deductible expenses include debt finance cost, fuel cost, and operations and maintenance costs. These costs are combined and tax savings are calculated by applying the after-tax cash flow; and, finally, the equivalent annual cost of the total costs during the construction and operational periods is determined.

In Figure 5-a, a cash flow model is presented where the horizontal line represents the time as years of construction and operational period and all the costs are shown by vertical arrows originating from the end of the year at which they are incurred. All the tax savings are represented by arrows pointing towards their receiving times.

For this model it is assumed that all the costs are incurred at the end of the year. A mixed financing policy is assumed where common stocks are sold to provide new equity, if there is not sufficient retained earnings to finance the project, and the remaining funds are provided by the selling of bonds.

During the construction period, the needed funds are financed at the beginning of each year. Interest on bonds and return on equity are paid cumulatively. The insurance cost and Ad valorem tax are also paid for the cumulative value of the cost. The interest paid on the indebtedness and ad valorem taxes are deductible as business expenses; thus, some tax savings are received. Investment tax credit is calculated by applying the proper tax rate to the total construction cost and is received at the end of the construction period.



C_{1-4}=di+er+ins+adv

where:
- di: debt interest
- er: equity return
- ins: insurance cost
- adv: Ad valorem tax
- ts = tax savings

ITC: Investment Tax Credit

C_{1-25} = DI+ER+INS+ADV +F+OF+OV

where
- F: Fuel cost
- OF: O&M (fixed) cost
- OV: O&M (variable) cost
- S: Salvage value

Fig. 5-a. Cash flow model

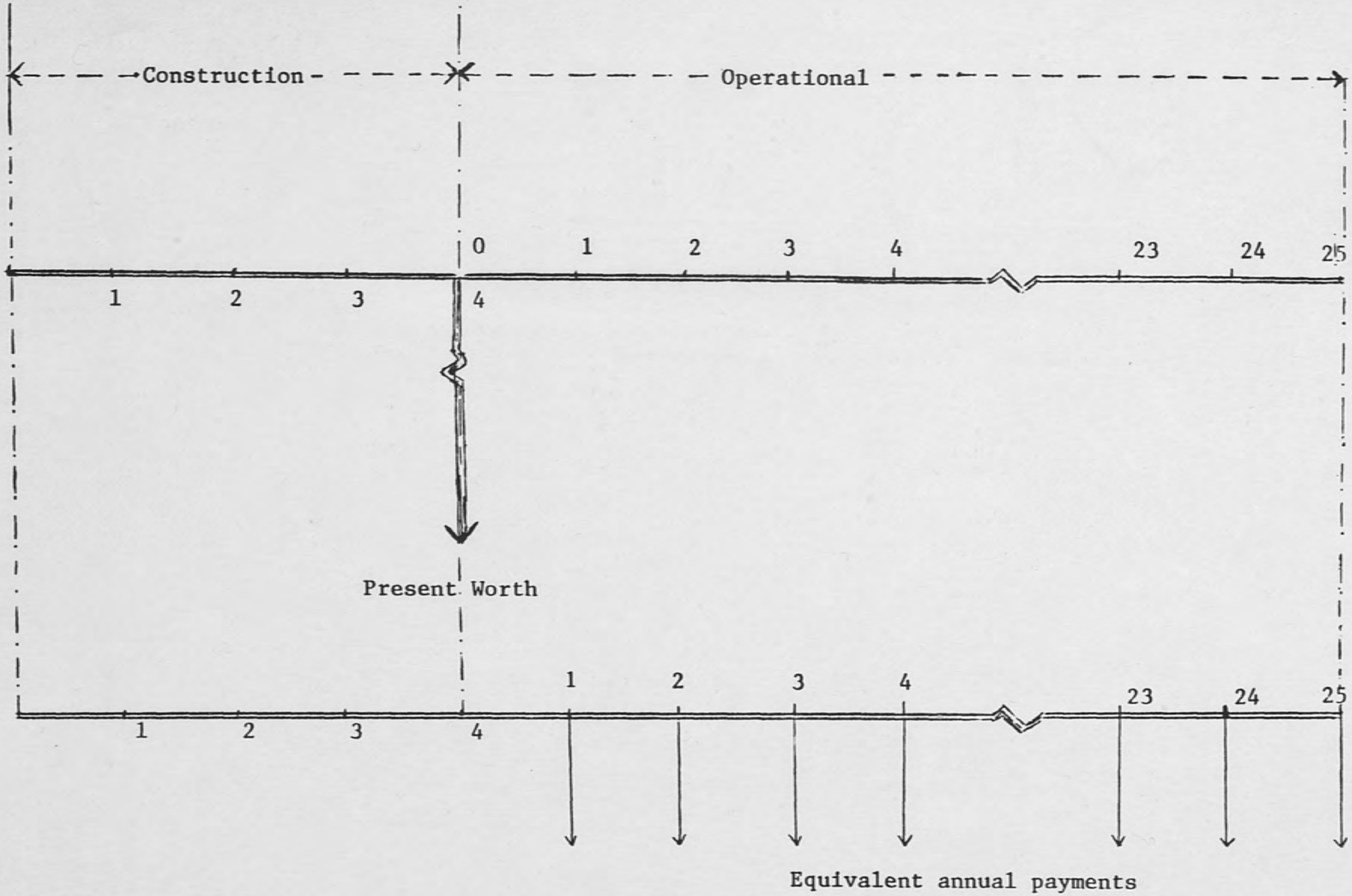


Fig. 5-b. Equivalent annual cost calculation

During the operational period, equal annual payments are made for the equity part of the funds. Each of these payments include principal repayments and return on equity. Annual interest is paid for issued bonds during the operational period, and the principal is paid at the end of the period. The fuel cost as well as variable O&M costs are functions of plant size, plant utilization, and the efficiency of the plant, whereas the fixed O&M cost is only a function of plant size. An escalation rate is assumed for each of these cost items to find their values during the years of operation. The insurance cost is constant throughout the plant life, whereas the ad valorem tax is paid for the book value of the plant at the end of each period. This book value is calculated by subtracting the cumulative value of depreciation from the total cost of the plant. (These two items are not included in the tax deductions.)

Figure 5-b shows the steps taken to calculate the equivalent annual cost of the project. The starting time for the operational period is considered the origin (Time 0) for cost analysis purposes. The net after-tax cash values of cost incurred during the construction years are inflated by a discount factor and accumulated at the origin. Similarly, the net after-tax cash flow during the operational period are deflated by a discount factor and accumulated at the origin. Adding these two cumulative values results in the value of "present worth" at the time the plant begins its commercial operation. The equivalent annual cost is calculated by applying the defined discount rate to the value of present worth calculated by the above process.

The effect of inflation can be incorporated in the analysis by combining a rate of inflation with the applied discount rate. A complete mathematical model for this study is shown in Appendix I. The algebraic relationships shown in this appendix closely follows the above simplified cash flow model.

Risk Analysis Model

"Risk analysis consists of estimating the probability distribution of each factor affecting the investment decision and, then, simulating the possible combinations of values for each factor to determine the range of possible outcomes and probability associated with each possible outcome." [5]

The first step for accomplishing risk analysis is the identification of parameters subject to uncertainty. Then, subjective probability distributions for the parameters are developed. Based on the analytical model described in this chapter, a computer program was developed in order to find the equivalent annual costs by incorporating the probabilistic information through Monte Carlo sampling techniques.

By referring to power generation literature and sensitivity analysis discussed in later chapters, the factors which significantly affect the results of this economic study are identified as:

- Construction cost
- Fuel cost
- Operating and maintenance cost (fixed and variable)

- Fuel escalation rate
- O&M escalation rate

Other parameters are predefined, or their optimum values are based on assumption.

Developing probability distributions

To accomplish risk analysis, subjective probability distributions are developed by applying data gathered from various sources. In many studies, normal distribution is commonly used to illustrate the estimation results, whereas the actual distributions would likely show some skewness. The skewness is observed particularly in the distributions of data related to investment projects such as synthetic fuel production.

The distribution developed for the factors listed above describe the likelihood of their occurrence. The probability distribution applied to these parameters is a beta distribution with properties of "lower bound," "mode," and "upper bound," which are estimated by "optimistic," "most likely," and "pessimistic," respectively. The standard deviation of beta distribution is (1/6) of the spread between the lower and upper bounds. Applying beta distribution is a very practical approach for incorporating uncertainties in the study. Gathering data as optimistic, most likely, and pessimistic is a very realistic approach for dealing with various inputs which cover a wide range of values.

Risk Analysis

In Figure 6, the process used for risk analysis is illustrated. This is primarily a simulation process which involves the calculation of equivalent annual costs corresponding to randomly selected values of the parameters involved. Monte Carlo methods are used to select values from probability distributions describing the likelihood of occurrence of the parameters. This process is repeated with different sets of selected data, and an equivalent annual cost is computed for each set. The number of repeats is large enough to result in a clear portrayal of the probability distribution for the equivalent annual cost.

Simulation Language

SLAM (Simulation Language for Alternative Modeling) is used as the simulation language in this study. In modeling the system of this study, the process orientation of SLAM is most important and also unique. The first step of programming is to design a pictorial representation of the model called "NETWORK." The entities in the system (in this case, different cash flows) flow through the NETWORK model for calculation of values of the desired parameters. This pictorial representation of system is transcribed into an equivalent statement model for input to the SLAM processor. Special characteristics of SLAM facilitate the development of the necessary computer codes to test and validate the risk analysis model. The condensed NETWORK Model and its explanation in terms of statement listing are shown in Appendix II.

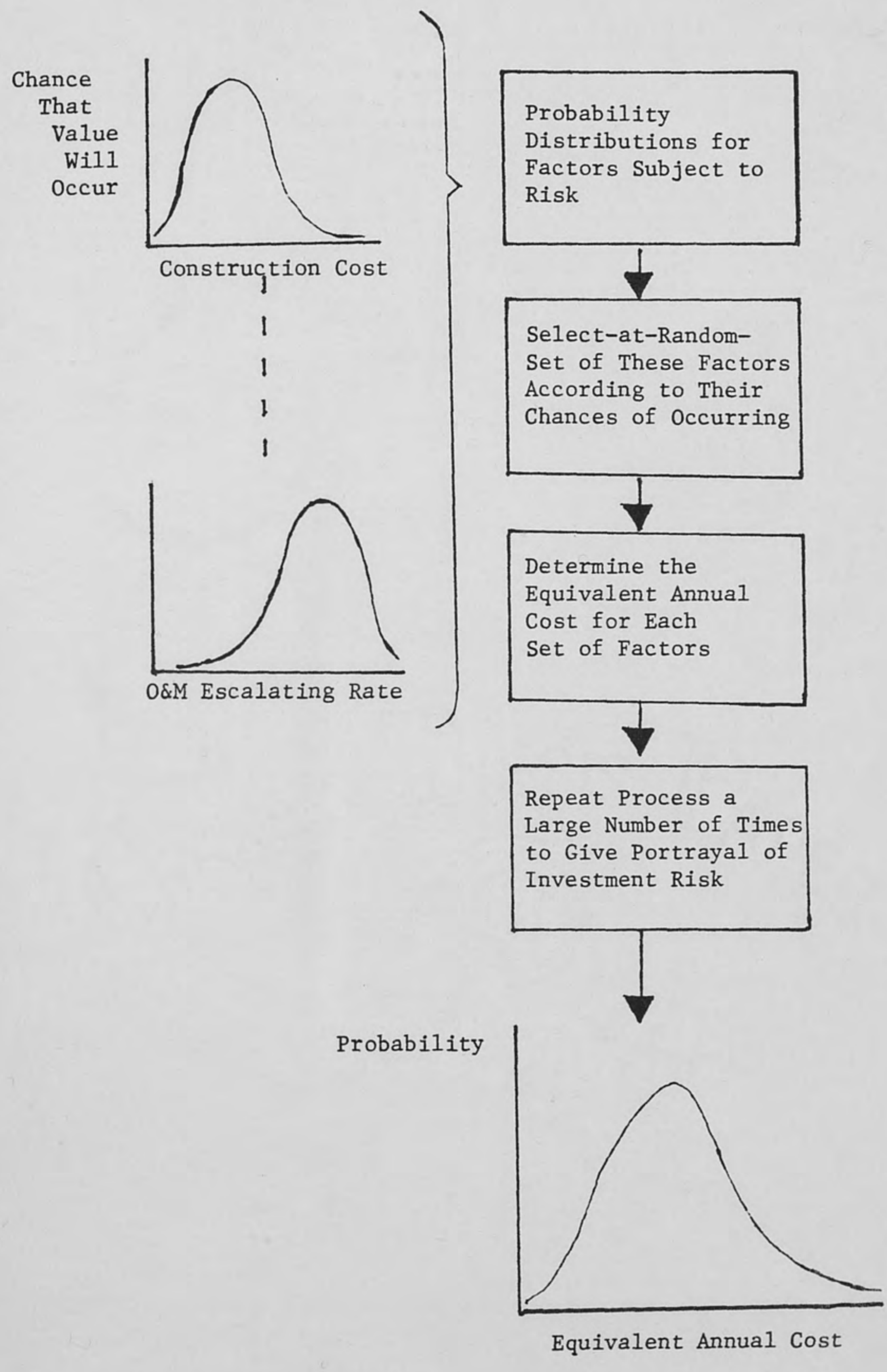


Fig. 6. Risk analysis model

CHAPTER 4

DESCRIPTION OF SELECTED PROCESS AND INPUT DATA

In the previous chapter, the cost analysis model was described and factors subject to risk were identified. In this chapter, input data for the cost analysis and the validity of their sources are discussed.

Scope of Evaluation

Conversion of coal to gas eliminates most of the air pollution problems associated with the direct combustion of coal. Distribution of gas through the existing pipeline system is far more economical than transportation of coal. To perform a complete environmental/economic evaluation, the capital and operating costs and savings due to the environmental advantages of synthetic fuels must be calculated. With the absence of a full-scale plant, these evaluations are rather difficult; thus, the estimations reveal a great deal of uncertainty.

The conversion of coal to gas also creates a set of environmental problems, the most serious being water pollution, which is more complex chemically than the problem with direct combustion. However, the process of high temperature coal gasification produces virtually no liquid streams that must be treated.

The location of synthetic fuel plants is a major factor which determines the amount and type of costs associated with the construction and operation of these plants. Western locations are normally preferred, since the coal from these locations has lower sulphur content resulting in less capital and operating costs associated with pollution control. In addition, western coal is currently cheaper. On the other hand, the western locations will require plant designs that minimize water use, and this will increase the capital cost. For this study, New Mexico was selected as the plant site where western coal will be processed. The Lurgi Methanation Model was selected with a plant capacity of 250 x $10^6 Ft^3$/day, requiring thirty pressure reactors of this type. Assuming a heat value of 1,000 BTU/Ft^3 and a heat rate of 1,000 BTU/KWH for the products, this plant would be approximately equivalent to a 1,000 MW plant in terms of capacity for the generation of electricity.

As discussed in the previous chapter, the important factors subject to risk for cost analysis of synthetic fuels are construction cost, fuel cost, O&M cost, and the escalation rates for fuel and O&M costs. These factors will be reviewed in the subsequent section. All data corresponding to past years were inflated by 7 percent, yearly inflation factor, to result in estimations for 1981.

Plant Construction Cost

As mentioned before, no full-scale synthetic fuel plants are currently in existence. To estimate the cost of building such plants, the related cost data for smaller plants was studied. The

unpredictability of cost of a new technology and lack of knowledge about reductions in unit cost for large size plants results in a high degree of uncertainty associated with the capital cost.

Construction cost is definitely a function of plant size. However, the nature of this function is not exactly known. For all existing conventional power plants, it has been observed that reductions in unit construction cost are realized as larger plants are built. Figure 7 shows the sensitivity of unit capital cost ($/Megawatt) to the plant size. In this figure, 1,000 MW plant is considered as the point of reference since this plant size is most commonly assumed for power generation cost analysis. For lower

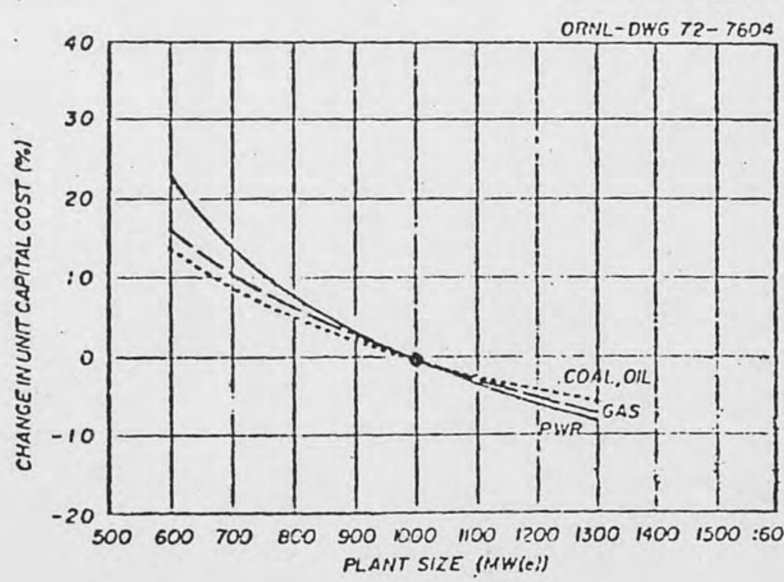


Fig. 7. The sensitivity of unit capital cost to plant size

SOURCE: Power Engineering (January 1973)

plant capacities, a higher unit capital cost would be incurred. For oil and coal power plants, the unit capital cost for a 1,000 MW plant is about 15 percent less than the unit capital cost for a 600 MW power

plant. Estimates with similar accuracy for synthetic fuel plants could only be made after plants of different sizes are built. Projections made by Gas Research Institute indicate that the unit cost of gas from plants producing 50 million cubic feet per day will be about 30 percent greater than the cost of gas from a 125 million cubic feet per day plant. By doubling the size of the plant to 250 million cubic feet per day, the unit cost may further be reduced by 20 to 25 percent.[6] In the computer program developed for this study, the economies of scale are accounted for by inflating or deflating the unit capital cost accordingly.

Projection of Fuel Cost

The cost of fuel is a very dominant factor in the choice of future fuel alternatives. This portion of the cost is subject to general uncertainty which must be reflected in the probability distributions developed for the respective escalation rates.

Coal conversion efficiency is the ratio between the energy in the useful products and the energy contained in the coal which is actually converted to the product. This efficiency is highly related to the applied state of technology, and the fuel cost is inversely proportional to its value. Total annual fuel cost is a function of plant size, efficiency of the electricity generation process (heat rate), plant utilization, and the efficiency of the conversion process. As discussed in Chapter 2, caking characteristics of coal must be eliminated before the gasification process.

This requires the coal fed to the processor to be refined and sized. In this study, the costs incurred by the process are also accounted for.

Operating and Maintenance Cost

Among all the variables subject to uncertainty, the O&M cost bears the highest risk. The future technological advancements, especially in the area of pollution control, will have a strong role in the determination of these costs.

O&M costs are categorized into two parts: variable and fixed. The fixed portion of O&M cost is only a function of plant size, and it reflects costs associated with the maintenance and upkeep of plant equipment. Also included is the cost of cleaning the pollution control scrubbers. The variable cost is a function of plant size, heat rate, and plant utilization. The costs of all the consumable materials such as limestone and water constitute part of the variable O&M cost. As discussed in Chapter 2, several saleable by-products are generated from the coal gasification process. The revenues gained from these products are assumed to be normally distributed with a mean of $\$15 \times 10^6$ and standard deviation of $\$5 \times 10^6$. The value of these by-products is deducted from O&M costs; thus, the tax savings are also affected.

Projection of Escalation Rates

As explained in Chapter 3, subjective probability distributions for fuel and O&M costs were developed. These distributions which

apply to the first year of operation are inflated year by year to achieve their respective values throughout the plant life. Lack of certainty in assuming an escalation rate during the plant life requires developing a probability distribution which reflects various estimations. The stability of energy markets, discoveries of new sources of energy, as well as future technological advancements in operating the synthetic fuel plants, are major factors affecting these escalation rates.

Learning Curve

"The term 'learning curve' refers to the phenomenon whereby a decreasing amount of input is required to accomplish a task each time the task is repeated." [7] It is expected that a learning curve can be applied to the operating and maintenance costs since each year portions of these costs are expected to be reduced from the previous year. This partially offsets the O&M escalation rates. The effect of learning is most significant in the estimation of the plant construction cost. However, this effect is not applicable in this study since construction of only one plant is being studied. The construction lead time and yearly construction schedule are listed in Table 1. As explained in Chapter 3, three estimations are applied for developing the beta distributions related to parameters subject to uncertainty. These estimations are shown in Table 2. Other data listed in Table 3 are predefined, and their values do not change in the program.

TABLE 1

CONSTRUCTION PLANNING FOR SNG PLANT

Construction Period	Portion Constructed
First Year	10%
Second Year	12%
Third Year	52%
Fourth Year	26%

SOURCE: U.S. Department of Interior, Federal Energy Administration, Task Force Report - Synthetic Fuels From Coal: 1974, (Washington, D.C.: U.S. Government Printing Office, 1974), p.49.

TABLE 2

ESTIMATED PROBABILISTIC VARIABLES FOR SNG PROJECT

Probabilistic Variables	Optimistic Value	Most Likely Value	Pessimistic Value
Construction Cost ($/KW)	550	650	900
Fuel Cost ($/$10^6$BTU) 1981	1.3	1.6	1.75
Fixed O&M Cost ($/KW) 1981	25	37	45
Variable O&M Cost ($/KW-Hr) 1981	0.0030	0.0056	0.0065
Fuel Escalation Rate (%/Year)	0.05	0.07	0.12
O&M Escalation Rate (%/Year)	0.03	0.07	0.09

SOURCES: R. Chandra, B. McElmurry, and S. Smelser, Economics of Fuel Gas From Coal - An Update, (Palo Alto, CA: Electric Power Research Institute, 1978), p. 5. W.L. Lom and A.F. Williams, Substitute Fuels From Coal, (London: Applied Science Publisher, Ltd., 1976).

TABLE 3

INPUT DATA ESTIMATED WITH CERTAINTY

INPUT	Data Used
1. Plant Size (MW)	1000
2. Plant Life (Year)	25
3. Depreciation (Year)	20
4. Construction Lead Time	4
5. Plant Load Factor	0.70
6. Heat Rate (BTU/KWH)	1000
7. Investment Tax Credit Rate	0.10
8. Ad Valorem Tax Rate	0.005
9. Insurance Rate	0.001
10. Debt Ratio	0.50
11. Equity Ratio	0.50
12. Debt Payment Rate (Bond Interest Rate)	0.09
13. Equity Return Rate	0.15
14. Discount Rate	12%
15. Effective Combined State and Federal Taxes	.50
16. Plant Salvage Value (% of Initial Investment)	-0.005

CHAPTER 5

ANALYSIS OF THE PRODUCTION OF HIGH BTU GAS

In this chapter, the simulation results showing the expected cost of producing high BTU gas are discussed and these values are compared to the current market price of natural gas. The distributions related to each of the variables subject to uncertainty are shown, and the values of cost elements and their ratios to the total cost are determined.

Simulation Results

The results of each simulation run include the probability distributions for the six parameters discussed in the previous chapter and the total equivalent annual cost. The standard deviations corresponding to these distributions indicate the degree of risk associated with each.

Simulation Experimental Design

In any statistical analysis, having a sufficiently large number of observations is required to achieve unbiased results. In this study, as the number of Monte Carlo trials is increased, the sampling variation is reduced. On the other hand, the cost associated with the computer simulation process is proportional to the number of observations desired. Thus, the number of trials should be determined such that the sampling error is reduced to an acceptable level and that it is

economically justified. In Table 4, the results of various simulations with different numbers of observations are listed.

TABLE 4
EQUIVALENT ANNUAL COST
SIMULATION RESULTS

No. of Observations	Mean ($)	Standard Deviation ($)
50	320×10^6	35.70×10^6
100	343×10^6	43.20×10^6
150	351×10^6	46.30×10^6
200	343.8×10^6	47.28×10^6
300	354×10^6	47.13×10^6

As it is expected, the value of outcome dampens or stabilizes as the number of trials is increased. The number of trials at which the results become stable appears to be 200.

Economic Feasibility of SNG

With $\$354 \times 10^6$ as equivalent annual cost and a daily production of $250 \times 10^6 Ft^3$, the cost of producing substitute natural gas is calculated to be $\$3.88/1,000 Ft^3$. (Given the heat value of 1,000 BTU/Ft^3, this also can be stated as $\$3.88/10^6 BTU$.) This value compared to \$2 to $\$3/1,000\ Ft^3$, the current price of natural gas, makes the production of SNG appear economically unattractive.

Explanation of Distributions

Figure 8-a through Figure 8-h depict the probability distributions of construction cost, fuel cost, O&M cost, escalation rates for fuel and O&M costs, and the equivalent annual cost. Also shown is the probability distribution for the revenues gained from by-products. In these illustrations, the stars represent a histogram with the probability values listed to their left. The "c's" represent the cumulative values of probabilities. As expected, the shape of these distributions correlate very closely with the parameters originally applied to develop the beta distributions.

Also shown in these figures are values of coefficients of variation for all parameters. These values are the ratio of standard deviation to the respective mean values of each parameter and can be considered more realistic risk measures.

The distribution shown in Figure 8-a was generated by the input data estimates of 550, 650, 900 $/KW as optimistic, most likely, and pessimistic values, respectively. As expected, this distribution is skewed to the left with about 59 percent of the total number of observations made located to the left of the mean value. Conversely, the distributions of fuel and fixed and variable O&M costs are all skewed to the right due to the nature of input data.

For the O&M escalation, 3 percent, 7 percent, and 9 percent were assumed as optimistic, most likely, and pessimistic values, respectively. These values result in a distribution which is skewed to the left. A symetric distribution is observed for the by-product revenues since normal distribution was assumed to represent the input values.

HISTOGRAM NUMBER 1

CONST.COST

OBSV FREQ	RELA FREQ	CUML FREQ	UPPER CELL LIMIT
0	0.0	0.0	0.5000E+09
0	0.0	0.0	0.5150E+09
0	0.0	0.0	0.5300E+09
0	0.0	0.0	0.5450E+09
10	0.050	0.050	0.5600E+09
17	0.085	0.135	0.5750E+09
18	0.090	0.225	0.5900E+09
24	0.120	0.345	0.6050E+09
18	0.090	0.435	0.6200E+09
13	0.065	0.500	0.6350E+09
22	0.110	0.610	0.6500E+09
14	0.070	0.680	0.6650E+09
14	0.070	0.750	0.6800E+09
5	0.025	0.775	0.6950E+09
7	0.035	0.810	0.7100E+09
9	0.045	0.855	0.7250E+09
6	0.030	0.885	0.7400E+09
3	0.015	0.900	0.7550E+09
3	0.015	0.915	0.7700E+09
3	0.015	0.930	0.7850E+09
4	0.020	0.950	0.8000E+09
6	0.030	0.980	0.8150E+09
2	0.010	0.990	0.8300E+09
1	0.005	0.995	0.8450E+09
1	0.005	1.000	0.8600E+09
0	0.0	1.000	0.8750E+09
0	0.0	1.000	0.8900E+09
0	0.0	1.000	0.9050E+09
0	0.0	1.000	0.9200E+09
0	0.0	1.000	0.9350E+09
0	0.0	1.000	0.9500E+09
0	0.0	1.000	INF

200			

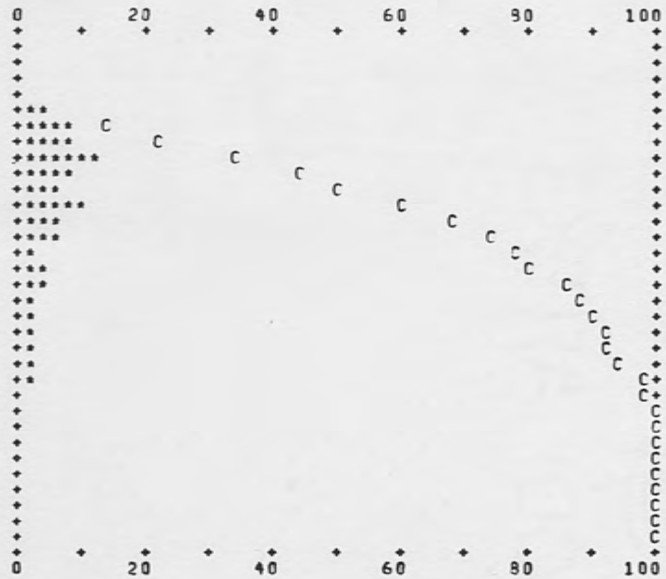


Fig. 8-a. Distribution of construction cost

Mean Value	Standard Deviation	Coefficient of Variation	Minimum Value	Maximum Value
$646 x 10^6$	$70.47 x 10^6$	0.1090	$550 x 10^6$	$857 x 10^6$

Number of observations = 200

HISTOGRAM NUMBER 1

FUEL COST

OBSV FREQ	RELA FREQ	CUML FREQ	UPPER CELL LIMIT
0	0.0	0.0	0.1500E+09
0	0.0	0.0	0.1520E+09
1	0.005	0.005	0.1540E+09
1	0.005	0.010	0.1560E+09
0	0.0	0.010	0.1580E+09
1	0.005	0.015	0.1600E+09
4	0.020	0.035	0.1620E+09
6	0.030	0.065	0.1640E+09
9	0.045	0.110	0.1660E+09
4	0.020	0.130	0.1680E+09
5	0.025	0.155	0.1700E+09
4	0.020	0.175	0.1720E+09
11	0.055	0.230	0.1740E+09
11	0.055	0.285	0.1760E+09
13	0.065	0.350	0.1780E+09
9	0.045	0.395	0.1800E+09
10	0.050	0.445	0.1820E+09
15	0.075	0.520	0.1840E+09
16	0.080	0.600	0.1860E+09
15	0.075	0.675	0.1880E+09
11	0.055	0.730	0.1900E+09
22	0.110	0.840	0.1920E+09
16	0.080	0.920	0.1940E+09
15	0.075	0.995	0.1960E+09
1	0.005	1.000	0.1980E+09
0	0.0	1.000	0.2000E+09
0	0.0	1.000	0.2020E+09
0	0.0	1.000	0.2040E+09
0	0.0	1.000	0.2060E+09
0	0.0	1.000	0.2080E+09
0	0.0	1.000	0.2100E+09
0	0.0	1.000	0.2120E+09
0	0.0	1.000	0.2140E+09
0	0.0	1.000	0.2160E+09
0	0.0	1.000	0.2180E+09
0	0.0	1.000	0.2200E+09
0	0.0	1.000	INF
200			

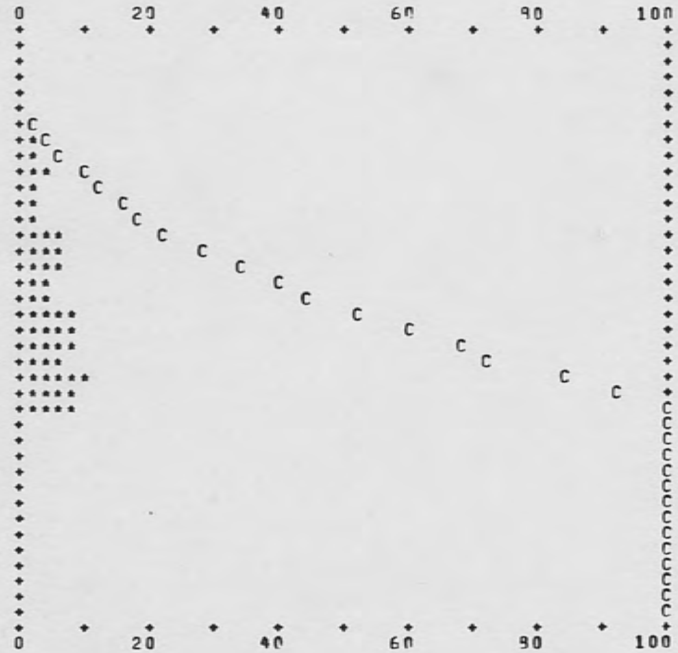


Fig. 8-b. Distribution of fuel cost

Mean Value	Standard Deviation	Coefficient of Variation	Minimum Value	Maximum Value
$181.6 x 10^6$	$10.11 x 10^6$	0.0557	$152.1 x 10^6$	$196.1 x 10^6$

HISTOGRAM NUMBER 3

FIXED O&M COST

OBSV FREQ	RELA FREQ	CUML FREQ	UPPER CELL LIMIT
0	0.0	0.0	0.2000E+08
0	0.0	0.0	0.2100E+08
0	0.0	0.0	0.2200E+08
0	0.0	0.0	0.2300E+08
0	0.0	0.0	0.2400E+08
0	0.0	0.0	0.2500E+08
1	0.005	0.005	0.2600E+08
0	0.0	0.005	0.2700E+08
4	0.020	0.025	0.2800E+08
3	0.015	0.040	0.2900E+08
6	0.030	0.070	0.3000E+08
6	0.030	0.100	0.3100E+08
10	0.050	0.150	0.3200E+08
16	0.080	0.230	0.3300E+08
13	0.065	0.295	0.3400E+08
10	0.050	0.345	0.3500E+08
10	0.050	0.395	0.3600E+08
14	0.070	0.465	0.3700E+08
11	0.055	0.520	0.3800E+08
19	0.095	0.615	0.3900E+08
14	0.070	0.685	0.4000E+08
18	0.090	0.775	0.4100E+08
19	0.095	0.870	0.4200E+08
10	0.050	0.920	0.4300E+08
9	0.045	0.965	0.4400E+08
7	0.035	1.000	0.4500E+08
0	0.0	1.000	0.4600E+08
0	0.0	1.000	0.4700E+08
0	0.0	1.000	0.4800E+08
0	0.0	1.000	0.4900E+08
0	0.0	1.000	0.5000E+08
0	0.0	1.000	INF
200			

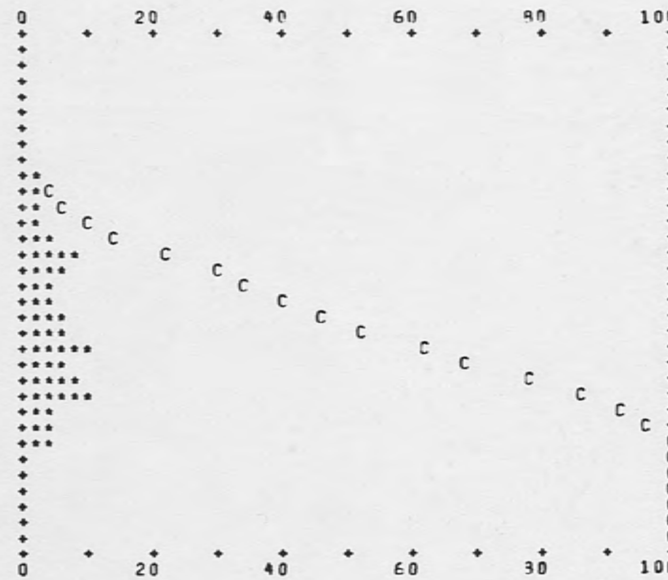


Fig. 8-c. Distribution of fixed O&M costs

Mean Value	Standard Devision	Coefficient of Variation	Minimum Value	Maximum Value
$\$37 \times 10^6$	$\$4.476 \times 10^6$	0.1210	$\$25.05 \times 10^6$	$\$44.97 \times 10^6$

HISTOGRAM NUMBER 2

VARIB.O&M COST

OBSV FREQ	RELA FREQ	CUML FREQ	UPPER CELL LIMIT
0	0.0	0.0	0.2000E+08
0	0.0	0.0	0.2100E+08
0	0.0	0.0	0.2200E+08
0	0.0	0.0	0.2300E+08
0	0.0	0.0	0.2400E+08
0	0.0	0.0	0.2500E+08
1	0.005	0.005	0.2600E+08
0	0.0	0.005	0.2700E+08
0	0.0	0.005	0.2800E+08
2	0.010	0.015	0.2900E+08
1	0.005	0.020	0.3000E+08
4	0.020	0.040	0.3100E+08
0	0.0	0.040	0.3200E+08
2	0.010	0.050	0.3300E+08
0	0.0	0.050	0.3400E+08
4	0.020	0.070	0.3500E+08
4	0.020	0.090	0.3600E+08
6	0.030	0.120	0.3700E+08
2	0.010	0.130	0.3800E+08
13	0.065	0.195	0.3900E+08
4	0.020	0.215	0.4000E+08
9	0.045	0.260	0.4100E+08
12	0.060	0.320	0.4200E+08
12	0.060	0.380	0.4300E+08
15	0.075	0.455	0.4400E+08
12	0.060	0.515	0.4500E+08
6	0.030	0.545	0.4600E+08
13	0.065	0.610	0.4700E+08
16	0.080	0.690	0.4800E+08
17	0.085	0.775	0.4900E+08
20	0.100	0.875	0.5000E+08
21	0.105	0.980	0.5100E+08
4	0.020	1.000	0.5200E+08
0	0.0	1.000	0.5300E+08
0	0.0	1.000	0.5400E+08
0	0.0	1.000	0.5500E+08
0	0.0	1.000	INF
200			

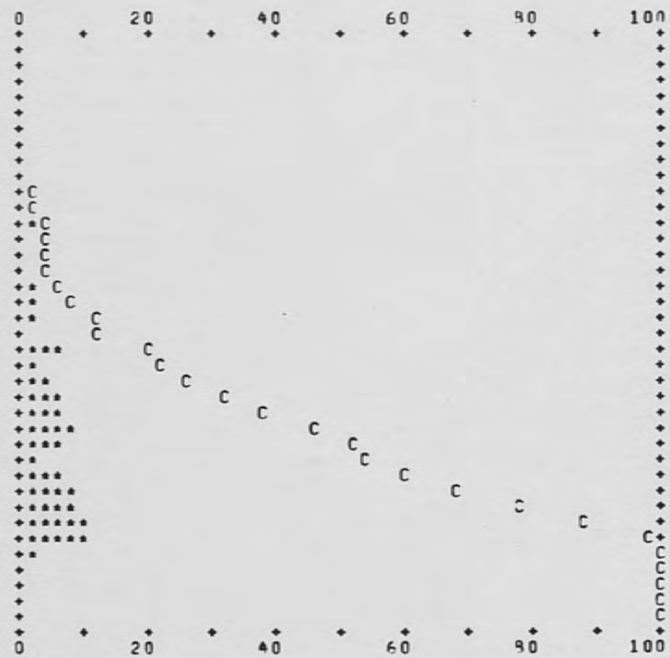


Fig. 8-d · Distribution of variable O&M cost

Mean Value	Standard Deviation	Coefficient of Variation	Minimum Value	Maximum Value
$44.09 x 10^6$	$5.55 x 10^6$	0.1258	$25.77 x 10^6$	$51.13 x 10^6$

HISTOGRAM NUMBER 6

FUEL ESC.RATE

OBSV FREQ	RELA FREQ	CUML FREQ	UPPER CELL LIMIT
0	0.0	0.0	0.0
0	0.0	0.0	0.4000E-02
0	0.0	0.0	0.8000E-02
0	0.0	0.0	0.1200E-01
0	0.0	0.0	0.1600E-01
0	0.0	0.0	0.2000E-01
0	0.0	0.0	0.2400E-01
0	0.0	0.0	0.2800E-01
0	0.0	0.0	0.3200E-01
0	0.0	0.0	0.3600E-01
0	0.0	0.0	0.4000E-01
0	0.0	0.0	0.4400E-01
0	0.0	0.0	0.4800E-01
17	0.085	0.085	0.5200E-01
21	0.105	0.190	0.5600E-01
15	0.075	0.265	0.6000E-01
25	0.125	0.390	0.6400E-01
15	0.075	0.465	0.6800E-01
22	0.110	0.575	0.7200E-01
15	0.075	0.650	0.7600E-01
18	0.090	0.740	0.8000E-01
12	0.060	0.800	0.8400E-01
15	0.075	0.875	0.8800E-01
12	0.060	0.935	0.9200E-01
3	0.015	0.950	0.9600E-01
3	0.015	0.965	0.1000E+00
1	0.005	0.970	0.1040E+00
3	0.015	0.985	0.1080E+00
3	0.015	1.000	0.1120E+00
0	0.0	1.000	0.1160E+00
0	0.0	1.000	0.1200E+00
0	0.0	1.000	0.1240E+00
0	0.0	1.000	0.1280E+00
0	0.0	1.000	0.1320E+00
0	0.0	1.000	0.1360E+00
0	0.0	1.000	0.1400E+00
0	0.0	1.000	INF

200			

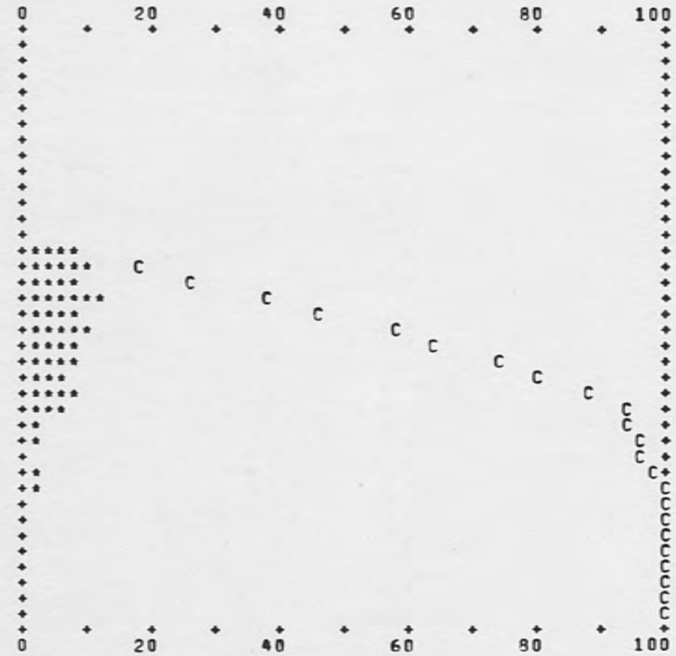


Fig. 8-e. Distribution of fuel escalation Rate

Mean Value	Standard Deviation	Coefficient of Variation	Minimum Value	Maximum Value
0.07064	0.0143	0.2027	0.0530	0.1110

HISTOGRAM NUMBER 5

O&M ESC.RATE

OBSV FREQ	RELA FREQ	CUML FREQ	UPPER CELL LIMIT
0	0.0	0.0	0.0
0	0.0	0.0	0.4000E-02
0	0.0	0.0	0.8000E-02
0	0.0	0.0	0.1200E-01
0	0.0	0.0	0.1600E-01
0	0.0	0.0	0.2000E-01
0	0.0	0.0	0.2400E-01
0	0.0	0.0	0.2800E-01
0	0.0	0.0	0.3200E-01
1	0.005	0.005	0.3600E-01
2	0.010	0.015	0.4000E-01
5	0.025	0.040	0.4400E-01
7	0.035	0.075	0.4800E-01
5	0.025	0.100	0.5200E-01
12	0.060	0.160	0.5600E-01
14	0.070	0.230	0.6000E-01
12	0.060	0.290	0.6400E-01
17	0.085	0.375	0.6800E-01
27	0.135	0.510	0.7200E-01
23	0.115	0.625	0.7600E-01
27	0.135	0.760	0.8000E-01
25	0.125	0.885	0.8400E-01
17	0.085	0.970	0.9800E-01
6	0.030	1.000	0.9200E-01
0	0.0	1.000	0.9600E-01
0	0.0	1.000	0.1000E+00
0	0.0	1.000	INF

200			

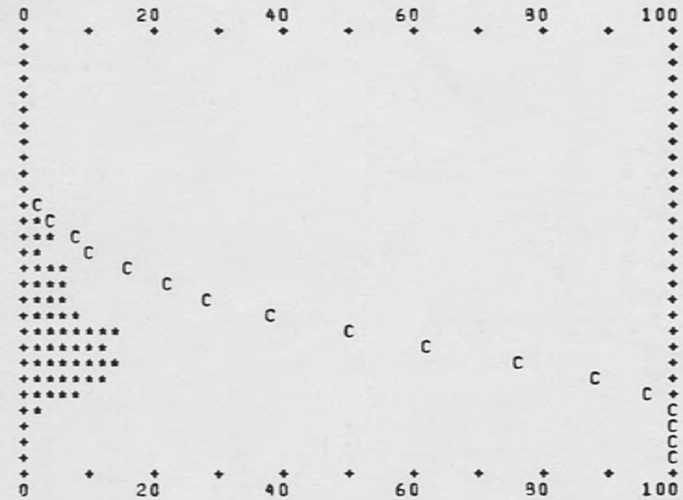


Fig 8-f. Distribution of O&M escalation rate

Mean Value	Standard Deviation	Coefficient of Variation	Minimum Value	Maximum Value
0.0699	0.0126	0.1801	0.0343	0.08408

HISTOGRAM NUMBER 4

VALUE OF BY PROD

OBSV FREQ	RELA FREQ	CUML FREQ	UPPER CELL LIMIT
1	0.005	0.005	0.1000E+07
0	0.0	0.005	0.2000E+07
1	0.005	0.010	0.3000E+07
2	0.010	0.020	0.4000E+07
1	0.005	0.025	0.5000E+07
3	0.015	0.040	0.6000E+07
7	0.035	0.075	0.7000E+07
6	0.030	0.105	0.8000E+07
3	0.015	0.120	0.9000E+07
10	0.050	0.170	0.1000E+08
18	0.090	0.260	0.1100E+08
17	0.085	0.345	0.1200E+08
14	0.070	0.415	0.1300E+08
15	0.075	0.490	0.1400E+08
13	0.065	0.555	0.1500E+08
18	0.090	0.645	0.1600E+08
19	0.095	0.740	0.1700E+08
17	0.085	0.825	0.1800E+08
10	0.050	0.875	0.1900E+08
7	0.035	0.910	0.2000E+08
4	0.020	0.930	0.2100E+08
5	0.025	0.955	0.2200E+08
2	0.010	0.965	0.2300E+08
4	0.020	0.985	0.2400E+08
1	0.005	0.990	0.2500E+08
2	0.010	1.000	0.2600E+08
0	0.0	1.000	0.2700E+08
0	0.0	1.000	0.2800E+08
0	0.0	1.000	0.2900E+08
0	0.0	1.000	0.3000E+08
0	0.0	1.000	0.3100E+08
0	0.0	1.000	INF
200			

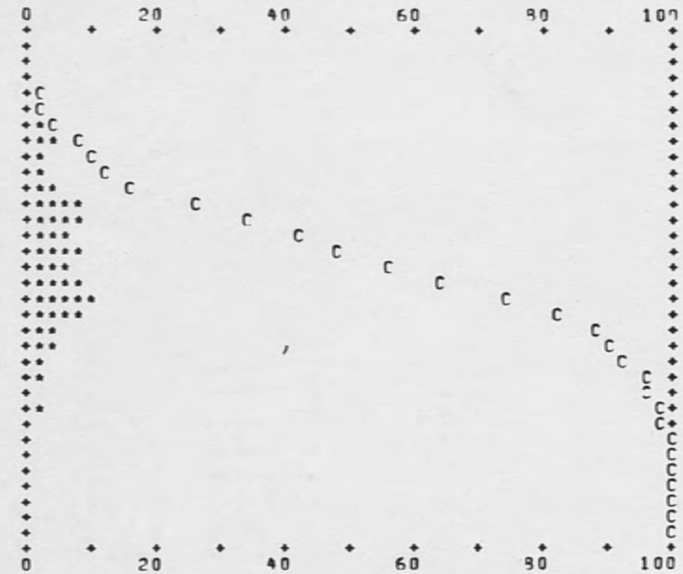


Fig. 8-g. Distribution of by-product income

Mean Value	Standard Deviation	Coefficient of Variation	Minimum Value	Maximum Value
15.04×10^6	4.546×10^6	0.3239	5.724×10^6	25.31×10^6

HISTOGRAM NUMBER 5

ANN.EQ COST

OBSV FREQ	RELA FREQ	CUML FREQ	UPPER CELL LIMIT
0	0.0	0.0	0.2000E+09
0	0.0	0.0	0.2075E+09
0	0.0	0.0	0.2150E+09
0	0.0	0.0	0.2225E+09
0	0.0	0.0	0.2300E+09
0	0.0	0.0	0.2375E+09
0	0.0	0.0	0.2450E+09
0	0.0	0.0	0.2525E+09
0	0.0	0.0	0.2600E+09
0	0.0	0.0	0.2675E+09
4	0.020	0.020	0.2750E+09
2	0.010	0.030	0.2825E+09
1	0.005	0.035	0.2900E+09
6	0.030	0.065	0.2975E+09
11	0.055	0.120	0.3050E+09
16	0.080	0.200	0.3125E+09
15	0.075	0.275	0.3200E+09
12	0.060	0.335	0.3275E+09
15	0.075	0.410	0.3350E+09
15	0.075	0.485	0.3425E+09
13	0.065	0.550	0.3500E+09
11	0.055	0.605	0.3575E+09
7	0.035	0.640	0.3650E+09
9	0.045	0.685	0.3725E+09
11	0.055	0.740	0.3800E+09
5	0.025	0.765	0.3875E+09
9	0.045	0.810	0.3950E+09
7	0.035	0.845	0.4025E+09
10	0.050	0.895	0.4100E+09
4	0.020	0.915	0.4175E+09
2	0.010	0.925	0.4250E+09
0	0.0	0.925	0.4325E+09
3	0.015	0.940	0.4400E+09
2	0.010	0.950	0.4475E+09
3	0.015	0.965	0.4550E+09
2	0.010	0.975	0.4625E+09
0	0.0	0.975	0.4700E+09
2	0.010	0.985	0.4775E+09
1	0.005	0.990	0.4850E+09
0	0.0	0.990	0.4925E+09
0	0.0	0.990	0.5000E+09
2	0.010	1.000	INF

200			

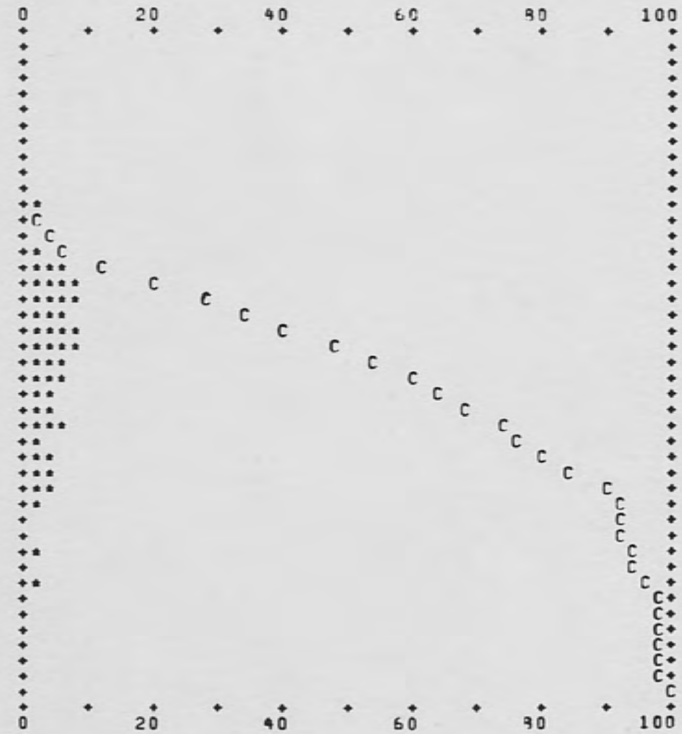


Fig. 8-h. Distribution of annual equivalent cost

Mean Value	Standard Deviation	Coefficient of Variable	Minimum Value	Maximum Value
$\$353.0 \times 10^6$	$\$47.28 \times 10^6$	0.1336	$\$269.6 \times 10^6$	$\$515 \times 10^6$

Evaluation of Cost Elements

According to the simulation results shown in Table 5, fuel cost constitutes 60 percent of the total cost of producing synthetic fuels. The construction cost accounts for only 12 percent of the total cost. This is a significant observation indicating that the problems associated with the capital cost are mainly due to its financing at the original construction stage rather than its magnitude as a portion of the overall cost.

As discovered in Chapter 4, the fixed portion of O&M cost is a function of the plant size and covers cost of maintaining the scrubbers and other air pollution control devices. This constitutes 13 percent of the total cost. The variable O&M cost which also includes the cost of consummable materials constitutes 15 percent of the total cost.

TABLE 5

COST ELEMENTS FOR SYNTHETIC FUEL PLANT

15%	O&M (Variable)
13%	O&M (Fixed)
60%	Fuel
12%	Construction and Other Costs

CHAPTER 6

ECONOMIC ANALYSIS OF ELECTRICITY GENERATION BY USING SNG

As a clean source of energy, natural gas has been long used for direct burning and production of electricity. The passage of recent government regulations related to pollution control has added to its demand for production of energy. Electricity generation is of particular interest in studying the impact of natural gas on the energy market. In 1980, of the total 2,285,593 x 10^6 kilowatt-hours of electricity produced, 345,914 x 10^6 kilowatt-hours were generated by natural gas. [8]

In this chapter, the expected cost of generating electricity by using SNG is compared to the expected cost when using oil, and the distributions resulting from risk analysis are compared for the two alternatives. Then, the cost elements for each alternative and their effects on the total cost are evaluated.

Scope of Study

In this study, the cost of 1,000 MW plant is studied where substitute natural gas produced from coal is used as the fuel. As explained in Chapter 4, the plant size of 1,000 MW requires an SNG plant with a capacity of 250 x $10^6 Ft^3$/day, and the Lurgi Model explained in Chapter 2 is also applied to this part of the study since

the applicability of this model at full commercial scale has been proven. Therefore, the data used for evaluation of this process can be considered to be reliable and defensible.

Explanation of the Risk Analysis Model

In Chapter 3, the cost analysis model for production of high BTU gas from coal was explained. The primary advantage of this model is that it accounts for uncertainties associated with the input parameters by developing probability distributions. Assessing the uncertainties with input parameters carries a higher degree of importance when two alternatives are being studied and compared.

Thus, the expected costs of alternatives can be compared to each other for decision making purposes. Similarly, comparing the standard deviations shows a measure of the risk involved in selecting between the alternatives. In Figure 9, the simulation analysis applied for comparing the alternatives is shown. The process evaluated is very similar to that explained in Chapter 3 where probability distribution for equivalent annual cost was developed through Monte Carlo sampling techniques. For this comparison, the parameters subject to uncertainty also were identified as construction cost, fuel cost, fixed and variable O&M costs, and escalation rates for fuel and O&M costs. The revenues gained from by-products were assumed to be normally distributed as in the previous chapters. The probability distributions of each alternative were found, and the probability distributions of the cost difference between alternatives I (SNG) and II

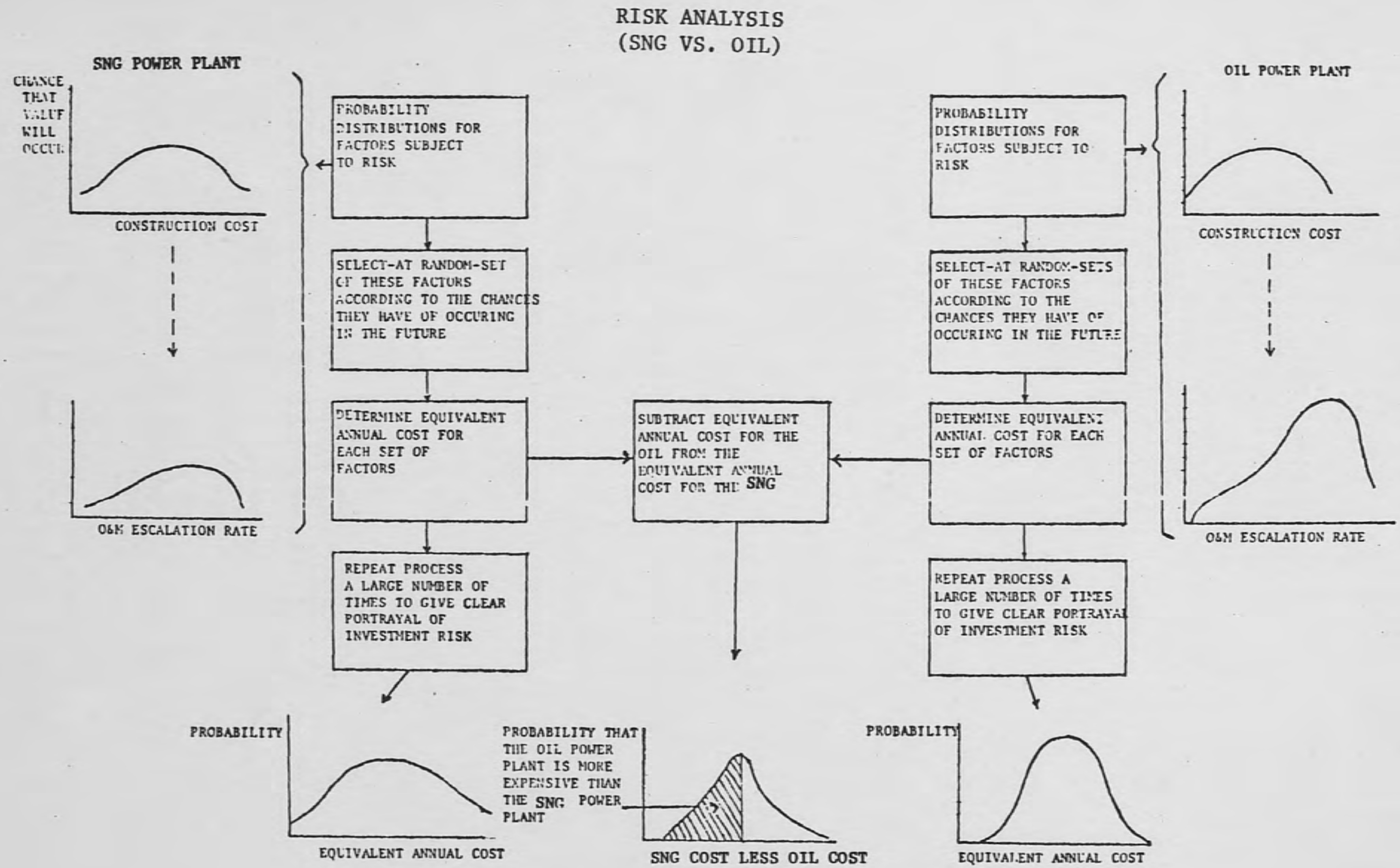


Fig. 9. Risk analysis simulation chart

were developed. From this probability distribution, the probability that alternative I will be less costly than alternative II can be determined.

Explanation of Input Data

Due to a low level of pollution resulting from burning SNG, the costs associated with pollution control equipment are relatively small. The SNG and the natural gas power plants are built simultaneously, which results in a lower cost compared to building them individually. A similar savings would be incurred in O&M costs.

There are a number of techniques that government could use to assist the development of synthetic fuel plants. One effective incentive has been providing additional investment tax credit to such energy projects. [6] In this study, an investment tax credit rate of 10 percent can be applied to the SNG power plant, whereas five percent is assumed as the investment tax credit for the oil power plant. Table 3 shows all the probabilistic cost values for this project. All the data estimated with certainty are the same as those in Tables 1 and 2 of Chapter 4, except the value of heat rate, which is 9,500 BTU/Kw.Hr for the oil power plant.

Simulation Results

The results of each simulation run include the probability distribution for the cost of each alternative and, also, the probability distribution of the cost difference between generating electricity by SNG and by oil. These results are shown in Figure 10. The

expected equivalent annual cost of alternative I (SNG) is $\$460 \times 10^6$, which is more than $\$356 \times 10^6$, the expected equivalent annual cost of the second alternative. Also, the standard deviation of the first alternative is higher than of the second alternative, indicating that the risk associated with alternative I is higher than alternative II. The probability distribution of the cost difference indicates that the alternative I would be less costly than alternative II four percent of the time (the cumulative frequency at this point where alternative I minus alternative II equals zero). The results clearly show the unfeasibility of production of electricity by burning synthetic natural gas.

TABLE 3
ESTIMATED PROBABILISTIC VARIABLES FOR SNG PROJECT

Probabilistic Variables	SNG Power Plant			Oil Power Plant		
	Optimistic Value	Most Likely Value	Pessimistic Value	Optimistic Value	Most Likely Value	Pessimistic Value
Construction Cost ($/KW)	1,000	1,300	1,500	490	540	585
Fuel Cost ($\$/10^6$BTU)	1.3	1.6	1.75	2.4	3.1	3.5
Fixed O&M Cost ($/KW)	35	50	57	1.55	1.90	2.10
Variable O&M Cost ($/KW.HR)	0.0060	0.0096	0.0115	0.0024	0.003	0.0035
Fuel Escalation Rate (%/Yr.)	0.050	0.070	0.12	0.045	0.0725	0.090
O&M Escalation Rate (%/Yr.)	0.030	0.070	0.09	0.06	0.08	0.12

SOURCE: R. Chandra, B. McElmurry, and S. Smelser, Economics of Fuel Gas From Coal - An Update, (Palo Alto, CA:: Electric Power Research Institute, 1978), pp. 3-5.

HISTOGRAM NUMBER 1

ANN.EC.COST1

OBSV FREQ	RELA FREQ	CUML FREQ	UPPER CELL LIMIT
0	0.0	0.0	0.3000E+09
0	0.0	0.0	0.3200E+09
0	0.0	0.0	0.3400E+09
0	0.0	0.0	0.3600E+09
6	0.030	0.030	0.3800E+09
14	0.070	0.100	0.4000E+09
14	0.070	0.170	0.4200E+09
38	0.190	0.360	0.4400E+09
35	0.175	0.535	0.4600E+09
39	0.195	0.730	0.4800E+09
22	0.110	0.840	0.5000E+09
10	0.050	0.890	0.5200E+09
6	0.030	0.920	0.5400E+09
10	0.050	0.970	0.5600E+09
2	0.010	0.980	0.5800E+09
0	0.0	0.980	0.6000E+09
1	0.005	0.985	0.6200E+09
3	0.015	1.000	0.6400E+09
0	0.0	1.000	0.6600E+09
0	0.0	1.000	0.6800E+09
0	0.0	1.000	0.7000E+09
0	0.0	1.000	0.7200E+09
0	0.0	1.000	0.7400E+09
0	0.0	1.000	0.7600E+09
0	0.0	1.000	0.7800E+09
0	0.0	1.000	0.8000E+09
0	0.0	1.000	0.8200E+09
0	0.0	1.000	0.8400E+09
0	0.0	1.000	0.8600E+09
0	0.0	1.000	0.8800E+09
0	0.0	1.000	0.9000E+09
0	0.0	1.000	INF

200			

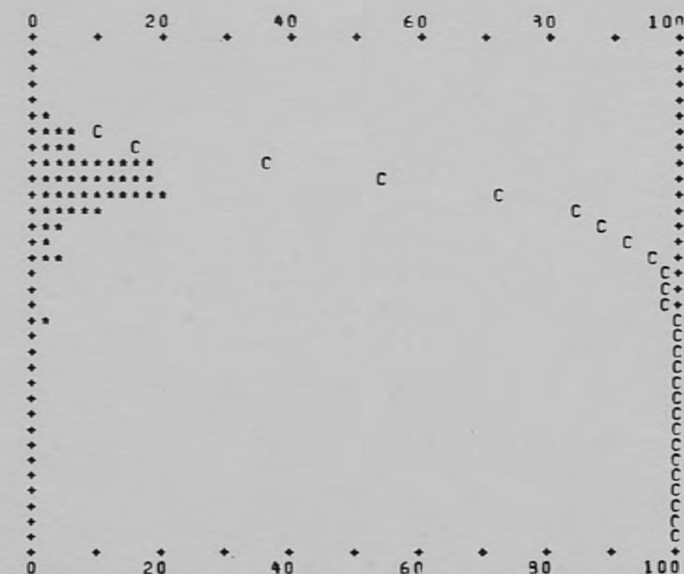


Fig.10-a. Distribution of equivalent annual cost of SNG power plant

Mean Value	Standard Deviation	Coefficient of Variation	Minimum Value	Maximum Value
$460 x 10^6$	$48.71 x 10^6$	0.1059	$365.3 x 10^6$	$731.7 x 10^6$

Number of observations = 200

HISTOGRAM NUMBER 2

ANN.EQ.COST2

OBSV FREQ	RELA FREQ	CUML FREQ	UPPER CELL LIMIT
0	0.0	0.0	0.2000E+09
0	0.0	0.0	0.2100E+09
0	0.0	0.0	0.2200E+09
0	0.0	0.0	0.2300E+09
0	0.0	0.0	0.2400E+09
0	0.0	0.0	0.2500E+09
0	0.0	0.0	0.2600E+09
1	0.005	0.005	0.2700E+09
1	0.005	0.010	0.2800E+09
10	0.050	0.060	0.2900E+09
4	0.020	0.080	0.3000E+09
13	0.065	0.145	0.3100E+09
14	0.070	0.215	0.3200E+09
19	0.095	0.310	0.3300E+09
15	0.075	0.385	0.3400E+09
19	0.095	0.480	0.3500E+09
11	0.055	0.535	0.3600E+09
13	0.065	0.600	0.3700E+09
17	0.085	0.685	0.3800E+09
14	0.070	0.755	0.3900E+09
17	0.085	0.840	0.4000E+09
7	0.035	0.875	0.4100E+09
9	0.045	0.920	0.4200E+09
9	0.045	0.965	0.4300E+09
4	0.020	0.985	0.4400E+09
1	0.005	0.990	0.4500E+09
2	0.010	1.000	0.4600E+09
0	0.0	1.000	0.4700E+09
0	0.0	1.000	0.4800E+09
0	0.0	1.000	0.4900E+09
0	0.0	1.000	0.5000E+09
0	0.0	1.000	INF
--- 200			

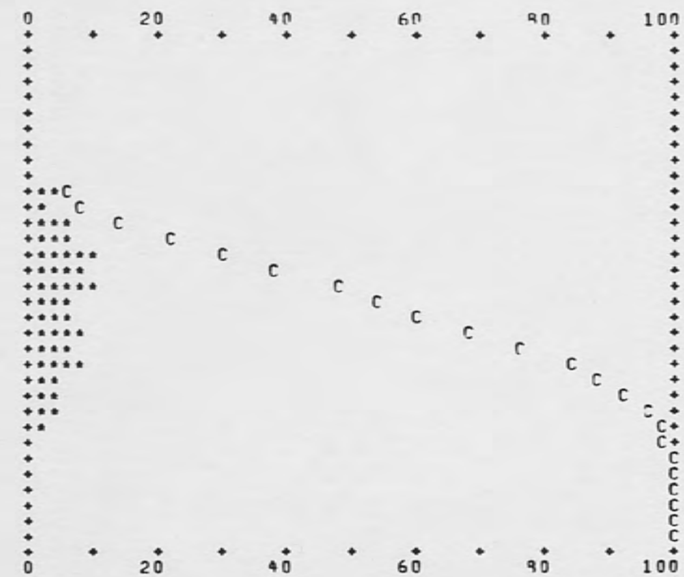


Fig. 10-b.Distribution of equivalent annual cost of oil power plant

Mean Value	Standard Deviation	Coefficienct of Variation	Minimum Value	Maximum Value
356.5×10^6	$\$42.06 \times 10^6$	0.118	$\$266.2 \times 10^6$	$\$452 \times 10^6$

Number of observations = 200

HISTOGRAM NUMBER 3 DIFFERENCE

OBSV FREQ	RELA FREQ	CUML FREQ	UPPER CELL LIMIT
0	0.0	0.0	-0.6000E+08
0	0.0	0.0	-0.5000E+08
1	0.005	0.005	-0.4000E+08
2	0.010	0.015	-0.3000E+08
2	0.010	0.025	-0.2000E+08
0	0.0	0.025	-0.1000E+08
3	0.015	0.040	0.8000E+01
5	0.025	0.065	0.1000E+08
3	0.015	0.080	0.2000E+08
9	0.045	0.125	0.3000E+08
8	0.040	0.165	0.4000E+08
7	0.035	0.200	0.5000E+08
11	0.055	0.255	0.6000E+08
11	0.055	0.310	0.7000E+08
15	0.075	0.385	0.8000E+08
12	0.060	0.445	0.9000E+08
10	0.050	0.495	0.1000E+09
14	0.070	0.565	0.1100E+09
8	0.040	0.605	0.1200E+09
11	0.055	0.660	0.1300E+09
9	0.045	0.705	0.1400E+09
9	0.045	0.750	0.1500E+09
17	0.085	0.835	0.1600E+09
7	0.035	0.870	0.1700E+09
5	0.025	0.895	0.1800E+09
5	0.025	0.920	0.1900E+09
6	0.030	0.950	0.2000E+09
2	0.010	0.960	0.2100E+09
1	0.005	0.965	0.2200E+09
1	0.005	0.970	0.2300E+09
0	0.0	0.970	0.2400E+09
0	0.0	0.970	0.2500E+09
2	0.010	0.980	0.2600E+09
2	0.010	0.990	0.2700E+09
0	0.0	0.990	0.2800E+09
1	0.005	0.995	0.2900E+09
0	0.0	0.995	0.3000E+09
0	0.0	0.995	0.3100E+09
0	0.0	0.995	0.3200E+09
0	0.0	0.995	0.3300E+09
0	0.0	0.995	0.3400E+09
1	0.005	1.000	0.3500E+09
0	0.0	1.000	0.3600E+09
0	0.0	1.000	0.3700E+09
0	0.0	1.000	0.3800E+09
0	0.0	1.000	0.3900E+09
0	0.0	1.000	0.4000E+09
0	0.0	1.000	0.4100E+09
0	0.0	1.000	0.4200E+09
0	0.0	1.000	0.4300E+09
0	0.0	1.000	0.4400E+09
0	0.0	1.000	INF
--- 200			

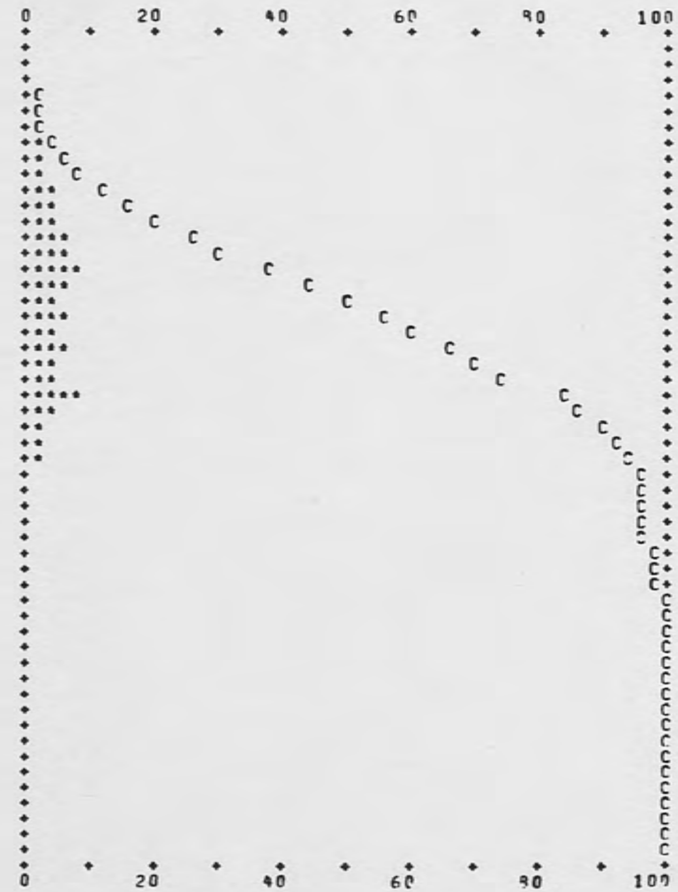


Fig. 10-c. Distribution of cost difference

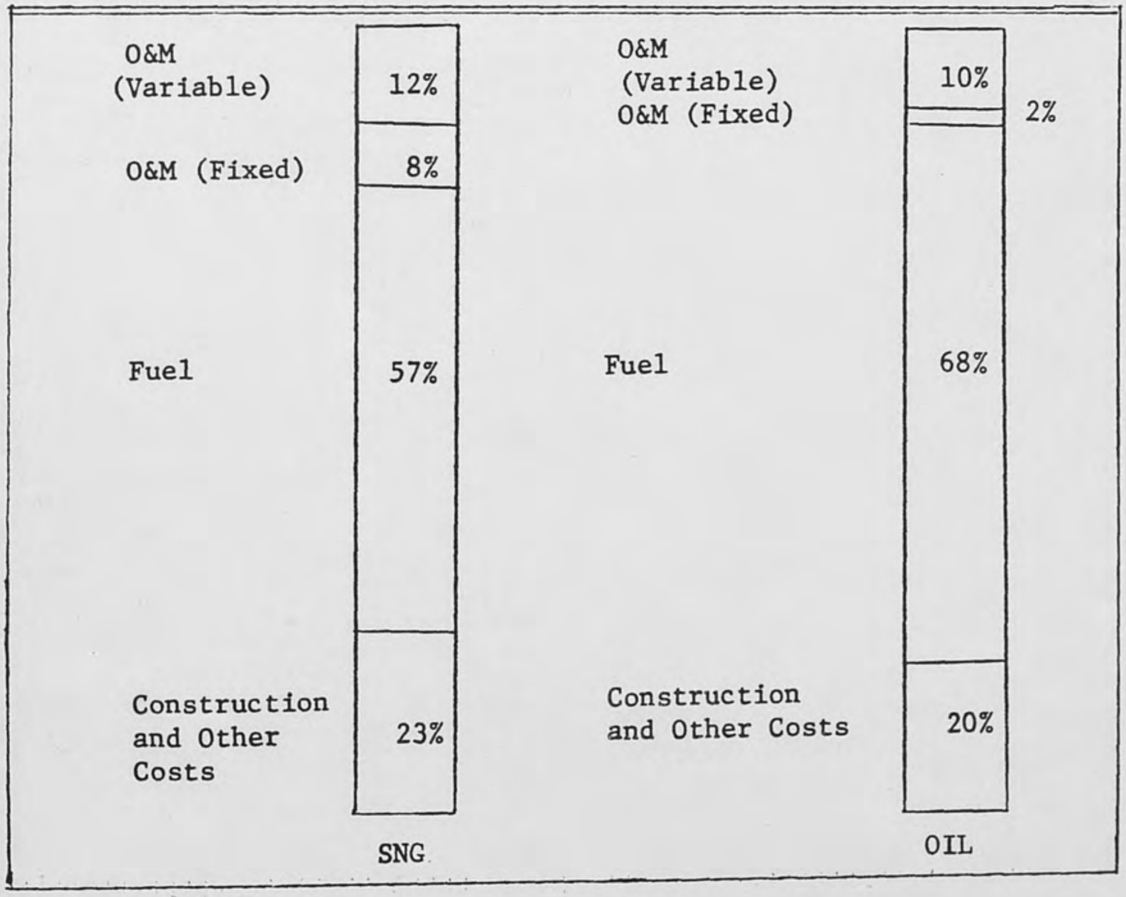
Mean Value	Standard Deviation	Coefficient of Variation	Minimum Value	Maximum Value
$103.5 x 10^6	$64.34 x 10^6	0.6019	-$43.04 x 10^6	$347 x 10^5

Evaluation of cost elements

Table 7 depicts the value of cost elements as percentages of the total cost for both the SNG and oil power plants. Based on these results, 68 percent of the total cost of oil power plant is used for fuel. The construction costs constitute a similar portion of the total cost for both plants (20% and 23%). The same observation is made with regard to the variable portion of the O&M cost (12 percent and 10 percent). However, the fixed portion of the O&M cost constitutes only two percent of the total cost for the oil power plant and 8 percent of the total cost of the SNG plant.

TABLE 7

COST ELEMENTS FOR THE TWO ALTERNATIVES



Sensitivity of the Total Cost to the Input Data

The cost of producing energy is subject to fluctuations due to a variety of factors, including national and international fuel markets and pollution control regulations. These factors bring inaccuracies to any cost analysis of power generation. However, these inaccuracies can be minimized by studying various sources of data and incorporating uncertainties into these studies. These steps were accomplished in the model developed in this study.

It is of interest to expand the study to include a sensitivity analysis where the total cost is calculated for a set of values for the input parameters. SLAM provides a great deal of flexibility for accomplishing this task since one simulation run can include numerous sets of data with an output reflecting the input data and their respective results.

Effect of fuel cost

Since the cost of fuel constitutes a high portion of the total cost of both SNG and oil plants, differences in the amount of uncertainty associated with escalation in the cost of coal and oil becomes very crucial. Coal is an abundant resource and its cost increases are relatively predictable; whereas, increases in oil prices are subject to a high degree of uncertainty.

In this section, two situations with regard to the oil prices are considered: a) the effect of a general increase, and b) the effect of an increase in the level of uncertainty. The scenarios

developed and the results are shown in Table 8. The results reveal significant information with respect to the economic feasibility of synthetic natural gas as the price of oil increases. An increase of one percent in the three estimates related to the fuel cost escalation rate resulted in an increase of $\$356.50 \times 10^6$ to $\$393 \times 10^6$. The economic attractiveness of SNG power plants also increased from four percent to 17.5 percent based of the observed values.

TABLE 8

SENSITIVITY OF THE RESULTS TO THE PRICE OF OIL

Case of Study	Fuel Escalation Rate			Results		
	Optimistic	Most Likely	Pessimistic	Mean ($)	Std.Dev.($)	P[Oil>SNG]
Original	0.045	0.0725	0.09	356.5×10^6	42.06	4.0%
Increase of Value	0.055	0.0825	0.10	393×10^6	49.50	17.5%
Increase certainty	0.04	0.0725	0.13	374.4×10^6	81.95	19.0%

In the second part of this scenario, the estimated values for the fuel escalation rates were assumed to be 4 percent, 7.25 percent, and 13 percent as optimistic, most likely, and pessimistic values, respectively. These changes of input parameters reflect an increase in the value as well as the level of uncertainty for the future fuel cost.

The results show a substantial increase in the standard deviation to \$81.95 x 10^6 which is almost twice as large as the original value of \$42 x 10^6. The expected cost also increases to \$374.7 x 10^6 from the original value of \$356.5 x 10^6.

The sensitivity analysis can be expanded for various other values for fuel cost. The results can be considered as guidelines for the evaluation of economic feasibility of synthetic fuels and their development in the future.

CHAPTER 7

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Summary and Conclusions

In this study, the economic feasibility of the production of synthetic natural gas (SNG) for both direct use and power generation was discussed. A general methodology of production of synthetic natural gas was explained and the Lurgi Model, the most common technique for the production of high BTU gas, was selected for economic analysis. Conversion of coal to gas reduces the pollution problems associated with the direct combustion of coal. Also, distribution of gas through the existing pipeline system is far more economical than rail transportation of coal. To perform a complete environmental/economic evaluation, the capital and operating costs and savings due to the environmental advantages of synthetic fuels must be calculated. With no assurance of a full-scale plant, these evaluations are rather difficult. The estimates reveal a great deal of uncertainty, and the analysis was primarily based on private costs which were relatively easier to measure. Nevertheless, the study does provide a basis on which national energy policy can be determined.

A risk analysis model was developed to account for the uncertainties associated with the estimation of parameters. This analysis was based on a comprehensive model where all the private cost elements as well as some of the social costs of pollution were calculated. SLAM was the computer language used to calculate the equivalent annual cost through Monte Carlo sampling techniques.

The factors subject to uncertainty were identified as construction cost, fuel cost, O&M cost (fixed and variable), and escalation rates for the fuel and O&M costs. For these factors, three estimates of "optimistic," "most likely," and "pessimistic" were made. These estimates were used in beta distributions to develop the probability distributions for these parameters.

The results of the computer simulation include the distributions for all the factors, subject to uncertainty and the equivalent annual cost of producing SNG. Also, the distribution of income received from saleable by-products is shown. According to the results achieved with 200 observations in a simulation run, fuel cost constitutes 60 percent of the total cost of producing synthetic natural gas. The construction cost accounts for only 12 percent of the total cost, indicating that the problems associated with the capital cost are mainly due to its financing at the original construction stage rather than its magnitude as a portion of the overall total cost. The fixed and variable portions of O&M cost constitute 13 percent and 15 percent of the total cost, respectively. Based on the computer results, $3.88/1000$Ft^3$ is the cost of

producing SNG. This value compared to \$2 to \$3/1000Ft^3, the current price of natural gas, makes the production of SNG appear economically unattractive.

This study was extended to the calculation of costs associated with the generation of electricity by burning synthetic natural gas. The results were then compared to the respective costs related to oil burning power plants. For power generation, burning oil was found to be far more economical than using synthetic natural gas. Fuel cost was found to constitute a major portion of the total cost of both oil and SNG power plants. Since the oil prices are subject to a high degree of uncertainty, the sensitivity of results to the fuel cost was examined. The results reveal that small increases in oil prices substantially increase the economic attractiveness of SNG. The conclusion of this study points to the fuel costs as the dominant factor in the choice of alternative techniques in the future.

Recommendations

The approach applied in this study was merely based on cost analysis from the point of view of a private investor. The steady increase in the prices of imported oil during the past decade, combined with periodic shortages, have revealed the economic vulnerability of this country to sudden curtailments in energy supplies. Production of synthetic fuels should be considered as a necessary step in reaching the goal of "energy independence" which provides external benefits to the nation as a whole rather than internal

benefits to a private investor. The following statements explain several supporting factors for synthetic fuel development:

1. Developing synthetic fuels could be a major factor in reducing the dependence of the United States on insecure overseas energy supplies. Thus, the current damage to the economy and balance of payments due to the current imports would be reduced.
2. Starting synthetic fuel projects is essential for developing a broad base of knowledge about long-term energy alternatives and reducing the uncertainties associated with developing these alternatives.
3. Having the capacity to produce synthetic fuels on a commercial scale would inhibit possible long-run attempts by foreign producers to raise their prices above the estimated cost of synthetic fuels.
4. Burning synthetic fuel, extracted from coal, results in less pollution than direct coal combustion. This also should be considered as a positive externality for society.

To accomplish these goals, government encouragement and assistance is needed. If it is perceived that the external benefits of SNG production more than offsets its "private" cost disadvantage, then government and business should start working together and share the enormous risk and capital requirements associated with developing synthetic fuels.

APPENDIX I

MATHEMATICAL MODELING

In this appendix a comprehensive mathematical model is presented for cost analysis of power generation.[9]

Phase I Model (Construction Period)

The costs incurred during the construction period are debt interest, equity return, Ad valorem tax, and insurance cost. Following are detailed cash flow formulation included in the Phase I Model.

i) Debt Interest

$$DI_n = \left(\sum_{j=1}^{n} C_j\right) d\ id \qquad \text{(1-a)}$$

$$n = 1, 2, \ldots, N$$

where

DI_n: Debt interest to be paid at the end of year n during the construction period.

N: The total number of years of construction

C_n: Plant construction cost in year n.

d: Debt ratio in financing mix.

i_d: Debt interest rate.

ii) Equity Return

$$ER_n = \left(\sum_{j=1}^{n} C_j\right) (i-d)\ ie \qquad \text{(1-b)}$$

$$n = 1, 2, \ldots, N$$

where

ER_n: Equity return to be made at the end of year n during the construction period.

i_e: Equity return rate per year.

iii) Ad valorem tax

$$ADV_n = (\sum_{j=1}^{n} C_j)\, t_a \qquad (1\text{-}c)$$

$$n = 1, 2, \ldots, N$$

where

ADV_n: Ad valorem tax to be paid at the end of year n during the construction period.

t_a: Ad valorem tax rate.

iv) Insurance cost

$$INS = (\sum_{j=1}^{n} C_j)\theta \quad n = 1, 2, \ldots, N \qquad (1\text{-}d)$$

where

INS_n: Insurance cost in year n.

Θ: Insurance rate per year (% of the total capital cost).

v) Before-tax cash flow

The before-tax cash flow during the construction period can be determined by adding i) through iv).

$$BTC_n = DI_n + ER_n + ADV_n + INS_n \qquad (1\text{-}e)$$

vi) Adjustment for tax purpose

Interest paid on indebtedness is deductible as a business expense. This means that a project which is financed with borrowed capital has its taxable income reduced by the amount of interest involved. Since the equity repayments and insurance payments are non-tax deductive expenses, the adjustment figure for tax purposes will be

$$TD_n = BTC_n - ER_n - INS_N \qquad (1\text{-}f)$$

vii) Tax savings

$$TS_n = TD_n \cdot t$$
$$= (DI_n + ADV_n) \cdot t \qquad (1\text{-}g)$$

where

TS_n: Tax saving in year n during the construction.

t: Federal and state combined tax rate for income.

viii) Investment tax credit

$$ITC_n = \begin{cases} mK & \text{if } n = N \\ 0 & \text{otherwise} \end{cases} \qquad (1\text{-}h)$$

where

ITC_n: Investment tax credit in year n.

m: Investment tax credit rate.

K: The total construction cost

viii) After-tax cash flow

$$ATC_n = BTC_n - TS_n$$

$$= DI_n + ER_n + ADV_n + INS_n - (DI_n + ADV_n)\cdot t$$

$$= (1-t)\ DI_n + ER_n + (1-t)\ ADV_n + INS_n$$

where

ATC_n = After-tax cash flows in year n during the construction.

ix) Equivalent construction cost

From equation 1-i, the total future worth of the Phase I Model at the same time the plant begins commercial operation operations can be computed as

$$FW)\ (i) = \sum_{n=1}^{N} (ATC_n)\ (1+i)^{N-n} \qquad (1\text{-}i)$$

where

$F_W(i)_I$: Future worth of the project for Phase I.

i: Discount rate (or cost of capital).

PHASE II Model (Operational Period)

The Phase II Model consists of the total generation cost and the capital recovery costs associated with the initial plant investment through the entire plant service life. To calculate the future fuel cost as well as the operating and maintenance costs,

costs, it is necessary to determine the corresponding escalation rates. Following are the detail cash flow formulations involved in the Phase II Model.

i) Fuel cost

The fuel cost is a function of plant size, thermal conversion efficiency, and plant unitilization factor. The fuel cost in each year would be calculated by the following:

$$F_n = (C)(H)(U_n)(8760/10^6)\ f_0(1+q)^{n-1} \qquad (1\text{-}k)$$

where

F_n: Annual fuel cost in year n (\$).

C: Plant size in KW.

H: Heat rate at operating conditions in BTU/KWH.

U_n: Plant utilization factor in year n.

f_0: Fuel cost at the starting year (\$/10^6BTU).

q: Average annual fuel escalation rate.

ii) Operating and Maintenance costs consist of the fixed and variable portions. The fixed O&M cost can be expressed as function of the plant size while the variable O&M cost is a function of the

of the plant size, plant utilization factor, and efficiency of the plant. The O&M cost can be written as:

$$(O\&M)_n = Of_n + OV_n \quad \text{and} \qquad (1-\ell)$$

Fixed cost

$$Of_n = (C)\ Of_o\ (1 + \Lambda)^{n-1} \qquad (1-\ell-1)$$

where

Of_n: Fixed O&M cost in year n ($).

Of_o: Fixed O&M cost at the starting year ($/KW)

Λ: Average annual escalation rate of fixed O&M cost.

Variable Cost

$$OV_n = (C)\ (H)\ (U_n)\ (8760/10^6) OV_o (1 + \theta)^{n-1} \qquad (1-\ell-2)$$

where

OV_n: Variable O&M cost in year n ($)

OV_o: Variable O&M cost at the starting year ($\$/10^6$BTU).

θ: Average annual escalation rate of variable O&M cost.

iii) Depreciation Cost

In computing depreciation deducations, a useful life and salvage value for the asset must be established. It is possible that the service life allowed for tax purpose may differ

from the actual physical life of the asset as employed by the firm. Yearly depreciation deductions can be calculated by the following methods:

a. Straight line depreciation method (1-m)

$$SLD = \frac{K - s}{n_d}$$

where SLD: Straight line depreciation

n_d: The depreciable life.

s: Salvage value

b. Declining balance method

$$DB_n = R(1-R)^{n-1} \quad (1-n)$$

where DB_n: Declining balance depreciation.

R: Depreciation factor.

c. Sum of years digit method

$SYD_n = (K-S)\left(\frac{nd-n+1}{n(n+1)/2}\right)$ years digit depreciation.

iv) <u>Debt Finance Repayment</u>

During the operational period the only payments for the debt portion of the funds are equal annual payments as the interest for the issued bonds and the principal of the debt portion is paid back at the end of the operational period.

$$DIn = Kd.i_d \quad , \text{ If } n = 1, 2, \ldots T-1 \quad (1-o)$$

$Kd+Kd.i_d$, If $n = T$

where T: Plant service life in years.

DI_n: Debt finance payment to be make in year n during plant service life.

v) Equity Finance Payment

The payments for the equity are paid by equal annual payments. A portion of this payment is for interest and can be calculated as:

$$ER_n = Kd(A/P, i_e, T)$$

where ER_n: Equity finance repayment to be made in year n during the plant service life.

and

$$EIP = (Kdi_e - ER_n)(1+i_e)^n + ER_n(1-p)$$

where

EIP: The interest portion of the equity finance payment.

The debt portion of the funds also could be paid back by equal annual payment. In this case the interest portion of the payments should be calculated by using equation 1-p and be considered as an expense for tax purposes.

vi) Ad valorem Tax

$$ADV_n = (K - \sum_{j=1}^{n} D_j)t \qquad (1-q)$$

where

ADV_n: Ad valorem tax to be paid in year n during the plant service period.

D_n: Depreciation deducted for year n.

vii) Insurance Cost

$$INS_n = (K) \quad (1\text{-}r)$$

where

INS_n: Insurance cost to be paid in year n during the plant service life.

viii) Salvage Cost (Value)

If S_T is defined as the salvage value at the end of service life, then the end of year salvage as a function of n is given by:

$$S_n = \begin{cases} 0 & \text{If}, Tn \neq T \\ sK & \text{If}, n = T \end{cases} \quad (1\text{-}s)$$

where

s: Salvage rate.

xi) Before Tax Cash Flow

The total cash flow before tax at the end of nth year will be calculated by:

$$BTC_c = F_n + Of_n + OV_n + DI_n + ER_n + ADV_n \mp INS_n - S_n \quad (1\text{-}t)$$

x) Adjustments for Tax Purposes

Fuel cost, O&M cost, Ad valorem tax, the interest paid for debt and the depreciation are tax deductible. For calculation of the tax deductible amount, the following expression can be used.

$$TD_n = \begin{cases} BTC_n + D_n - ER_n - INS_n & \text{If } n = 1, 2, \ldots, T-1 \\ BTC_n + D_n - ER_n - INS_n + S_n - Kd & \text{If } n = T \end{cases} \quad (1\text{-}u)$$

where

TD_n: Tax deductions in year n

xi) Tax Savings

$$TS_n = TD_n \cdot t$$

where

TS_n: Tax savings in year n (1-v)

xii) After-Tax Cash Flow

$$ATC_n = BTC_n - TS_n - ITC_n \qquad (1\text{-w})$$

xiii) Present Worth Equivalent

The total present worth of the Phase II model can be computed by using equation 1-y. This is the present worth at the time the plant begins its commercial operation.

$$PW(i)_{II} = \sum_{t=1}^{T} (ATC)\,(1 + i)^{-n} \qquad (1\text{-y})$$

Annual Equivalent Cost Model

The cost of the two phases are combined together in order to find the annual equivalent cost.

$$AE(T,N,i) = FW(i)_I + PW(i)_{II}\,(A/P,T,i)$$

where

$AE(T,N,i)$: The annual equivalent cost of the project.

The mathematical model developed in this chapter includes all the cost elements which constitute the total cost of an investment.

In order to incorportate explicitly the effect of inflation in the analysis, it becomes necessary to use a combined discount rate in computing the annual equivalent cost. The combined discount rate is simply found by the following relation:

$$(1 + i) = (1 + k)\ (1 + i')$$

where

i = combined discount rate

k = the average inflation rate

i' = the rate representing the earning power of money with no inflation.

APPENDIX II

SLAM NETWORK MODEL AND STATEMENT LISTING

In this appendix, a condensed network model and the statement listing is presented. The explanation of the model is given in terms of statement listing. [9]

Figure 11 depicts the network model applied for the cost analysis of SNG. The methodology of comparing two alternatives explained in Chapter 6 is also reflected at the end of this network model.

Statement listing and the computer printout for cost comparison of generation of electricity by burning SNG and oil are also included in this appendix.

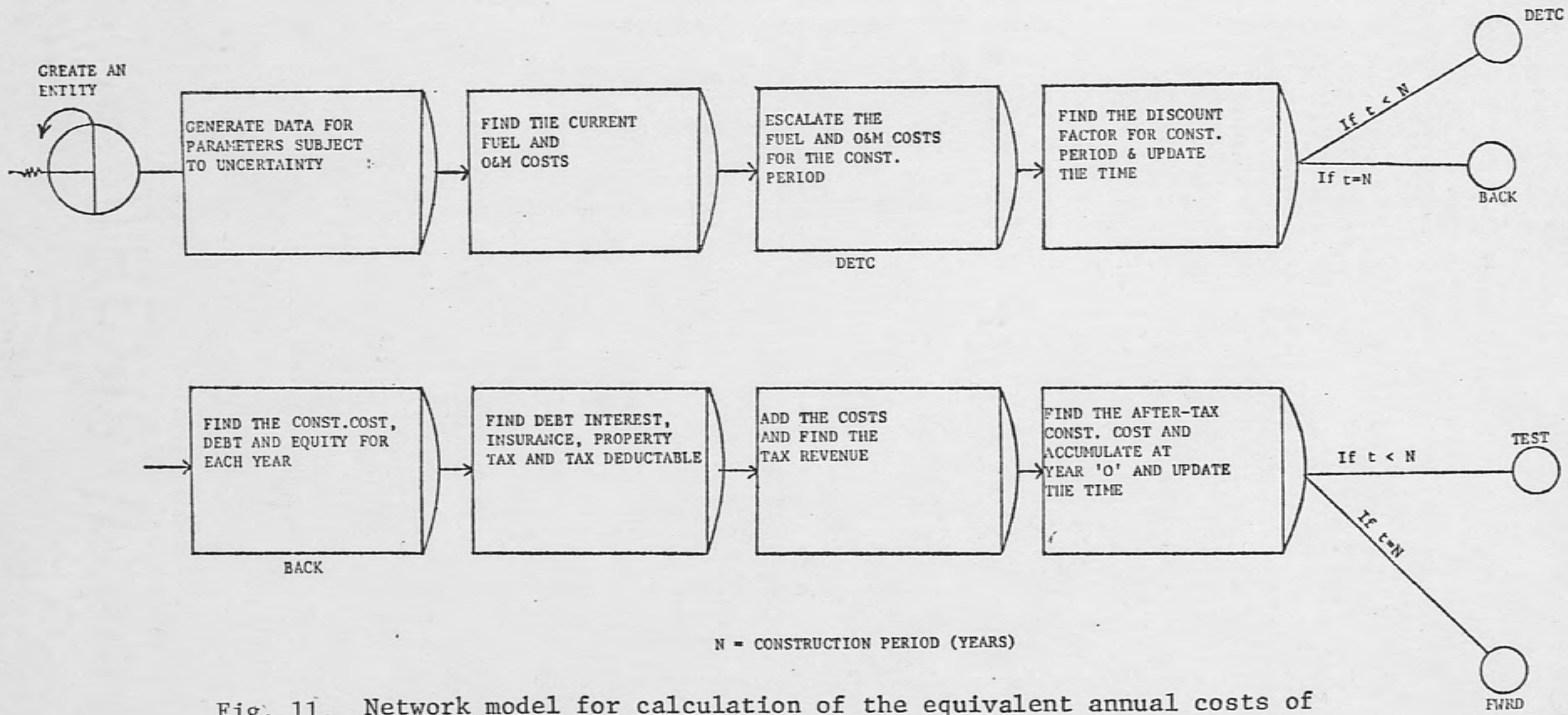


Fig. 11. Network model for calculation of the equivalent annual costs of the two alternatives and their difference

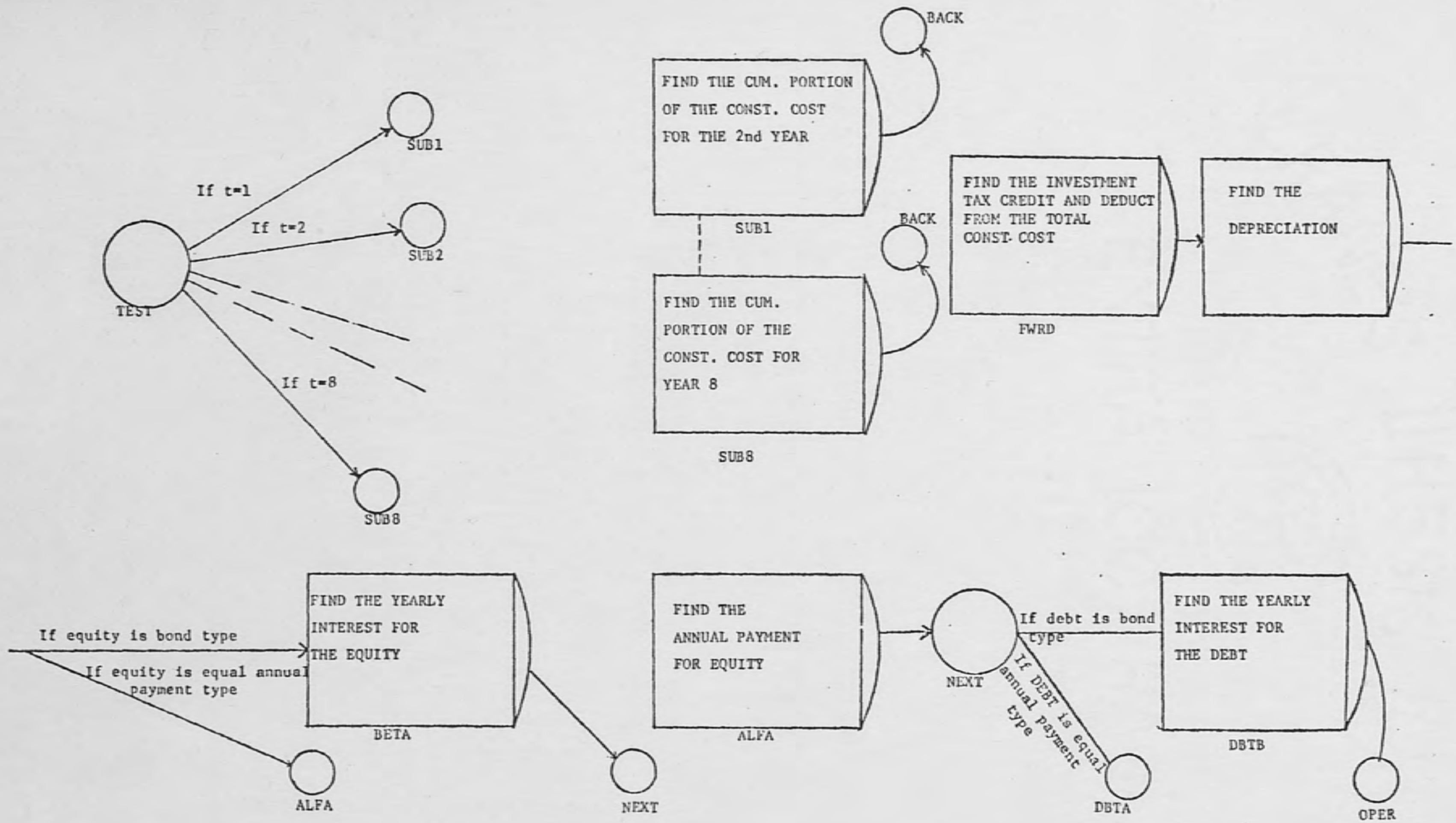


Fig. 11. (Continued)

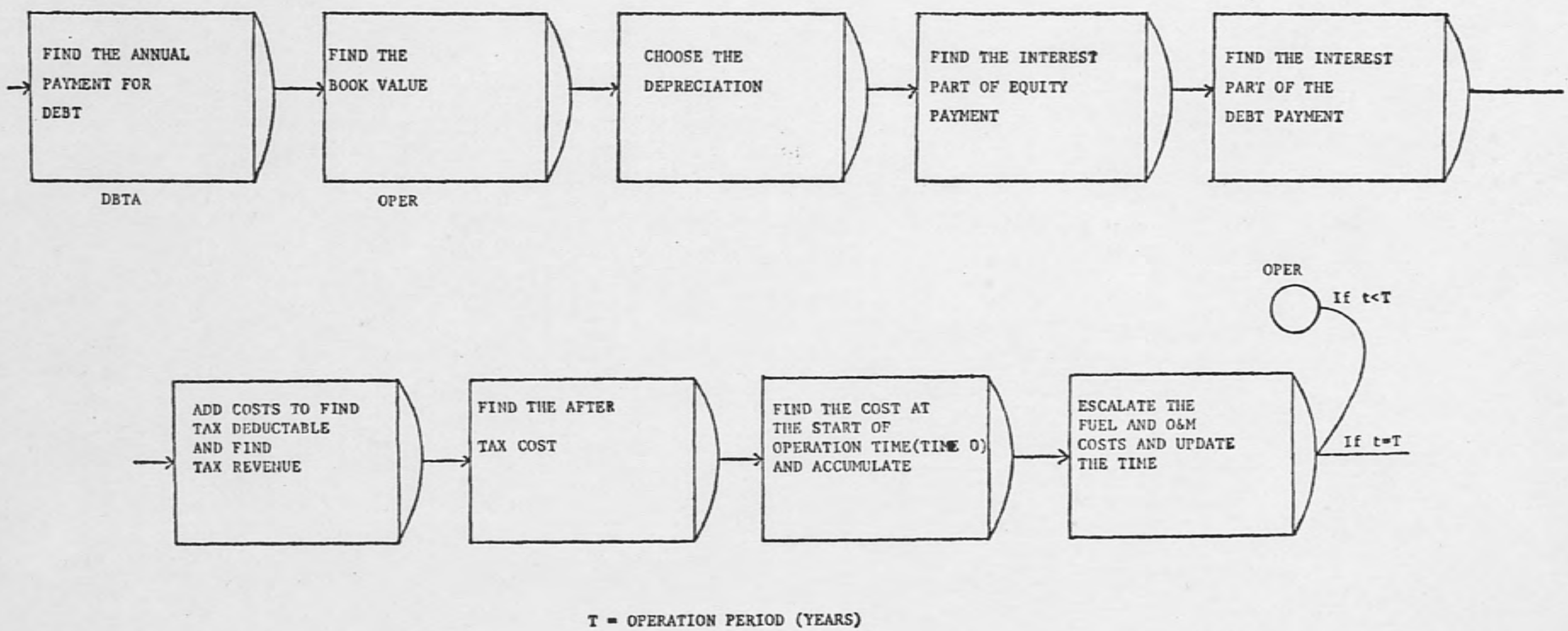


Fig. 11, (Continued)

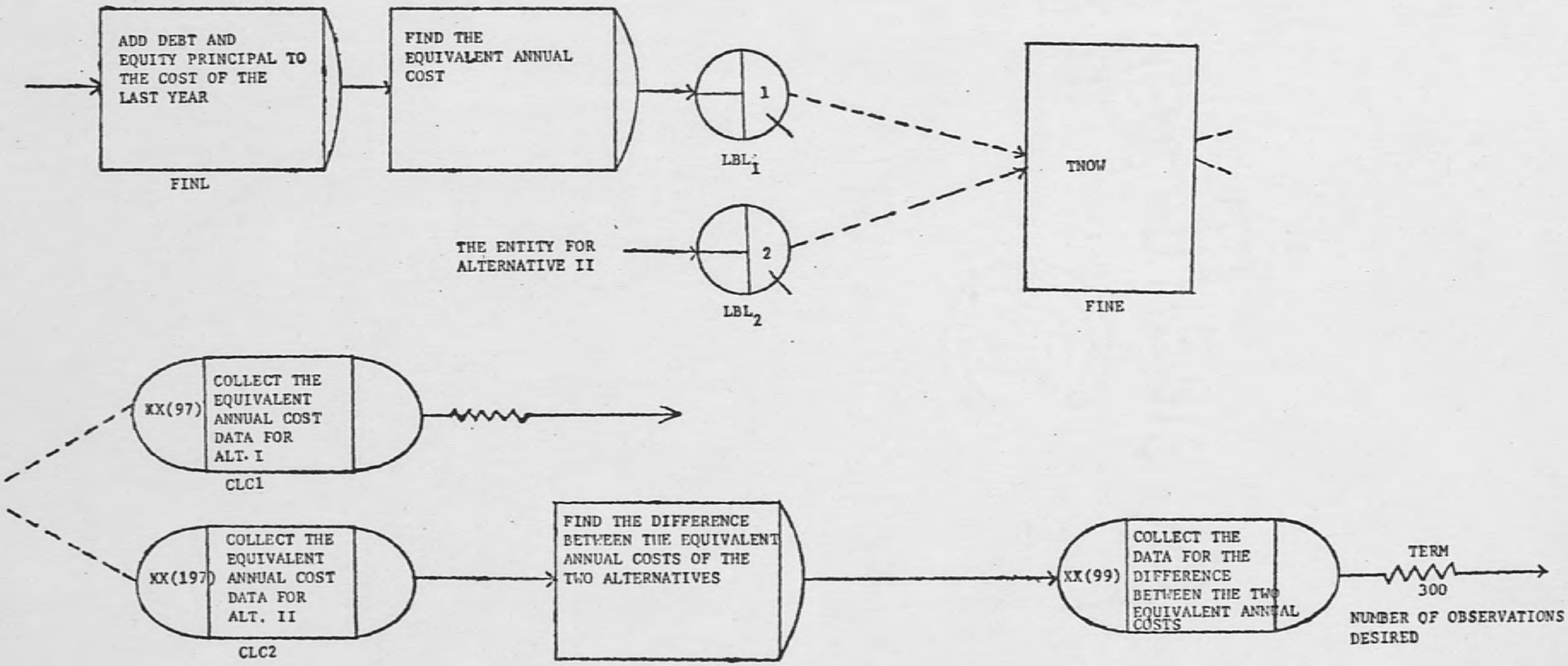


Fig. 11. (Continued)

entities with the equivalent annual cost statistics wait in file 2 at the LAB2 QUEUE node to be compared with those of alternative I.

In order to compare the two investment alternatives, a MATCH node holds entities in file 1 and file 2 and QUEUE nodes LAB1 and LAB2 until there is an entity in each QUEUE node that has an ATTRIBUTE 90 value that is the same. ATTRIBUTE 90 represents the mark time of both entities of alternatives I and II and their creation. This implies that the equivalent annual costs sampled from each alternative be compared in terms of their respective common sampling period. Once a match occurs, the entity associated with alternative I is routed to the COLCT node LAB2 while the entity associated with alternative II is routed to the node CLC_2 where statistics are collected on the equivalent annual cost. Following the node CLC_2, both entities arrive at the assign node (statement 815) where the difference equivalent annual costs is computed by XX(99) = XX(97) - XX(197). At the completion of the computation of the difference in equivalent annual cost, the entity arrives at the COLCT node where statistics are collected on the difference in annual equivalent costs. The 'TERM' statement then destroys the entity. The above process will repeat until the total number of entities to be processed on a simulation run reaches the number listed with TERM statement. The ENDNET statement denotes an end to the network description.

The model can be divided into four major segments. The first segment represents the initialization for all the data related to alternatives I (SNG) and II (oil) and consists of statements 9 through 89. Statements 9 through 14 are initializations for values subject to uncertainty related to alternative I where three estimates; "optimistic," "most likely," and "pessimistic," are assigned to global variables.

The second segment shows the Monte Carlo sampling process for equivalent annual cost for alternative I and consists of statements 91 through 554. In this segment, the costs during the construction and operational period are calculated and combined to give the result for the total cost for alternative I. The segment starts with the "NETWORK" statement, which is the first statement of the network.

In the first part of this segment, all the data subject to uncertainty are generated by the program. The following formulae show the relationship used for developing the distributions.

$$M = \frac{A\beta+B\alpha}{\alpha + \beta} \quad (2\text{-a})$$

$$E = A + \frac{(B-A)\ (\alpha+1)}{\alpha+\beta+2} = \frac{1}{6}\ (A+B+4M) \qquad (2\text{-b})$$

where M: The most likely value of the parameter.

A: The optimistic value of the parameter.

B: The pessimistic value of the parameter.

E: The expected value of the parameter.

α and β Parameters used to generative the beta distrubution by solving equations (2-a) and (2-b)

The values of α and β were found to be

$$\alpha = \frac{4(A-M)\ (A\ B-2M)}{A^2 - B^2 - 2M(A-B)}, \quad \beta = (\frac{M-B}{A-M})\ \alpha$$

These values were used in the SLAM statement, beta (α, β, 2) where 2 is the random number stream. The value generated by the computer is the $\frac{\alpha+1}{\alpha+\beta+2}$ portion of the equation (2-b), which is the mean of beta distribution and its value is between 0 and 1. Thus, the value of random variable would be:

$$E = A+(B-A).\ \ Beta(\alpha,\beta,2) \qquad (2\text{-}c)$$

The fuel cost is calculated by using equation (1-k) of Appendix I. Also, the O&M costs are found by applying expressions (1-ℓ-1) and (1-ℓ-2) of Appendix I. These costs are for the year when the construction begins and are escalated throughout the construction period. In the mathematical modeling explained in Chapter 3, different escalation rates were assumed for the fixed and variable portions of the O&M cost. However, based on the gathered data, a single escalation rate can be applied to both portions of the O&M cost and, in this study, the rate is determined by ATRIB (85).

The present worth of the construction cost is calculated by statements 225 through 336.

The costs to be incurred during the construction period are equity return, debt interest, insurance cost, and Ad valorem tax, which are tax deductible items. The tax savings for each year are calculated by equation (1-g). The present worth of the cost is calculated by multiplying the total construction cost of each year by a compound-amount factor to find the equivalent cost at the beginning of the operational period.

Calculation of the costs during the operational period from statement 345. The investment tax credit is received at the beginning of the operational period, and this is shown in statement 346.

This program is designed to calculate three types of depreciation. Straight line (ATRIB [31]), Sum of the Year's Digits (ATRIB [58]), and declining balance (ATRIB [53]) depreciation are calculated. Global variable XX (32) is related to straight line depreciation, and XX (33) and XX (34) correspond to declining line balance and sum of the year's digits, respectively. According to the depreciation policy adopted, one (1) is assigned to the respective global variable and zero (0) is assigned to the other two global variables. Statements 447 through 450 are for selection of the desired depreciation policy.

As discussed in Chapter 3, the equity and debt portion of the investment could be financed by equal annual payment policy or by issuing bonds. This program is designed with the flexibility of

handling all possible cases of financing the investment. The global variables XX(48) and XX(51) correspond to equity and debt portion of the investment, respectively. According to the financing policy, these global variables are initialized at the beginning of the program. If the equal annual payment policy is adopted, one (1); and if bonds are issued, zero (0) is assigned to the corresponding global variables. The interest paid for the debt portion of the investment is regarded as an expense and is a tax deductible expense. If the debt portion is financed by the equal annual payment policy, the interest portion of the payment should be calculated according to expression.

This is accomplished in the program by statements 461 through 467.

In Appendix I the costs incurred during the operational period are discussed in detail. The fuel cost, O&M cost, Ad valorem taxes, and the interest paid for the debt are tax deductible expenses. These are all added to the depreciation to get the total tax deductible expenses, and then tax savings for each year are determined (statements 474 through 481). The total after-tax cash flow during the operational period is multiplied by a discount factor to calculate the present worth at the time when the operation starts (statement 499). Then, all the values for the operation year are accumulated to find the total present worth of the investment.

The fuel and O&M costs are escalated by using the escalation rates which are generated at the earlier part of the program. Thus,

a single escalation rate is assumed for the whole period of plant operation.

The principal for the totalconstruction cost is paid back at the end of the operational period if the funds are financed by issuing bonds. Finally, the equivalent annual cost is found by multiplying the capital recovery factor by ATRIB (50), which is the present worth for the total cost during the construction and operational periods.

The third segment of the program represents the Monte Carlo sampling process for the equivalent annual cost of alternative II, which is compared with alternative I. This is identical to the above procedure and consists of statements 563 through 804.

The last segment of the program represents a collection of equivalent annual cost statistics for each alternative and comparison of the two alternatives. The statements 805 through 815 represent this operation. The specific explanations are as follows:

By representing one particular sequence of Monte Carlo sampling of cash flow realizations as an entity, these entities are generated by the "CREATE" node (statement 91) and are routed to the "ASSIGN" node. The entities with the equivalent annual cost statistics wait in file 1 at the LAB1 QUEUE node to be compared with an entity generated for alternative II. The identical simulation process is done for alternative II and the global variable XX(97) which carries the value of equivalent annual cost for alternative I can be interpreted as the counterpart of XX(197) for alternative II. The

SLAM

VERSION 1.0
RELEASE 1.0

PRITSKER AND ASSOCIATES, INC.

P.O. BOX 2413

WEST LAFAYETTE, INDIANA 47906

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STMT NO. MESSAGE
-
    4      IEF653I SUBSTITUTION JCL - PGM=SLAM500
IEF236I ALLOC. FOR SLAMII IRF4X
IEF237I 481  ALLOCATED TO STEPLIB
IEF237I 481  ALLOCATED TO SYS01400
IEF237I JES2 ALLOCATED TO FT05F001
IEF237I JES2 ALLOCATED TO FT06F001
IEF237I 383  ALLOCATED TO FT07F001
IEF142I SLAMII IRF4X - STEP WAS EXECUTED - COND CODE 0000
IEF285I   FTU.SS.IRLINK                                   KEPT
IEF285I   VOL SER NOS= FTUPK2.
IEF285I   SYSCTLG.VFTUPK2                                 KEPT
IEF285I   VOL SER NOS= FTUPK2.
IEF285I   JES2..CB01401.SI0101                            SYSIN
IEF285I   JES2..CB01401.SO0102                            SYSOUT
IEF285I   SYS81200.T213321.RA000.SLAMII.R0000001          DELETED
IEF285I   VOL SER NOS= SYSWK3.
IEF373I STEP /IRF4X   / START 81200.2133
IEF374I STEP /IRF4X   / STOP  81200.2138 CPU    1MIN 06.53SEC SRB    0MIN 04.04SEC VIRT   396K SYS   216K
IEF375I  JOB /SLAMII  / START 81200.2133
IEF376I  JOB /SLAMII  / STOP  81200.2138 CPU    1MIN 06.53SEC SRB    0MIN 04.04SEC
****************************************************************************************************
   JOB PERFORMANCE ANALYSIS AND CHARGES FOR USE OF C.F.R.D.C.                    SYSID- IP01   RELEASE-

    JOBNAME -  SLAMII        PROJECT NO. - 20206001000     DATE - 07/19/81    JOB CLASS - 5
      21:32:25 STARTED           21:38:25 ENDED         00:06:00 ELAPSED      00:05:03 NET TIME           JOB PRTY

   JOB STEP(S)                                 1               $     0.00
   JOB(S) SUBMITTED                            1               $     0.07
   SECONDS CPU TIME(TCB)                   66.53               $     7.98
   1K-SECONDS MEMORY                   26,345.88               $    25.02
   DISK I/O OPERATIONS (EXCPS)             5,042               $     1.00
   CARDS READ IN                             820               $     0.14

   TOTAL JOB CHARGE     $    34.21     PROJECT BALANCE         $   185.07
****************************************************************************************************
****************************************************************************************************
```

```
GEN,MEDI,EXERCISE,09/20/81,1;
LIMITS,2,50,200;
;
;
;          ***********************************************************************
;                      INITIALIZATION FOR ALTERNATIVE   I
;
;********************VARIABLES SUBJECT TO UNCERTAINTY *************************
INTLC,XX(74)=1000 ,XX(73)=1300 ,XX(83)=1500 ; CONST.COST
INTLC,XX(18)=1.3  ,XX(19)=1.6  ,XX(20)=1.75; FUEL COST
INTLC,XX(80)=35,XX(86)=50,XX(88)=57 ; O&M COST(FIXED)
INTLC,XX(28)=0.0060,XX(29)=0.0096,XX(30)=0.0115 ; O&M COST(VARIB.)
INTLC,XX(37)=0.030,XX(39)=0.070,XX(24)=0.09 ; O&M ESC.RATE
INTLC,XX(93)=0.05 ,XX(94)=0.07 ,XX(95)=0.12 ;FUEL ESC.RATE
;          ***********************************************************************
;;      *******************VARIABLES ESTIMATED WITH CERTAINTY ******************
;
INTLC,XX(26)=25 ; OP.LIFE
;
INTLC,XX(66)=20 ;DEP.LIFE
;
INTLC,XX(27)=0.1 ; INV.TAX CREDIT
;
INTLC,XX(2)=0.50 ;TAX RATE
;
INTLC,XX(16)=4 ; CONST.PERIOD
;
INTLC,XX(5)=0.005 ; PROPERTY TAX
;
INTLC,XX(6)=0.001 ; INSURANCE RATE
;
INTLC,XX(32)=1,XX(33)=0,XX(34)=0 ;STRAIGHT LINE DEP.
;
INTLC,XX(77)=-0.005 ; SALVAGE VALUE(%OF INIT. VALUE)
;
INTLC,XX(78)=10000 ; HEAT RATE
;
INTLC,XX(82)=0.90 ;LOAD FACTOR
;
INTLC,XX(90)=1000000,XX(300)=0 ; PLANT SIZE(KW)
;
INTLC,XX(51)=0;DEBT:BOND TYPE
;
INTLC,XX(48)=1 ; EQUITY:EQUAL ANNUAL PAYMENTS
;
INTLC,XX(1)=1.12 ; 1+INTEREST RATE
;
INTLC,XX(3)=0.15 ;EQUITY RETURN
;
INTLC,XX(4)=0.09 ;DEBT INT.RATE
;
INTLC,XX(11)=0.50 ;DEBT PORTION OF INVEST.
;
INTLC,XX(12)=0.10 ;PORTION TO BE CONSTRUCTED BY THE END OF YEAR1
;
;
INTLC,XX(13)=0.22; PORTION TO BE CONSTRUCTED BY THE END OF YEAR2
;
INTLC,XX(14)=0.74; PORTION TO BE CONSTRUCTED BY THE END OF YEAR3
;
INTLC,XX(15)=1.00; PORTION TO BE CONSTRUCTED BY THE END OF YEAR4
;
INTLC,XX(58)=0,XX(59)=0,XX(60)=0,XX(62)=0; REMAINING YRS
;
INTLC,XX(35)=0.10;DECLING BALANCE DEP.FACTOR
;
INTLC,XX(7)=0,XX(8)=0,XX(36)=1 ; INITIALIZATIONS
;
INTLC,XX(498)=0.70 ; THE EFFICIENCY OF COAL CONVERSION TO GAS
;          ***********************************************************************
```

```
;                      INITIALIZATION FOR ALTERNATIVE II
;      ******************************************************************************
INTLC,XX(174)=490,XX(173)=540,XX(183)=585;  CONSTRUCTION COST
INTLC,XX(118)=2.4 ,XX(119)=3.1 ,XX(120)=3.5 ;     FUEL COST
INTLC,XX(180)=1.55 ,XX(186)=1.90,XX(188)=2.10 ; O&M COST(FIXED)
INTLC,XX(128)=0.0024,XX(129)=0.003,XX(130)=0.0035 ;    O&M COST (VRBL.)
INTLC,XX(137)=0.06 ,XX(139)=0.08 ,XX(124)=0.12 ;  ESC. RATE (O&M)
INTLC,XX(193)=0.045,XX(194)=0.0725,XX(195)=0.090 ; FUEL ESC.RATE
INTLC,XX(126)=25,XX(166)=20,XX(127)=0.05,XX(102)=0.50,XX(116)=4;
INTLC,XX(105)=0.005,XX(106)=0.001,XX(132)=1,XX(133)=0,XX(134)=0 ;
INTLC,XX(177)=-0.005,XX(178)=9500,XX(182)=0.90,XX(190)=1000000 ;
INTLC,XX(400)=0,XX(151)=0,XX(148)=1,XX(101)=1.12,XX(103)=0.15;
INTLC,XX(104)=0.09 ,XX(111)=0.50 ,XX(112)=0.15,XX(113)=0.35 ,XX(114)=0.65;
INTLC,XX(115)=1.0,XX(158)=0,XX(159)=0,XX(160)=0,XX(161)=0,XX(162)=0;
INTLC,XX(135)=0.10,XX(107)=0,XX(108)=0,XX(136)=1;
;      ******************************************************************************
;          CONSTANTS USED FOR ADJUSTING ESCALATION RATES
INTLC,XX(279)=1,XX(273)=1 ,XX(285)=1 ,XX(284)=1 ,XX(281)=1 ,  XX(282)=1      ;
INTLC,XX(379)=1,XX(373)=1 ,XX(385)=1 ,XX(384)=1 ,XX(381)=1 ,  XX(382)=1      ;
;      ******************************************************************************
NETWORK;
      CREATE,1;
      ASSIGN,ATRIB(90)=TNOW;
;
;
;                      THIS PART GENERATES DATA BY BETA DISTRIBUTION
;   *********************     CONSTRUCTION COST      ********************************
      ASSIGN,ATRIB(1)=XX(74)-XX(73),ATRIB(2)=XX(74)+XX(83),
      ATRIB(3)=XX(73)*2,ATRIB(4)=ATRIB(2)-ATRIB(3);
      ASSIGN,ATRIB(4)=ATRIB(4)*ATRIB(1),ATRIB(4)=ATRIB(4)*4;
      ASSIGN,ATRIB(5)=XX(74)*XX(74),ATRIB(6)=XX(83)*XX(83);
      ASSIGN,ATRIB(6)=ATRIB(5)-ATRIB(6),ATRIB(7)=XX(74)-XX(83);
      ASSIGN,ATRIB(7)=ATRIB(7)*ATRIB(3),ATRIB(7)=ATRIB(6)-ATRIB(7),
      ATRIB(8)=ATRIB(4)/ATRIB(7),ATRIB(9)=XX(73)-XX(83);
      ASSIGN,ATRIB(9)=ATRIB(9)/ATRIB(1),ATRIB(10)=ATRIB(8)*ATRIB(9);
      ASSIGN,XX(92)=ATRIB(8),XX(87)=ATRIB(10),
      XX(89)=BETA(XX(92),XX(87),2),XX(81)=XX(83)-XX(74);
      ASSIGN,XX(81)=XX(81)*XX(89),XX(21)=XX(81)+XX(74);
      ASSIGN,ATRIB(73)=XX(21)*XX(90);
      ASSIGN,ATRIB(73)=ATRIB(73)*XX(273) ;
;   *********************         FUEL COST          ********************************
      ASSIGN,ATRIB(1)=XX(18)-XX(19),ATRIB(2)=XX(18)+XX(20),
      ATRIB(3)=XX(19)*2;
      ASSIGN,ATRIB(4)=ATRIB(2)-ATRIB(3),ATRIB(4)=ATRIB(4)*ATRIB(1),
      ATRIB(4)=ATRIB(4)*4;
      ASSIGN,ATRIB(5)=XX(18)*XX(18),ATRIB(6)=XX(20)*XX(20),
      ATRIB(6)=ATRIB(5)-ATRIB(6),ATRIB(7)=XX(18)-XX(20);
      ASSIGN,ATRIB(7)=ATRIB(7)*ATRIB(3),ATRIB(7)=ATRIB(6)-ATRIB(7),
      ATRIB(8)=ATRIB(4)/ATRIB(7);
      ASSIGN,ATRIB(9)=XX(19)-XX(20),
      ATRIB(9)=ATRIB(9)/ATRIB(1),ATRIB(10)=ATRIB(8)*ATRIB(9);
      ASSIGN,XX(92)=ATRIB(8),XX(87)=ATRIB(10),
      XX(89)=BETA(XX(92),XX(87),2);
      ASSIGN,XX(81)=XX(20)-XX(18),XX(81)=XX(81)*XX(89),
      ATRIB(79)=XX(81)+XX(18);
      ASSIGN,ATRIB(79)=ATRIB(79)*XX(279);
;   *********************       O&M COST(FIXED)      ********************************
      ASSIGN,ATRIB(1)=XX(80)-XX(86),ATRIB(2)=XX(80)+XX(88),
      ATRIB(3)=XX(85)*2;
      ASSIGN,ATRIB(4)=ATRIB(2)-ATRIB(3),ATRIB(4)=ATRIB(4)*ATRIB(1),
      ATRIB(4)=ATRIB(4)*4;
      ASSIGN,ATRIB(5)=XX(90)*XX(80),ATRIB(6)=XX(88)*XX(88),
      ATRIB(6)=ATRIB(5)-ATRIB(6),ATRIB(7)=XX(80)-XX(88);
      ASSIGN,ATRIB(7)=ATRIB(7)*ATRIB(3),ATRIB(7)=ATRIB(6)-ATRIB(7),
      ATRIB(8)=ATRIB(4)/ATRIB(7);
      ASSIGN,ATRIB(9)=XX(86)-XX(88),
      ATRIB(9)=ATRIB(9)/ATRIB(1),ATRIB(10)=ATRIB(8)*ATRIB(9);
      ASSIGN,XX(92)=ATRIB(8),XX(87)=ATRIB(10),
      XX(89)=BETA(XX(92),XX(87),2);
      ASSIGN,XX(81)=XX(88)-XX(80),XX(81)=XX(81)*XX(89),
      ATRIB(81)=XX(31)+XX(80);
      ASSIGN,ATRIB(81)=ATRIB(81)*XX(281) ;
```

```
;    ********************     O&M COST(=VRBL.)     ******************************
       ASSIGN,ATRIB(1)=XX(28)-XX(29),ATRIB(2)=XX(28)+XX(30),
       ATRIB(3)=XX(29)*2;
       ASSIGN,ATRIB(4)=ATRIB(2)-ATRIB(3),ATRIB(4)=ATRIB(4)*ATRIB(1),
       ATRIB(4)=ATRIB(4)*4;
       ASSIGN,ATRIB(5)=XX(28)*XX(28),ATRIB(6)=XX(30)*XX(30),
       ATRIB(6)=ATRIB(5)-ATRIB(6),ATRIB(7)=XX(28)-XX(30);
       ASSIGN,ATRIB(7)=ATRIB(7)*ATRIB(3),ATRIB(7)=ATRIB(6)-ATRIB(7),
       ATRIB(8)=ATRIB(4)/ATRIB(7);
       ASSIGN,ATRIB(9)=XX(29)-XX(30),
       ATRIB(9)=ATRIB(9)/ATRIB(1),ATRIB(10)=ATRIB(8)*ATRIB(9);
       ASSIGN,XX(92)=ATRIB(8),XX(87)=ATRIB(10),
       XX(89)=BETA(XX(92),XX(87),2);
       ASSIGN,XX(81)=XX(30)-XX(28),XX(81)=XX(81)*XX(89),
       ATRIB(82)=XX(81)+XX(28);
       ASSIGN,ATRIB(82)=ATRIB(82)*XX(282) ;
;    ********************     O&M ESC.RATE          ******************************
       ASSIGN,ATRIB(1)=XX(37)-XX(39),ATRIB(2)=XX(37)+XX(24),
       ATRIB(3)=XX(39)*2,;
       ASSIGN,ATRIB(4)=ATRIB(2)-ATRIB(3),ATRIB(4)=ATRIB(4)*ATRIB(1),
       ATRIB(4)=ATRIB(4)*4;
       ASSIGN,ATRIB(5)=XX(37)*XX(37),ATRIB(6)=XX(24)*XX(24),
       ATRIB(6)=ATRIB(5)-ATRIB(6),ATRIB(7)=XX(37)-XX(24);
       ASSIGN,ATRIB(7)=ATRIB(7)*ATRIB(3),ATRIB(7)=ATRIB(6)-ATRIB(7),
       ATRIB(8)=ATRIB(4)/ATRIB(7);

       ASSIGN,ATRIB(9)=XX(39)-XX(24),
       ATRIB(9)=ATRIB(9)/ATRIB(1),ATRIB(10)=ATRIB(8)*ATRIB(9);
       ASSIGN,XX(92)=ATRIB(8),XX(87)=ATRIB(10),
       XX(89)=BETA(XX(92),XX(87),2);
       ASSIGN,XX(81)=XX(24)-XX(37),XX(81)=XX(81)*XX(89),
       ATRIB(85)=XX(81)+XX(37);
       ASSIGN,ATRIB(85)=ATRIB(85)*XX(285) ;
;    ********************     FUEL ESC. RATE        ******************************
       ASSIGN,ATRIB(1)=XX(93)-XX(94),ATRIB(2)=XX(93)+XX(95),
       ATRIB(3)=XX(94)*2;
       ASSIGN,ATRIB(4)=ATRIB(2)-ATRIB(3),ATRIB(4)=ATRIB(4)*ATRIB(1),
       ATRIB(4)=ATRIB(4)*4;
       ASSIGN,ATRIB(5)=XX(93)*XX(93),ATRIB(6)=XX(95)*XX(95),
       ATRIB(6)=ATRIB(5)-ATRIB(6),ATRIB(7)=XX(93)-XX(95);
       ASSIGN,ATRIB(7)=ATRIB(7)*ATRIB(3),ATRIB(7)=ATRIB(6)-ATRIB(7),
       ATRIB(8)=ATRIB(4)/ATRIB(7);
       ASSIGN,ATRIB(9)=XX(94)-XX(95),
       ATRIB(9)=ATRIB(9)/ATRIB(1),ATRIB(10)=ATRIB(8)*ATRIB(9);
       ASSIGN,XX(92)=ATRIB(8),XX(87)=ATRIB(10),
       XX(89)=BETA(XX(92),XX(87),2);
       ASSIGN,XX(81)=XX(95)-XX(93),XX(81)=XX(81)*XX(89),
       ATRIB(84)=XX(81)+XX(93);
       ASSIGN,ATRIB(84)=ATRIB(84)*XX(284) ;
;
;
;
;        ***********************************************************************
;                                        FIND THE FUEL COST
;
       ASSIGN,ATRIB(77)=XX(78),
       ATRIB(78)=XX(82),
              XX(22)=ATRIB(77)*ATRIB(78),
              XX(22)=XX(22)*ATRIB(79) ,
              XX(22)=XX(22)*XX(90),XX(22)=XX(22)*0.00876 ;
       ASSIGN,XX(22)=XX(22)/XX(498); ADJUSTMENT FOR EFFICIENCY OF PROCESS
;
;         XX(22) IS THE FUEL COST (1980)
;
;       ***********************************************************************
;                                        FIND THE O&M COST
       ASSIGN,XX(23)=ATRIB(81)*XX(90),
              ATRIB(83)=ATRIB(82)*ATRIB(78),
              ATRIB(83)=ATRIB(83)*8760,
              ATRIB(83)=ATRIB(83)*XX(90);
       ASSIGN,XX(23)=ATRIB(83)+XX(23);
;           VALUE OF BY-PRODUCTS
       ASSIGN,XX(499)=RNORM(15.7,5,2),
              XX(499)=XX(499)*XX(82),
              XX(499)=XX(499)*XX(90),
              XX(23)=XX(23)-XX(499);
;         XX(23) IS THE TOTAL O&M COST LESS THE REVENUES FROM BY-PRODUCTS
```

```
      ;         *********************************************************************
      ;         *********************************************************************
      ;                       ***THIS PART OF THE PROGRAM  CALCULATES THE TOTAL COST
      ;                          DURING THE CONSTRUCTION PERIOD
      ;         *********************************************************************
      ;         *********************************************************************
           ASSIGN,XX(9)=ATRIB(84)+1,
                  XX(10)=ATRIB(85)+1;
      ;
      ;         *********************************************************************
      ;                                         THE PERCENTAGE OF CONSTRUCTION PER YEAR
           ASSIGN,ATRIB(20)=XX(12),
           ATRIB(1)=XX(1),
           ATRIB(61)=1,
                  ATRIB(65)=1,
                  ATRIB(71)=1,
                  ATRIB(2)=2;
           ASSIGN,ATRIB(24)=XX(22),
                  ATRIB(24)=ATRIB(24)*XX(9),
                  ATRIB(24)=ATRIB(24)*XX(9),
           ATRIB(25)=XX(23),
                  ATRIB(25)=ATRIB(25)*XX(10),
                  ATRIB(25)=ATRIB(25)*XX(10);
           ASSIGN,XX(21)=XX(300)*ATRIB(73),XX(21)=XX(21)+ATRIB(73),
                  XX(25)=XX(21)*XX(77);
      ;       XX(300) IS THE ADJUSTING FACTOR FOR CONSTRUCTION COST
      ;       XX(25) IS THE SALVAGE VALUE
      ;         *********************************************************************
      ;                                         THE FACTOR TO BRING THE COST TO TIME '0'
DETC       ASSIGN,ATRIB(2)=ATRIB(2)+1,
           ATRIB(3)=XX(1),
                  ATRIB(24)=ATRIB(24)*XX(9),
                  ATRIB(25)=ATRIB(25)*XX(10),
           ATRIB(19=XX(1)*ATRIB(1);
      ;
      ;       AT(24) IS THE ESCALATED FUEL COST AT THE START OF OPERATION YEAR
      ;       AT(25) IS THE ESCALATED O&M COST AT THE START OF OPERATION YEAR
      ;
           ACT,,ATRIB(2).LT.XX(16),DETC;
           ACT,,ATRIB(2).GE.XX(16),BACK;
      ;
      ;
      ;         *********************************************************************
      ;                                         THE CONSTRUCTION COST PER YEAR
BACK       ASSIGN,ATRIB(4)=XX(21)*ATRIB(20);
           ASSIGN,ATRIB(5)=XX(11)*ATRIB(4),
           ATRIB(6)=ATRIB(4)-ATRIB(5),
           ATRIB(7)=ATRIB(5)*XX(4),
           ATRIB(8)=ATRIB(6)*XX(3);
      ;
      ;
      ;       AT(5) IS THE DEBT PORTION AND AT(6) IS THE EQUITY PORTION
      ;
      ;         *********************************************************************
      ;                                         FIND THE INSURANCE COST AND ADD DEBT
      ;                                         INTEREST TO PROPERTY TAX TO GET TAXABLE
      ;
           ASSIGN,ATRIB(9)=ATRIB(4)*XX(6),
           ATRIB(10)=ATRIB(9)*XX(1),
           ATRIB(11)=ATRIB(4)*XX(5),
           ATRIB(12)=ATRIB(7)+ATRIB(11);
      ;
      ;       AT(10) IS THE YEARLY INSURANCE PAID
      ;       AT(12) IS THE TAX DEDUCTABLE AMOUNT
      ;
      ;         *********************************************************************
      ;                                         ADD THE COSTS
           ASSIGN,ATRIB(13)=ATRIB(12)*XX(2),
           ATRIB(14)=ATRIB(8),
           ATRIB(14)=ATRIB(14)+ATRIB(10),
           ATRIB(14)=ATRIB(14)+ATRIB(12);
      ;
      ;       AT(13) IS THE TAX REVENUE
      ;
      ;         *********************************************************************
```

```
;                                       FIND THE COST AFTER TAXES AT YEAR '0'
        ASSIGN,ATRIB(14)=ATRIB(14)-ATRIB(13),
        ATRIB(15)=ATRIB(14)*ATRIB(1),
        ATRIB(16)=ATRIB(16)+ATRIB(15),
        ATRIB(1)=ATRIB(1)/XX(1);
;
;          AT(16) IS THE CUM.CONST.COST AT YEAR '0'
;
;          ***********************************************************************
;                                       THE YEARS OF CONSTRUCTION
        ASSIGN,ATRIB(17)=ATRIB(17)+1;
;
        ACT,,ATRIB(17).LT.XX(16),TEST;
        ACT,,ATRIB(17).GE.XX(16),FWRD;
;
TEST    GOON,8;
        ACT,,ATRIB(17).EQ.1,SUB1;
        ACT,,ATRIB(17).EQ.2,SUB2;
        ACT,,ATRIB(17).EQ.3,SUB3;
        ACT,,ATRIB(17).EQ.4,SUB4;
        ACT,,ATRIB(17).EQ.5,SUB5;
        ACT,,ATRIB(17).EQ.6,SUB6;
        ACT,,ATRIB(17).EQ.7,SUB7;
        ACT,,ATRIB(17).EQ.8,SUB8;
;
;          ***********************************************************************
;                                       FIND THE TOTAL CONSTRUCTION AT YEAR END
SUB1    ASSIGN,ATRIB(20)=XX(13);
        ACT,,,BACK;
SUB2    ASSIGN,ATRIB(20)=XX(14);
        ACT,,,BACK;
SUB3    ASSIGN,ATRIB(20)=XX(15);
        ACT,,,BACK;
SUB4    ASSIGN,ATRIB(20)=XX(58);
        ACT,,,BACK;
SUB5    ASSIGN,ATRIB(20)=XX(59);
        ACT,,,BACK;
SUB6    ASSIGN,ATRIB(20)=XX(60);
        ACT,,,BACK;
SUB7    ASSIGN,ATRIB(20)=XX(61);
          ACT,,,BACK;
SUB8    ASSIGN,ATRIB(20)=XX(62);

        ACT,,,BACK;
;
;          AT(20) IS THE CUM.PORTION OF THE PROJECT CONSTRUCTED AT THE END OF YEAR
;
;          ***********************************************************************
;                        ***THIS PART OF THE PROGRAM CALCULATES THE TOTAL COST
;                           DURING THE OPERATION PERIOD
;          ***********************************************************************
;
FWRD    ASSIGN,ATRIB(27)=XX(27)*XX(21),
        ATRIB(16)=ATRIB(16)-ATRIB(27),
        ATRIB(26)=ATRIB(6),
        ATRIB(34)=XX(21);
;
 ;         AT(27) IS THE INVESTMENT TAX CREDIT @IS DEDUCTED FROM TOTAL COST
;
;          ***********************************************************************
;                                       FIND THE DEPRECIATION
        ASSIGN,ATRIB(30)=XX(21)-XX(25),
               ATRIB(76)=ATRIB(30),
               XX(76)=XX(66),
               ATRIB(31)=ATRIB(30)/XX(66),
               ATRIB(51)=XX(35),
        ATRIB(52)=XX(36)-ATRIB(51);
        ASSIGN,ATRIB(56)=XX(66),
                     ATRIB(54)=XX(66)+XX(36),
                     ATRIB(55)=ATRIB(54)*XX(66),
               ATRIB(55)=ATRIB(55)/2;
```

```
;        AT(30) IS (P-L) FOR SLD&AT(55) IS N(N+1)/2 FOR SYC DEPRECIATION
;        *****************************************************************
;                                          CHECK FOR TYPE OF EQUITY
;
      ACT,,XX(48).EQ.0,BETA;
      ACT,,XX(48).EQ.1,ALFA;
;        **********************************************************  ******
;                                          WHEN EQUITY IS BOND TYPE FIND YRLY INTRST
BETA  ASSIGN,ATRIB(64)=ATRIB(6)*XX(3),
      ATRIB(63)=ATRIB(6);
      ACT,,,NEXT;
;
;        AT(64) IS THE YEARLY INTEREST FOR THE EQUITY
;        *****************************************************************
;                                          WHEN EQUITY IS EQUAL ANNUAL PYMNT TYPE
;                                          FIND THE ANNUAL PAYMENT
ALFA  ASSIGN,XX(40)=XX(3)+1,
              XX(41)=XX(3)+1;
EQIT  ASSIGN,ATRIB(61)=ATRIB(61)+1,
      XX(41)=XX(41)*XX(40);
      ACT,,ATRIB(61).LT.XX(26),EQIT;
      ACT,,ATRIB(61).GE.XX(26),EQCT;
EQCT  ASSIGN,XX(42)=XX(41)-1,
      XX(43)=XX(41)*XX(3),
      XX(44)=XX(43)/XX(42),
      ATRIB(36)=ATRIB(6)*XX(44);
      ASSIGN,XX(45)=ATRIB(6)*XX(3),
      XX(46)=XX(45)-ATRIB(36),
      ATRIB(62)=XX(40)/XX(40);
;
;        AT(36) IS ANNUAL PAYMENT (A=INTRST+PRINCP.)&XX(46) IS(P*I-A)
;
;        *****************************************************************
;                                          CHECK FOR TYPE OF DEBT
NEXT  GOON,2;
      ACT,,XX(51).EQ.0,DBTB;
      ACT,,XX(51).EQ.1,DBTA;
;
;        *****************************************************************
;                                          WHEN DEBT IS BOND TYPE FIND YRLY INTRST
DBTB  ASSIGN,ATRIB(66)=ATRIB(5)*XX(4),
              ATRIB(67)=ATRIB(5);
      ACT,,,OPER;
;
;        AT(66) IS THE YEARLY INTEREST FOR THE DEBT
;
;        *****************************************************************
;                                          WHENDEBT IS EQUAL ANNUAL PAYMENT TYPE
;                                          FIND THE ANNUAL PAYMENT
DBTA  ASSIGN,XX(45)=XX(4)+1,
              ATRIB(7)=0,
              XX(50)=XX(4)+1;
REDO  ASSIGN,ATRIB(65)=ATRIB(65)+1,
              XX(50)=XX(50)*XX(49);
      ACT,,ATRIB(65).LT.XX(26),REDO;
      ACT,,ATRIB(65).GE.XX(26),CALC;


CALC  ASSIGN,XX(52)=XX(50)-1,
              XX(53)=XX(50)*XX(4),
              XX(54)=XX(53)/XX(52),
              ATRIB(68)=ATRIB(5)*XX(54);
      ASSIGN,XX(55)=ATRIB(5)*XX(4),
              XX(56)=XX(55)-ATRIB(68),
              ATRIB(69)=XX(49)/XX(49);
;
;        AT(68) IS ANNUAL PAYMNT FOR DEBT @INCLUDES INTRST  AND XX(56)=P*I-A
;
;        *****************************************************************
OPER  ASSIGN,ATRIB(56)=XX(66)-ATRIB(46),
              ATRIB(57)=ATRIB(56)/ATRIB(55),
              ATRIB(58)=ATRIB(57)*ATRIB(30);
;
;        AT(58) IS SYC DEPRETIATION
```

```
;
        ASSIGN,ATRIB(31)=ATRIB(76)/XX(76),
               ATRIB(76)=ATRIB(76)-ATRIB(31),
               XX(76)=XX(76)-1;
        ACT,,XX(76).LE.0.,CRCT;
        ACT,,XX(76).GT.0.,OKEY;
CRCT    ASSIGN,XX(76)=1,
               XX(33)=0;
;          AT(31) IS THE SLD @AT(76) IS THE BOOK VALUE
;          *************************************************************
;                                    CHOOSE THE PROPER DEPRECIATION
OKEY    ASSIGN,ATRIB(53)=XX(21)*ATRIB(51),
               ATRIB(53)=ATRIB(53)*XX(33),
               ATRIB(58)=ATRIB(58)*XX(34),
               ATRIB(31)=ATRIB(31)*XX(32);
;
;          ******************************************************************
;                                          FINT INTRST PART OF EQUITY PAYMNT,AT(37)
        ASSIGN,ATRIB(37)=XX(46)*ATRIB(62),
        ATRIB(37)=ATRIB(37)+ATRIB(36),
        XX(47)=ATRIB(36)-ATRIB(37);
;
;          AT(37) IS THE INTERST(I) AND XX(47) IS THE PRINCIPAL (P-I)
;          ******************************************************************
;                                          FIND INTRST PART OF DEBT PAYMNT,AT(70)
        ASSIGN,ATRIB(70)=XX(56)*ATRIB(69),
               ATRIB(70)=ATRIB(70)+ATRIB(68),
               XX(57)=ATRIB(68)-ATRIB(70);
        ASSIGN,ATRIB(34)=ATRIB(34)-ATRIB(31),
               ATRIB(34)=ATRIB(34)-ATRIB(53),
               ATRIB(34)=ATRIB(34)-ATRIB(58),
        ATRIB(35)=ATRIB(34)*XX(5);
;
;          XX(57) IS (A-I),THE PTINCP. PAID  FOR DEBT
;
;          ******************************************************************
;                                          ADD FUEL COST,O&M,PROPERTY TAX AND
;                                          DEPRETITTION  TO FIND TAX DEDUCTABLE
        ASSIGN,ATRIB(40)=ATRIB(24)+ATRIB(25),
        ATRIB(40)=ATRIB(40)+ATRIB(7),
               ATRIB(40)=ATRIB(40)+ATRIB(70),
        ATRIB(40)=ATRIB(40)+ATRIB(35),
        ATRIB(41)=ATRIB(40)+ATRIB(31),
               ATRIB(41)=ATRIB(41)+ATRIB(58),
               ATRIB(41)=ATRIB(41)+ATRIB(53),
        ATRIB(42)=ATRIB(41)*XX(2);
;
;          AT(41) IS TAX DEDUCTABLE @ AT(42) IS THE TAX REVENUE
;
;          ******************************************************************
;                                          ADD FUEL COST,O&M,PROP.TAX,DEBT INTRST @
;                                          EQUITY RETURN TO FIND THE TOTAL COST AND
;                                          FIND THE AFTER TAX COST
        ASSIGN,ATRIB(40)=ATRIB(40)+ATRIB(10),
        ATRIB(40)=ATRIB(40)+ATRIB(36),
        ATRIB(40)=ATRIB(40)+ATRIB(54),
               ATRIB(40)=ATRIB(40)+XX(57),
        ATRIB(40)=ATRIB(40)-ATRIB(42);
;
;          AT(40) IS THE AFTER TAX COST AT THE END OF EACH YEAR
;
;          ******************************************************************
;                                          BRING THE COST TO TIME '0' AND ACCUMILATE
        ASSIGN,ATRIB(43)=ATRIB(40)/ATRIB(3),
        ATRIB(62)=ATRIB(62)*XX(40),
        ATRIB(69)=ATRIB(69)*XX(49),
        ATRIB(45)=ATRIB(45)+ATRIB(43);
;
```

```
;        AT(43) IS THE COST AT YEAR '0' AND AT(45) IS THE CUM.TOTAL COST
;
;        ************************************************************************
;                                      ESCALATE THE FUEL AND O&M COSTS
      ASSIGN,ATRIB(24)=ATRIB(24)*XX(9),
      ATRIB(25)=ATRIB(25)*XX(10),
      ATRIB(26)=ATRIB(26)-ATRIB(35),
              ATRIB(51)=ATRIB(51)*ATRIB(52),
      ATRIB(3)=ATRIB(3)*XX(1);
;
;        AT(3)=(1+I)**N FOR DISCOUNT FACTOR
;
;
;        ************************************************************************
;
;                                      CHECK FOR END OF OPERATION YEARS
      ASSIGN,ATRIB(46)=ATRIB(46)+1 ;
      ACT,,ATRIB(46).LT.XX(26),OPER;
      ACT,,ATRIB(46).GE.XX(26),FINL;
;        ************************************************************************
;
;                                      DEBT MONEY PAID BACK
FINL  ASSIGN,ATRIB(47)=ATRIB(3)/XX(1),
              ATRIB(67)=ATRIB(67)+ATRIB(63),
              ATRIB(67)=ATRIB(67)-XX(25),
              ATRIB(48)=ATRIB(67)/ATRIB(47),
      ATRIB(49)=ATRIB(45)+ATRIB(48),
      ATRIB(50)=ATRIB(49)+ATRIB(16);
;
;        AT(67) IS THE DEBT PRINCP.&AT(63) IS THE EQUITY PRINCP.
;
;        AT(50) IS THE TOTAL COST:OPERATION+CONSTRUCTION
;
;        ************************************************************************
;                                      THIS PART OF THE PROGRAM FINDS THE ANNUAL
;                                      EQUIVALENT COST OF THE PLANT
;
;        ************************************************************************
;
      ASSIGN,XX(67)=XX(1)-1,
              XX(69)=XX(1);
LAST  ASSIGN,ATRIB(71)=ATRIB(71)+1,
              XX(65)=XX(65)*XX(1);
      ACT,,ATRIB(71).LT.XX(26),LAST;
      ACT,,ATRIB(71).GE.XX(26),EDAM;
EDAM  ASSIGN,XX(70)=XX(67)*XX(69),
      XX(71)=XX(69)-1,
      XX(72)=XX(70)/XX(71),
              ATRIB(75)=XX(72),
              ATRIB(72)=ATRIB(50)*XX(72),
              XX(97)=ATRIB(72);
;
;        AT(72) IS THE ANNUAL EQUIVALENT COST
;
LBL1  QUEUE(1),,,,FINE;
;        *************************************************************************
;        *************************************************************************
;                    THIS PART OF THE PROGRAM IS FOR THE ALTERNATIVE II
;
      CREATE,1;
      ASSIGN,ATRIB(90)=TNOW;
;
;                    THIS PART GENERATES DATA BY BETA DISTRIBUTION
;    *********************    CONSTRUCTION COST     ******************************
      ASSIGN,ATRIB(1)=XX(174)-XX(173),ATRIB(2)=XX(174)+XX(183),
      ATRIB(3)=XX(173)*2;
      ASSIGN,ATRIB(4)=ATRIB(2)-ATRIB(3),ATRIB(4)=ATRIB(4)*ATRIB(1),
      ATRIB(4)=ATRIB(4)*4 ;
      ASSIGN,ATRIB(5)=XX(174)*XX(174),ATRIB(6)=XX(183)*XX(183),
      ATRIB(6)=ATRIB(5)-ATRIB(6),ATRIB(7)=XX(174)-XX(183);
      ASSIGN,ATRIB(7)=ATRIB(7)*ATRIB(3),ATRIB(7)=ATRIB(6)-ATRIB(7),
      ATRIB(8)=ATRIB(4)/ATRIB(7);
      ASSIGN,ATRIB(9)=XX(173)-XX(183),
      ATRIB(9)=ATRIB(9)/ATRIB(1),ATRIB(10)=ATRIB(8)*ATRIB(9);
      ASSIGN,XX(92)=ATRIB(8),XX(97)=ATRIB(10),
```

```
      XX(89)=BETA(XX(92),XX(87),2);
      ASSIGN,XX(81)=XX(183)-XX(174),XX(81)=XX(81)*XX(89),
      XX(121)=XX(81)+XX(174),ATRIB(73)=XX(121)*XX(190);
      ASSIGN,ATRIB(73)=ATRIB(73)*XX(373)  ;
 ;
 ;  ********************     FUEL COST          ******************************
      ASSIGN,ATRIB(1)=XX(118)-XX(119),ATRIB(2)=XX(118)+XX(120),
      ATRIB(3)=XX(119)*2;
      ASSIGN,ATRIB(4)=ATRIB(2)-ATRIB(3),ATRIB(4)=ATRIB(4)*ATRIB(1),


      ATRIB(4)=ATRIB(4)*4 ;
      ASSIGN,ATRIB(5)=XX(118)*XX(118),ATRIB(6)=XX(120)*XX(120),
      ATRIB(6)=ATRIB(5)-ATRIB(6),ATRIB(7)=XX(118)-XX(120);
      ASSIGN,ATRIB(7)=ATRIB(7)*ATRIB(3),ATRIB(7)=ATRIB(6)-ATRIB(7),
      ATRIB(8)=ATRIB(4)/ATRIB(7);
      ASSIGN,ATRIB(9)=XX(119)-XX(120),
      ATRIB(9)=ATRIB(9)/ATRIB(1),ATRIB(10)=ATRIB(8)*ATRIB(9);
      ASSIGN,XX(92)=ATRIB(8),XX(87)=ATRIB(10),
      XX(89)=BETA(XX(92),XX(87),2);
      ASSIGN,XX(81)=XX(120)-XX(118),XX(81)=XX(81)*XX(89),
      ATRIB(79)=XX(81)+XX(118);
      ASSIGN,ATRIB(79)=ATRIB(79)*XX(379)  ;B
 ;
 ;  ********************     O&M COST(FIXED)    ******************************
      ASSIGN,ATRIB(1)=XX(180)-XX(186),ATRIB(2)=XX(180)+XX(188),
      ATRIB(3)=XX(186)*2;
      ASSIGN,ATRIB(4)=ATRIB(2)-ATRIB(3),ATRIB(4)=ATRIB(4)*ATRIB(1),
      ATRIB(4)=ATRIB(4)*4 ;
      ASSIGN,ATRIB(5)=XX(180)*XX(180),ATRIB(6)=XX(188)*XX(188),
      ATRIB(6)=ATRIB(5)-ATRIB(6),ATRIB(7)=XX(180)-XX(188);
      ASSIGN,ATRIB(7)=ATRIB(7)*ATRIB(3),ATRIB(7)=ATRIB(6)-ATRIB(7),
      ATRIB(8)=ATRIB(4)/ATRIB(7);
      ASSIGN,ATRIB(9)=XX(186)-XX(188),
      ATRIB(9)=ATRIB(9)/ATRIB(1),ATRIB(10)=ATRIB(8)*ATRIB(9);
      ASSIGN,XX(92)=ATRIB(8),XX(87)=ATRIB(10),
      XX(89)=BETA(XX(92),XX(87),2);
      ASSIGN,XX(81)=XX(188)-XX(180),XX(81)=XX(81)*XX(89),
      ATRIB(81)=XX(81)+XX(180);
 ;
      ASSIGN,ATRIB(81)=ATRIB(81)*XX(381)  ;
 ;  ********************     O&M COST(VARBL.)   ******************************
      ASSIGN,ATRIB(1)=XX(128)-XX(129),ATRIB(2)=XX(128)+XX(130),
      ATRIB(3)=XX(129)*2;
      ASSIGN,ATRIB(4)=ATRIB(2)-ATRIB(3),ATRIB(4)=ATRIB(4)*ATRIB(1),
      ATRIB(4)=ATRIB(4)*4 ;
      ASSIGN,ATRIB(5)=XX(128)*XX(128),ATRIB(6)=XX(130)*XX(130),
      ATRIB(6)=ATRIB(5)-ATRIB(6),ATRIB(7)=XX(128)-XX(130);
      ASSIGN,ATRIB(7)=ATRIB(7)*ATRIB(3),ATRIB(7)=ATRIB(6)-ATRIB(7),
      ATRIB(8)=ATRIB(4)/ATRIB(7);
      ASSIGN,ATRIB(9)=XX(129)-XX(130),
      ATRIB(9)=ATRIB(9)/ATRIB(1),ATRIB(10)=ATRIB(8)*ATRIB(9);
      ASSIGN,XX(92)=ATRIB(8),XX(87)=ATRIB(10),
      XX(89)=BETA(XX(92),XX(87),2);
      ASSIGN,XX(81)=XX(130)-XX(128),XX(81)=XX(81)*XX(89),
      ATRIB(82)=XX(81)+XX(128);
      ASSIGN,ATRIB(82)=ATRIB(82)*XX(382)  ;
 ;
 ;  ********************     O&M ESC.RATE       ******************************
      ASSIGN,ATRIB(1)=XX(137)-XX(139),ATRIB(2)=XX(137)+XX(124),
      ATRIB(3)=XX(139)*2;
      ASSIGN,ATRIB(4)=ATRIB(2)-ATRIB(3),ATRIB(4)=ATRIB(4)*ATRIB(1),
      ATRIB(4)=ATRIB(4)*4 ;
      ASSIGN,ATRIB(5)=XX(137)*XX(137),ATRIB(6)=XX(124)*XX(124),
      ATRIB(6)=ATRIB(5)-ATRIB(6),ATRIB(7)=XX(137)-XX(124);
      ASSIGN,ATRIB(7)=ATRIB(7)*ATRIB(3),ATRIB(7)=ATRIB(6)-ATRIB(7),
      ATRIB(8)=ATRIB(4)/ATRIB(7);
      ASSIGN,ATRIB(9)=XX(139)-XX(124),
      ATRIB(9)=ATRIB(9)/ATRIB(1),ATRIB(10)=ATRIB(8)*ATRIB(9);
      ASSIGN,XX(92)=ATRIB(8),XX(87)=ATRIB(10),
      XX(89)=BETA(XX(92),XX(87),2);
      ASSIGN,XX(81)=XX(124)-XX(137),XX(81)=XX(81)*XX(89),
      ATRIB(85)=XX(81)+XX(137);
      ASSIGN,ATRIB(85)=ATRIB(85)*XX(385)  ;
```

```
;
;    *********************      FUEL ESC.RATE        ********************************
        ASSIGN,ATRIB(1)=XX(193)-XX(194),ATRIB(2)=XX(193)+XX(195),
        ATRIB(3)=XX(194)*2;                                   ;
        ASSIGN,ATRIB(4)=ATRIB(2)-ATRIB(3),ATRIB(4)=ATRIB(4)*ATRIB(1),
        ATRIB(4)=ATRIB(4)*4 ;
        ASSIGN,ATRIB(5)=XX(193)*XX(193),ATRIB(6)=XX(195)*XX(195),
        ATRIB(6)=ATRIB(5)-ATRIB(6),ATRIB(7)=XX(193)-XX(195);
        ASSIGN,ATRIB(7)=ATRIB(7)*ATRIB(3),ATRIB(7)=ATRIB(6)-ATRIB(7),
        ATRIB(8)=ATRIB(4)/ATRIB(7);
        ASSIGN,ATRIB(9)=XX(194)-XX(195),
        ATRIB(9)=ATRIB(9)/ATRIB(1),ATRIB(10)=ATRIB(8)*ATRIB(9);
        ASSIGN,XX(92)=ATRIB(8),XX(87)=ATRIB(10),
        XX(89)=BETA(XX(92),XX(87),2);
        ASSIGN,XX(81)=XX(195)-XX(193),XX(81)=XX(81)*XX(89),
        ATRIB(84)=XX(81)+XX(193) ;
        ASSIGN,ATRIB(84)=ATRIB(84)*XX(384) ;
;
        ASSIGN,ATRIB(77)=XX(178),ATRIB(78)=XX(182),XX(122)=ATRIB(77)*ATRIB(78),
        XX(122)=XX(122)*ATRIB(79),XX(122)=XX(122)*XX(190),
        XX(122)=XX(122)*0.00876;


        ASSIGN,XX(123)=ATRIB(81)*XX(190),ATRIB(83)=ATRIB(82)*ATRIB(78),
        ATRIB(83)=ATRIB(83)*8760,ATRIB(83)=ATRIB(83)*XX(190),
        XX(123)=ATRIB(83)+XX(123);
        ASSIGN,XX(109)=ATRIB(84)+1,XX(110)=ATRIB(85)+1 ;
        ASSIGN,ATRIB(20)=XX(112),ATRIB(1)=XX(101),ATRIB(61)=1,ATRIB(65)=1,
        ATRIB(71)=1,ATRIB(2)=2;
        ASSIGN,ATRIB(24)=XX(122),ATRIB(24)=ATRIB(24)*XX(109),
        ATRIB(24)=ATRIB(24)*XX(109),ATRIB(25)=XX(123),
        ATRIB(25)=ATRIB(25)*XX(110),ATRIB(25)=ATRIB(25)*XX(110);
        ASSIGN,XX(121)=XX(400)*ATRIB(73),XX(121)=XX(121)+ATRIB(73),
        XX(125)=XX(121)*XX(177);
DET2    ASSIGN,ATRIB(2)=ATRIB(2)+1,ATRIB(3)=XX(101),ATRIB(24)=ATRIB(24)*XX(109),
        ATRIB(25)=ATRIB(25)*XX(110),ATRIB(1)=XX(101)*ATRIB(1);
        ACT,,ATRIB(2).LT.XX(116),DET2;
        ACT,,ATRIB(2).GE.XX(116),BAC2;
BAC2    ASSIGN,ATRIB(4)=XX(121)*ATRIB(20);
        ASSIGN,ATRIB(5)=XX(111)*ATRIB(4),ATRIB(6)=ATRIB(4)-ATRIB(5),
        ATRIB(7)=ATRIB(5)*XX(104),ATRIB(8)=ATRIB(6)*XX(103);
        ASSIGN,ATRIB(9)=ATRIB(4)*XX(106),ATRIB(10)=ATRIB(9)*XX(101),
        ATRIB(11)=ATRIB(4)*XX(105),ATRIB(12)=ATRIB(7)+ATRIB(11);
        ASSIGN,ATRIB(13)=ATRIB(12)*XX(102),ATRIB(14)=ATRIB(8),
        ATRIB(14)=ATRIB(14)+ATRIB(10),ATRIB(14)=ATRIB(14)+ATRIB(12);
        ASSIGN,ATRIB(14)=ATRIB(14)-ATRIB(13),ATRIB(15)=ATRIB(14)*ATRIB(1),
        ATRIB(16)=ATRIB(16)+ATRIB(15),ATRIB(1)=ATRIB(1)/XX(101);
        ASSIGN,ATRIB(17)=ATRIB(17)+1;
        ACT,,ATRIB(17).LT.XX(116),TES2;
        ACT,,ATRIB(17).GE.XX(116),FWR2;
TES2    GOON,8;
        ACT,,ATRIB(17).EQ.1,SUC1;
        ACT,,ATRIB(17).EQ.2,SUC2;
        ACT,,ATRIB(17).EQ.3,SUC3;
        ACT,,ATRIB(17).EQ.4,SUC4;
        ACT,,ATRIB(17).EQ.5,SUC5;
        ACT,,ATRIB(17).EQ.6,SUC6;
        ACT,,ATRIB(17).EQ.7,SUC7;
        ACT,,ATRIB(17).EQ.8,SUC8;
SUC1    ASSIGN,ATRIB(20)=XX(113);
        ACT,,,BAC2;
SUC2    ASSIGN,ATRIB(20)=XX(114);
        ACT,,,BAC2;
SUC3    ASSIGN,ATRIB(20)=XX(115);
        ACT,,,BAC2;
SUC4    ASSIGN,ATRIB(20)=XX(158);
        ACT,,,BAC2;
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SUC5  ASSIGN,ATRIB(20)=XX(159);
      ACT,,,BAC2;
SUC6  ASSIGN,ATRIB(20)=XX(160);
      ACT,,,BAC2;
SUC7  ASSIGN,ATRIB(20)=XX(161);
      ACT,,,BAC2;
SUC8  ASSIGN,ATRIB(20)=XX(162);
      ACT,,,BAC2;
FLR2  ASSIGN,ATRIB(27)=XX(127)*XX(121), ATRIB(16)=ATRIB(16)-ATRIB(27),
      ATRIB(26)=ATRIB(6),ATRIB(34)=XX(121);
      ASSIGN,ATRIB(30)=XX(121)-XX(125),ATRIB(76)=ATRIB(30),XX(176)=XX(166),
      ATRIB(31)=ATRIB(30)/XX(166),ATRIB(51)=XX(135),ATRIB(52)=XX(136)-ATRIB(51);
      ASSIGN,ATRIB(56)=XX(166),ATRIB(54)=XX(166)+XX(136),
      ATRIB(55)=ATRIB(54)*XX(166),ATRIB(55)=ATRIB(55)/2;
      ACT,,XX(148).EQ.0,BET2;
      ACT,,XX(148).EQ.1,ALF2;
BET2  ASSIGN,ATRIB(64)=ATRIB(6)*XX(103),ATRIB(63)=ATRIB(6);
      ACT,,,NEX2;
ALF2  ASSIGN,XX(140)=XX(103)+1,XX(141)=XX(103)+1;
EQI2  ASSIGN,ATRIB(61)=ATRIB(61)+1,XX(141)=XX(141)*XX(140);
      ACT,,ATRIB(61).LT.XX(126),EQI2;
      ACT,,ATRIB(61).GE.XX(126),EQC2;
EQC2  ASSIGN,XX(142)=XX(141)-1,XX(143)=XX(141)*XX(103),
      XX(144)=XX(143)/XX(142),ATRIB(36)=ATRIB(6)*XX(144);
      ASSIGN,XX(145)=ATRIB(6)*XX(103),XX(146)=XX(145)-ATRIB(36),
      ATRIB(62)=XX(140)/XX(140);
NEX2  GOON,2;
      ACT,,XX(151).EQ.0,DBT2;
      ACT,,XX(151).EQ.1,DBT3;
DBT2  ASSIGN,ATRIB(66)=ATRIB(5)*XX(104),ATRIB(67)=ATRIB(5);
      ACT,,,OPE2;
DBT3  ASSIGN,XX(149)=XX(104)+1,ATRIB(7)=0,XX(150)=XX(104)+1;
RED2  ASSIGN,ATRIB(65)=ATRIB(65)+1,XX(150)=XX(150)*XX(149);
      ACT,,ATRIB(65).LT.XX(126),RED2;
      ACT,,ATRIB(65).GE.XX(126),CAL2;
CAL2  ASSIGN,XX(152)=XX(150)-1,XX(153)=XX(150)*XX(104),
      XX(154)=XX(153)/XX(152),ATRIB(68)=ATRIB(5)*XX(154);
      ASSIGN,XX(155)=ATRIB(5)*XX(104),XX(156)=XX(155)-ATRIB(68),
      ATRIB(69)=XX(149)/XX(149);
OPE2  ASSIGN,ATRIB(56)=XX(166)-ATRIB(46),


              ATRIB(57)=ATRIB(56)/ATRIB(55),
              ATRIB(58)=ATRIB(57)*ATRIB(30);
      ASSIGN,ATRIB(31)=ATRIB(76)/XX(176),ATRIB(76)=ATRIB(76)-ATRIB(31),
      XX(176)=XX(176)-1;
      ACT,,XX(176).LE.0.,CRC2;
      ACT,,XX(176).GT.0.,OKE2;
CRC2  ASSIGN,XX(176)=1,XX(133)=0;
OKE2  ASSIGN,ATRIB(53)=XX(121)*ATRIB(51),ATRIB(53)=ATRIB(53)*XX(133),
      ATRIB(58)=ATRIB(58)*XX(134),ATRIB(31)=ATRIB(31)*XX(132);
      ASSIGN,ATRIB(37)=XX(146)*ATRIB(62),ATRIB(37)=ATRIB(37)+ATRIB(36),
      XX(147)=ATRIB(36)-ATRIB(37);
      ASSIGN,ATRIB(70)=XX(156)*ATRIB(69),ATRIB(70)=ATRIB(70)+ATRIB(68),
      XX(157)=ATRIB(68)-ATRIB(70);
      ASSIGN,ATRIB(34)=ATRIB(34)-ATRIB(31),
              ATRIB(34)=ATRIB(34)-ATRIB(53),
              ATRIB(34)=ATRIB(34)-ATRIB(58),
      ATRIB(35)=ATRIB(34)*XX(105);
      ASSIGN,ATRIB(40)=ATRIB(24)+ATRIB(25),
      ATRIB(40)=ATRIB(40)+ATRIB(7),
              ATRIB(40)=ATRIB(40)+ATRIB(70),
      ATRIB(40)=ATRIB(40)+ATRIB(35),
      ATRIB(41)=ATRIB(40)+ATRIB(31),
              ATRIB(41)=ATRIB(41)+ATRIB(58),
              ATRIB(41)=ATRIB(41)+ATRIB(53),
      ATRIB(42)=ATRIB(41)*XX(102);
      ASSIGN,ATRIB(40)=ATRIB(40)+ATRIB(10),
      ATRIB(40)=ATRIB(40)+ATRIB(36),
      ATRIB(40)=ATRIB(40)+ATRIB(64),
      ATRIB(40)=ATRIB(40)+XX(157),ATRIB(40)=ATRIB(40)-ATRIB(42);
      ASSIGN,ATRIB(43)=ATRIB(40)/ATRIB(3),
      ATRIB(62)=ATRIB(62)*XX(140),ATRIB(69)=ATRIB(69)*XX(149),
```

```
     ATRIB(45)=ATRIB(45)+ATRIB(43);
     ASSIGN,ATRIB(24)=ATRIB(24)*XX(109),ATRIB(25)=ATRIB(25)*XX(110),
     ATRIB(26)=ATRIB(26)-ATRIB(36),
           ATRIB(51)=ATRIB(51)+ATRIB(52),ATRIB(3)=ATRIB(3)*XX(101);
     ASSIGN,ATRIB(46)=ATRIB(46)+1 ;
     ACT,,ATRIB(46).LT.XX(126),OPE2;
     ACT,,ATRIB(46).GE.XX(126),FIN2;
FIN2 ASSIGN,ATRIB(47)=ATRIB(3)/XX(101),
           ATRIB(67)=ATRIB(67)+ATRIB(63),
     ATRIB(67)=ATRIB(67)-XX(125),ATRIB(48)=ATRIB(67)/ATRIB(47),
     ATRIB(49)=ATRIB(45)+ATRIB(48),
     ATRIB(50)=ATRIB(49)+ATRIB(15);
     ASSIGN,XX(167)=XX(101)-1,XX(169)=XX(101);
LAS2 ASSIGN,ATRIB(71)=ATRIB(71)+1,XX(169)=XX(169)*XX(101);
     ACT,,ATRIB(71).LT.XX(126),LAS2;
     ACT,,ATRIB(71).GE.XX(126),EDA2;
EDA2 ASSIGN,XX(170)=XX(167)*XX(169),XX(171)=XX(169)-1, XX(172)=XX(170)/XX(171),
     ATRIB(75)=XX(172),ATRIB(72)=ATRIB(50)*XX(172),XX(197)=ATRIB(72);
LBL2 QUEUE(2),,,,FINE;
FINE MATCH,90,LBL1/CLC1,LBL2/CLC2;
;
;      ***********************************************************************
;                                    COLLECTION OF DESIRED DATA
;
CLC1 COLCT,XX(97),ANN.EQ.COST1,30,0.30E+09,0.20E+08;
     TERM;
CLC2 COLCT,XX(197),ANN.EQ.COST2,30,0.20E+09,0.10E+08;
     ASSIGN,XX(99)=XX(97)-XX(197);
     COLCT,XX(99),DIFFERENCE,50,-0.60E+08,0.1E+8;
;      ***********************************************************************
;                                    NUMBER OF OBSERVATIONS DESIRED
     TERM,200 ;                                                      ;052,MRET
     ENDNET;
FIN;
```

S L A M   S U M M A R Y   R E P O R T

SIMULATION PROJECT EXERCISE   BY MEDI

DATE 9/20/1981   RUN NUMBER 1 OF 1

CURRENT TIME 0.1990E+03
STATISTICAL ARRAYS CLEARED AT TIME 0.0

STATISTICS FOR VARIABLES BASED ON OBSERVATION

	MEAN VALUE	STANDARD DEVIATION	COEFF. OF VARIATION	MINIMUM VALUE	MAXIMUM VALUE	NUMBER OF OBSERVATIONS
ANN.EQ.COST1	0.4600E+09	0.4871E+08	0.1059E+00	0.3653E+09	0.6317E+09	200
ANN.EQ.COST2	0.3565E+09	0.4206E+08	0.1180E+00	0.2662E+09	0.4520E+09	200
DIFFERENCE	0.1035E+09	0.6434E+08	0.6219E+00	-0.4304E+08	0.3470E+09	200

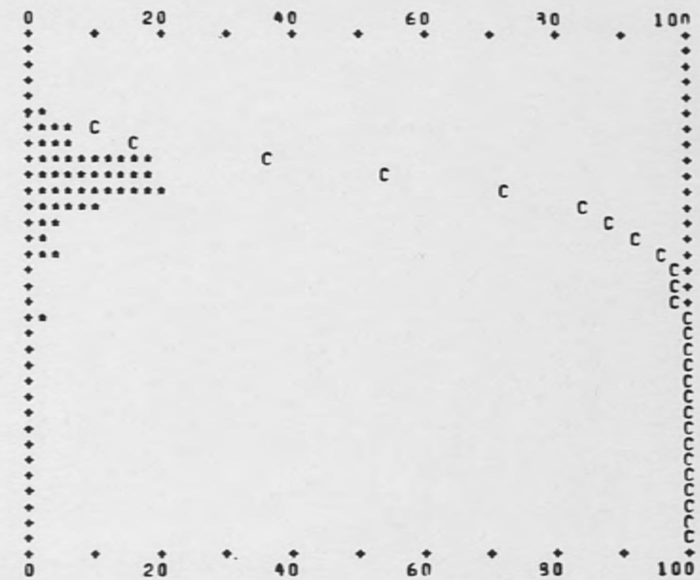
FILE STATISTICS

FILE NUMBER	ASSOCIATED NODE TYPE	AVERAGE LENGTH	STANDARD DEVIATION	MAXIMUM LENGTH	CURRENT LENGTH
1	QUEUE	0.0	0.0	1	0
2	QUEUE	0.0	0.0	1	0
3		2.0000	0.0	4	2

HISTOGRAM NUMBER 1

ANN.EC.COST1

OBSV FREQ	RELA FREQ	CUML FREQ	UPPER CELL LIMIT
0	0.0	0.0	0.3000E+09
0	0.0	0.0	0.3200E+09
0	0.0	0.0	0.3400E+09
0	0.0	0.0	0.3600E+09
6	0.030	0.030	0.3800E+09
14	0.070	0.100	0.4000E+09
14	0.070	0.170	0.4200E+09
38	0.190	0.360	0.4400E+09
35	0.175	0.535	0.4600E+09
39	0.195	0.730	0.4800E+09
22	0.110	0.840	0.5000E+09
10	0.050	0.890	0.5200E+09
6	0.030	0.920	0.5400E+09
10	0.050	0.970	0.5600E+09
2	0.010	0.980	0.5800E+09
0	0.0	0.980	0.6000E+09
1	0.005	0.985	0.6200E+09
3	0.015	1.000	0.6400E+09
0	0.0	1.000	0.6600E+09
0	0.0	1.000	0.6800E+09
0	0.0	1.000	0.7000E+09
0	0.0	1.000	0.7200E+09
0	0.0	1.000	0.7400E+09
0	0.0	1.000	0.7600E+09
0	0.0	1.000	0.7800E+09
0	0.0	1.000	0.8000E+09
0	0.0	1.000	0.8200E+09
0	0.0	1.000	0.8400E+09
0	0.0	1.000	0.8600E+09
0	0.0	1.000	0.8800E+09
0	0.0	1.000	0.9000E+09
0	0.0	1.000	INF
200			

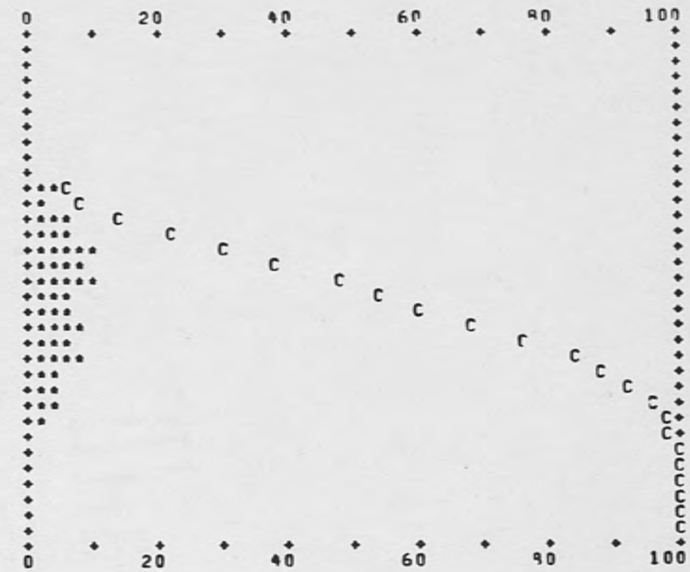


HISTOGRAM NUMBER 2

ANN.EQ.COST2

OBSV FREQ	RELA FREQ	CUML FREQ	UPPER CELL LIMIT
0	0.0	0.0	0.2000E+09
0	0.0	0.0	0.2100E+09
0	0.0	0.0	0.2200E+09
0	0.0	0.0	0.2300E+09
0	0.0	0.0	0.2400E+09
0	0.0	0.0	0.2500E+09
0	0.0	0.0	0.2600E+09
1	0.005	0.005	0.2700E+09
1	0.005	0.010	0.2800E+09
10	0.050	0.060	0.2900E+09
4	0.020	0.080	0.3000E+09
13	0.065	0.145	0.3100E+09
14	0.070	0.215	0.3200E+09
19	0.095	0.310	0.3300E+09
15	0.075	0.385	0.3400E+09
19	0.095	0.480	0.3500E+09
11	0.055	0.535	0.3600E+09
13	0.065	0.600	0.3700E+09
17	0.085	0.685	0.3800E+09
14	0.070	0.755	0.3900E+09
17	0.085	0.840	0.4000E+09
7	0.035	0.875	0.4100E+09
9	0.045	0.920	0.4200E+09
9	0.045	0.965	0.4300E+09
4	0.020	0.985	0.4400E+09
1	0.005	0.990	0.4500E+09
2	0.010	1.000	0.4600E+09
0	0.0	1.000	0.4700E+09
0	0.0	1.000	0.4800E+09
0	0.0	1.000	0.4900E+09
0	0.0	1.000	0.5000E+09
0	0.0	1.000	INF

200			

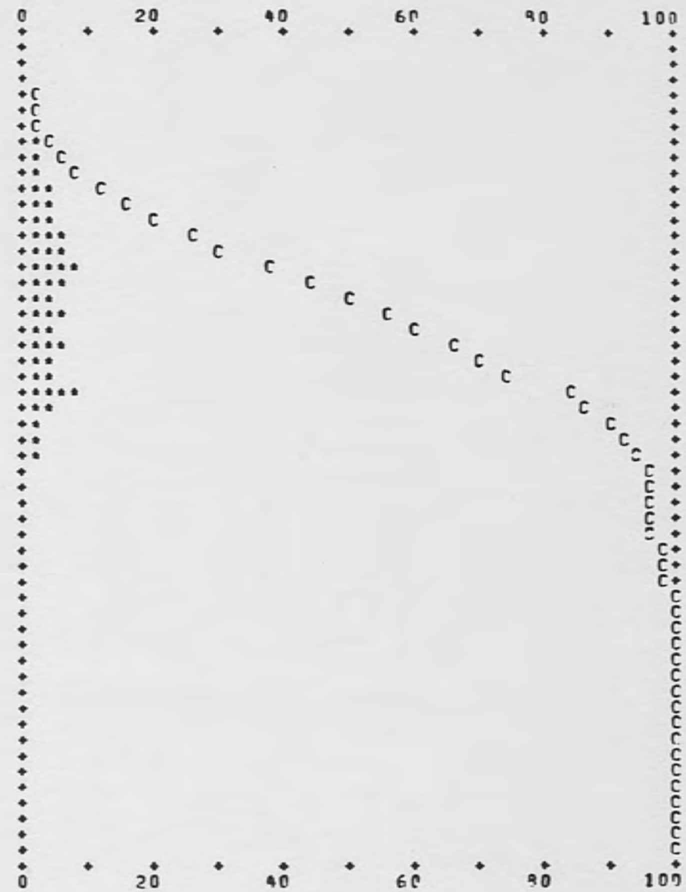


HISTOGRAM NUMBER 3

DIFFERENCE

OBSV FREQ	RELA FREQ	CUML FREQ	UPPER CELL LIMIT
0	0.0	0.0	-0.6000E+08
0	0.0	0.0	-0.5000E+08
1	0.005	0.005	-0.4000E+08
2	0.010	0.015	-0.3000E+08
2	0.010	0.025	-0.2000E+08
0	0.0	0.025	-0.1000E+08
3	0.015	0.040	0.8000E+01
5	0.025	0.065	0.1000E+08
3	0.015	0.080	0.2000E+08
9	0.045	0.125	0.3000E+08
8	0.040	0.165	0.4000E+08
7	0.035	0.200	0.5000E+08
11	0.055	0.255	0.6000E+08
11	0.055	0.310	0.7000E+08
15	0.075	0.385	0.8000E+08
12	0.060	0.445	0.9000E+08
10	0.050	0.495	0.1000E+09
14	0.070	0.565	0.1100E+09
8	0.040	0.605	0.1200E+09
11	0.055	0.660	0.1300E+09
9	0.045	0.705	0.1400E+09
9	0.045	0.750	0.1500E+09
17	0.085	0.835	0.1600E+09
7	0.035	0.870	0.1700E+09
5	0.025	0.895	0.1900E+09
5	0.025	0.920	0.1900E+09
6	0.030	0.950	0.2000E+09
2	0.010	0.960	0.2100E+09
1	0.005	0.965	0.2200E+09
1	0.005	0.970	0.2300E+09
0	0.0	0.970	0.2400E+09
0	0.0	0.970	0.2500E+09
2	0.010	0.980	0.2600E+09
2	0.010	0.990	0.2700E+09
0	0.0	0.990	0.2800E+09
1	0.005	0.995	0.2900E+09
0	0.0	0.995	0.3000E+09
0	0.0	0.995	0.3100E+09
0	0.0	0.995	0.3200E+09
0	0.0	0.995	0.3300E+09
0	0.0	0.995	0.3400E+09
1	0.005	1.000	0.3500E+09
0	0.0	1.000	0.3600E+09
0	0.0	1.000	0.3700E+09
0	0.0	1.000	0.3800E+09
0	0.0	1.000	0.3900E+09
0	0.0	1.000	0.4000E+09
0	0.0	1.000	0.4100E+09
0	0.0	1.000	0.4200E+09
0	0.0	1.000	0.4300E+09
0	0.0	1.000	0.4400E+09
0	0.0	1.000	INF

200			



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